APORTE DE DICTAMEN PERICIAL CIRUJANO PEDIATRA - PROC. 2022 00 195 - DTE. JORGE ANDRES VELASCO Y OTROS VS VANESSA PEREZ SARDY

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19 archivos adjuntos (8 MB)

DICTAMEN PERICIAL - DR. ANDRES FELIPE MARIN.pdf; Comparación entre puberal y postpuberal.pdf; Funcion hormonal depues de torsion.pdf; Fijación con punto Vs jaboulay.pdf; Metaanalisis predictores perdida testicular.pdf; Flap de túnica vaginal.pdf; Efecto en la función testicular a corto plazo.pdf; predictores de viabilidad testicular 2007.pdf; Revisión urológica.pdf; score en asia.pdf; Predictores de la viabilidad gonadal.pdf; Predictores de salvamento.pdf; Repetir el US.pdf; Seguimiento de pacientes a largo plazo.pdf; Torsión testicular neonatal metaanálisis.pdf; Torsión testicular rev 2.017.pdf; Sintomas y orquidectomia.pdf; US por emergenciólogos.pdf; HOJA DE VIDA - DR. ANDRES FELIPE MARIN GIRALDO (ACTUALIZADA).pdf;

Señores:
JUZGADO PRIMERO CIVIL DEL CIRCUITO DE ORALIDAD
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Asunto. **TRASLADO DE DICTAMEN PERICIAL - DR. ANDRÉS FELIPE MARÍN GIRALDO (CIRUJANO PEDIÁTRA)**
Ref. **PROCESO VERBAL DE MAYOR CUANTÍA**
Demandante: **JORGE ANDRÉS VELASCO HERNÁNDEZ Y OTROS.**
Demandados. **VANESSA PÉREZ SARDY, Y OTROS.**
Rad. **2022-00195-00**

Reciban un cordial saludo.

LADY DIANA BERMÚDEZ GALLEGO, mayor de edad, vecina de Santiago de Cali, abogada titulada y en ejercicio identificada tal y como aparece al pie de mi firma, actuando como apoderada judicial de la doctora **VANESSA PÉREZ SARDY**, me dirijo al despacho de manera respetuosa, con la finalidad de trasladar el dictamen pericial que se rindió por parte del **Dr. ANDRÉS FELIPE MARÍN GIRALDO** como perito experto en CIRUGÍA PEDIÁTRICA, prueba que se aporta dentro del término concedido por el despacho.

Así las cosas, se trasladan los siguientes documentos:

a. Dictamen pericial desarrollado por el Dr. ANDRÉS FELIPE MARÍN GIRALDO.
b. Literatura científica que soporta el mismo.
c. Hoja de Vida del Dr. ANDRÉS FELIPE MARÍN GIRALDO.

Lo anterior, para los fines pertinentes.

Muchas gracias.

Del señor Juez,

LADY DIANA BERMUDEZ GALLEGO
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ESTUDIOS POSTGRADO: Cirugía general
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CURSADO ACTUALMENTE: Julio/ 2019 - Presente

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-Pediatría: agosto 6-2007/septiembre 2-2007. Hospital infantil.

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OTROS ESTUDIOS

- PRIMERA JORNADA DE ACTUALIZACIÓN EN TEMAS SELECTOS, ASOCIACIÓN NACIONAL DE INTERNOS Y RESIDENTES, UNIVERSIDAD DE CALDAS, OCTUBRE 29 DE 2004.

- PRIMER SIMPOSIO DE ENFERMEDADES RENALES DEL EJE CAFETERO, MARZO 11 DE 2005.

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- SEGUNDA JORNADA DE ACTUALIZACIÓN EN INFECTOLOGÍA, ASOCIACIÓN COLOMBIANA DE INFECTOLOGÍA CAPÍTULO EJE CAFETERO, 10 DE NOVIEMBRE DE 2005.
- XXXII CONGRESO NACIONAL AVANCES EN CIRUGÍA, CENTRO DE CONVENCIONES GONZALO JIMENEZ DE QUESADA, BOGOTÁ, 22 AL 25 DE AGOSTO DE 2006.
- SOPORTE VITAL BÁSICO PARA PERSONAL DEL EQUIPO DE SALUD. CENTRO DE ENTRENAMIENTO JERSEY CITY MEDICAL CENTER, UNIVERSIDAD DE CALDAS: 20 DE SEPTIEMBRE DE 2008.
- APOYO VITAL CARDIOVASCULAR AVANZADO, CENTRO DE ENTRENAMIENTO JERSEY CITY MEDICAL CENTER, UNIVERSIDAD DE CALDAS, 28 DE SEPTIEMBRE DE 2008.
- ACTALIZACIÓN EN REANIMACIÓN BÁSICA Y AVANZADA, SALAMANDRA, CALI. JULIO 2019.
- CURSO VIRTUAL, CORRECTO LLENADO DE CERTIFICADOS DE DEFUNCIÓN: ORGANIZACIÓN PANAMERICANA DE LA SALUD, JULIO 2019.
- CONGRESO COLOMBIANO DE CRUGÍA GENERAL: 2.011
- CONGRESO COLOMBIANO DE CRUGÍA GENERAL: 2013.
- CONGRESO COLOMBIANO DE CIRUGÍA PEDIÁTRICA, CALI, COL. 2020.
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- SESIÓN DE DISCUSIÓN DE REFLUJO VESICOURETERAL, SOCIEDAD MEXICANA DE CIRUGÍA PEDIÁTRICA, MARZO 2020.
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- ❖ DOCENTE HORA CATEDRA EN CIRUGÍA GENERAL, UNIVERSIDAD ICESI, AGOSTO DE 2014/JUNIO DE 2018.
- ❖ CIRUJANO PEDIATRA CLÍNICA IMBANACO, JULIO 2021- HASTA LA FECHA.

**PRESENTACIONES EN CONGRESOS
Y ACTIVIDADES ACADÉMICAS:**

- ❖ PRESENTACIÓN DEL TRABAJO: CIRUGÍA DE CONTROL DE DAÑOS EN URGENCIAS ABDOMINALES NO TRAUMÁTICAS: CONGRESO COLOMBIANO DE CIRUGÍA, BOGOTÁ 2011.
- ❖ TRABAJO LIBRE, MODALIDAD DE PRESENTACIÓN ORAL: PRESENTACIÓN DE UN MODELO DE SIMULACIÓN EXVIVO EN ÓRGANOS PORCINOS DE CIRUGÍA MÍNIMAMENTE INVASIVA EN ATRESIA DE ESÓFAGO TIPO III: CONGRESO COLOMBIANO DE CIRUGÍA PEDIÁTRICA, CALI, COL 2020. GANADOR DE SEGUNDO LUGAR.
- ❖ PRESENTACIÓN DE TRABAJO LIBRE, MODALIDAD VIDEO: NEFROURETERECTOMÍA LAPAROSCÓPICA EN PIONEFROSIS GIGANTE. CONGRESO COLOMBIANO DE CIRUGÍA PEDIÁTRICA, CALI, COL 2020.
- ❖ PRESENTACIÓN DE TRABAJO LIBRE, MODALIDAD POSTER: MANEJO MÍNIMAMENTE INVASIVO DE TRAUMA PENETRANTE DE RECTO EXTRAPERITONEAL EN CIRUGÍA PEDIÁTRICA. CONGRESO COLOMBIANO DE CIRUGÍA PEDIÁTRICA, CALI, COL 2020.

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- PRESENTACIÓN DE TRABAJO LIBRE, MODALIDAD DE POSTER: INVAGINACIÓN INTESTINAL ASOCIADA A INFECCIÓN POR VIRUS SARS-COV-2: REPORTE DE CASO: CONGRESO COLOMBIANO DE CIRUGÍA PEDIÁTRICA, CALI COL 2020
- CONFERENCISTA: TRAUMA DE TÓRAX. CONGRESO COLOMBIANO DE CIRUGÍA PEDIÁTRICA 2022.
- PRESENTACIÓN DE TRABAJO LIBRE MODALIDAD PÓSTER BRONCOTOMÍA PARA EXTRACCIÓN DE CUERPO EXTRAÑO METÁLICO IMPACTADO EN EL BRONQUIO INTERMEDIARIO. CONGRESO COLOMBIANO DE CIRUGÍA PEDIÁTRICA 2022.
- PRESENTACIÓN DE TRABAJO MODALIDAD VIDEO; RESECCIÓN LAPAROSCÓPICA TRANSHIATAL DE DIVERTÍCULO ESOFÁGICO EPIFÉNICO Y ESOFOGAMIOTOMÍA DE HÉLLER. CONGRESO COLOMBIANO DE CIRUGÍA PEDIÁTRICA 2022.
- PRESENTACIÓN DE TRABAJO MODALIDAD VIDEO: RESECCIÓN TORASOCÓPICA DE ESTENOSIS ESOFÁGICA SEVERA EN UN LACTANTE CON CORRECCIÓN ABIERTA DE ATRESIA DE ESÓFAGO TIPO III
- PRESENTACIÓN DE TRABAJO MODALIDAD VIDEO: CORRECCIÓN LAPAROSCÓPICA DE ESTENOSIS DUODENAL CONGÉNITA POR PÁNCREAS ANULAR EN RECIÉN NACIDO DE 1500 GR.
- PRESENTACIÓN DE TRABAJO MODALIDAD TRABAJO LIBRE (COAUTOR): RESECCIÓN TORASOCÓPICA DE ESTENOSIS ESOFÁGICA SEVERA EN UN LACTANTE CON CORRECCIÓN ABIERTA DE ATRESIA DE ESÓFAGO TIPO III
- NEUMOTÓRAX ESPONTANEO EN LA POBLACIÓN PEDIÁTRICA. ¿VIDEOTORACOSCOPIA TEMPRANA COMO UNA OPCION? SERIE DE CASOS EN INSTITUCIONES DE COLOMBIA. (COAUTOR) CONGRESO COLOMBIANO DE CIRUGÍA PEDIÁTRICA 2022.
- PRESENTACIÓN DE TRABAJO LIBRE MODALIDAD PÓSTER: BLASTOMA PLEUROPULMONAR EN PACIENTE DE 4 AÑOS. REPORTE DE UN CASO Y REVISION DE LA LITERATURA. CONGRESO COLOMBIANO DE CIRUGÍA 2022.

PUBLICACIONES:

- Estrategias de educación en un programa de formación

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en cirugía pediátrica, como respuesta a la pandemia por COVID-19. Rev Colomb Cir. 2020;35:553 https://doi.org/10.30944/20117582.780

- Novel Coronavirus Infection in an Infant with Intussusception- case report. Global Pediatric Health Volume 8: 1–3. The Author(s) 2021 Article reuse guidelines: sagepub.com/journals-permissions. DOI:10.1177/2333794X211012978.

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En nombre de la República de Colombia
y por autorización del Ministerio de Educación Nacional

La Universidad de Caldas

En atención a que

Andrés Felipe Marín Giraldo

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MÉDICO CIRUJANO

Y le expide el presente diploma. En testimonio de ello, se refrenda con las firmas y registro respectivos

Rector

Secretario General

Manizales, 1 de febrero de 2003 Oficina de Registro Académico folio 36/1061 del libro No 4

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INDICE DERECHO

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Journal of Pediatric Urology (2019) **15**, 608.e1—608.e6

Accuracy of point-of-care ultrasound by pediatric emergency physicians for testicular torsion

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Keywords
Testicular torsion; Acute scrotum; Point-of-care ultrasound

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Summary

Introduction
Acute scrotum is a common presentation to the pediatric emergency department, and ultrasound is frequently used to narrow the differential diagnosis. Point-of-care ultrasound (POCUS) is increasingly used by urologists and emergency physicians and could potentially be used to detect pediatric testicular torsion.

Objectives
This study aimed to determine the accuracy of POCUS by pediatric emergency physicians in diagnosing testicular torsion and the agreement between point-of-care ultrasound and final diagnosis for other causes of acute scrotum.

Study design
A chart review of patients presenting to the study emergency department who received POCUS by a pediatric emergency physician, as well as radiology department ultrasound and/or surgery, was performed. Charts were reviewed for POCUS diagnoses, final diagnoses, and imaging time metrics.

Results
A total of 120 patients met study criteria, with 12 cases of testicular torsion. The diagnostic accuracy of POCUS for testicular torsion is described in the summary table. For all causes of acute scrotum, point-of-care ultrasound agreed with final diagnosis in 70% (95% confidence interval [CI] 62—78%) of cases, and more experienced point-of-care ultrasound users displayed higher agreement with final diagnosis. Point-of-care ultrasound results were generated a median of 73 min (Q1 = 51, Q3 = 112) before radiology department ultrasound results.

Discussion
Scrotal POCUS performed by pediatric emergency physicians appears to be an accurate tool to detect testicular torsion in children with acute scrotum and saves time compared with radiology ultrasound. The study results may not be generalizable to hospitals without a multidisciplinary POCUS system for quality assurance and image sharing. Future work on POCUS for acute scrotum should investigate its impact on patient outcomes, cost-effectiveness, and family satisfaction.

Conclusion
Point-of-care ultrasound by pediatric emergency physicians is accurate for detecting testicular torsion in children with acute scrotum and could expedite diagnosis of this time-sensitive condition.

Table Accuracy of POCUS by pediatric emergency physicians in diagnosing testicular torsion in children with acute scrotum.

Sensitivity (%, 95% CI)	100 (73.5—100)
Specificity (%, 95% CI)	99.1 (95.0—100)
PPV (%, 95% CI)	92.3 (63.0—98.8)
NPV (%, 95% CI)	100 (NC[a])
+LR (95% CI)	108.0 (15.4—759.8)
−LR (95% CI)	0 (NC[a])

CI, confidence interval; PPV, positive predictive value; NPV, negative predictive value; POCUS, point-of-care ultrasound; LR, likelihood ratio.
[a] NC = non-calculable.

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1477-5131/

Introduction

Acute scrotum is a common reason for presentation to the pediatric emergency department (PED) [1]. It is caused most commonly by benign temporary conditions (such as epididymitis, orchitis, or torsion of the testicular appendix), but the surgical emergency of testicular torsion can be missed because its clinical presentation often overlaps with these benign conditions [2–5]. Ultrasound is instrumental in the diagnosis of testicular torsion [2,6–9], but any time delay for diagnostic imaging increases the risk of testicular loss and future morbidity such as infertility [10–12].

As opposed to comprehensive ultrasonography by radiologists, point-of-care ultrasonography (POCUS) by clinicians answers binary yes/no questions about actionable sonographic findings that alter the next steps of clinical care [13]. Growing recent evidence supports the accuracy of POCUS by PED physicians in a variety of diagnostic applications [14–18], and it can decrease PED length of stay [19–21] and resource utilization [20,22–24]. Some adult studies suggest POCUS can be used by appropriately trained emergency physicians to risk-stratify cases of acute scrotum, expediting appropriate surgery in cases of testicular torsion [25,26]. Some urologists have recently expressed interest in whether scrotal POCUS might decrease the time to surgical detorsion in children with testicular torsion [27], but the literature on pediatric scrotal POCUS is limited to case reports [28,29].

Many specialties use POCUS at our tertiary academic pediatric hospital, which has hosted a PED POCUS fellowship program for the past 8 years. The study urology and emergency medicine divisions participate in a joint genitourinary POCUS teaching program, and the study center's PED physicians often use scrotal POCUS in cases of acute scrotum. The study authors aimed to determine the accuracy of this POCUS use in the detection of testicular torsion, as well as POCUS agreement with final diagnosis for all causes of acute scrotum. The time difference between results generated by POCUS and by radiology department ultrasound (RADUS) was also investigated.

Materials and methods

Study design and setting

A retrospective chart review of patients aged 0–18 years presenting to the study tertiary academic PED with a chief complaint of acute scrotum was performed. Charts from March 2015 to January 2018 were reviewed for POCUS diagnosis, final diagnosis (a reference standard determined by chart review), and imaging time metrics. The study was approved by the Research Ethics Board of The Hospital for Sick Children.

Selection of participants

Patients were included if they received scrotal POCUS by a pediatric emergency physician and then received RADUS of the scrotum or urology intervention in the subsequent 24 h. Patients were excluded if (1) POCUS was performed after RADUS (patients excluded to ensure the POCUS user was not biased by knowledge of RADUS results), (2) scrotal pain was a result of trauma (as these patients do not reflect the spontaneous acute scrotum patient), (3) the patient had a prior visit to the PED for acute scrotum in the 7 days before POCUS (patients excluded to ensure the POCUS user was not biased by knowledge prior testing), or (4) documentation of POCUS findings was incomplete.

For study purposes, 9 different possible diagnostic categories reflecting the principal ultrasound findings in pediatric acute scrotum were generated: normal examination, testicular torsion, epididymo-orchitis, hydrocele, torsion of the appendix testis, varicocele, scrotal edema, and tumor. An investigator (N.F.) reviewed charts to extract POCUS documentation for each case: This investigator was blinded to the other parts of the charts. The final diagnosis reference standard was a composite of results of RADUS, urology consultations, operating room reports, hospital discharge diagnoses, and reports from any clinic follow-up visits. These results were extracted by 3 investigators (Z.P., R.S., and F.T.) who were blinded to the POCUS sections of the charts. These extracted results were then presented to 2 PED experts (M.S.L. and M.O.T.). These experts applied one of the 9 diagnostic categories to the POCUS results and to the final diagnosis reference standard results. These experts were blinded to each other's diagnostic categorizations. Extracted chart sections were presented to the experts in a randomized fashion to prevent the experts from linking POCUS results to final diagnosis reference standard results, in an attempt to limit bias that might then arise in diagnostic categorizations. In cases where these 2 experts disagreed on a diagnostic categorization for either the POCUS result or the reference standard result, a third PED expert (L.M., who also was fellowship-trained in pediatric emergency medicine (PEM) and PED POCUS) served as a tiebreaker.

Outcomes

The primary outcome was the accuracy of POCUS by PED physicians in diagnosing testicular torsion in cases of acute scrotum, overall as well as according to POCUS experience level.

The secondary outcomes were agreement of POCUS with final diagnosis for all diagnostic categories and time difference between POCUS interpretation by PED physicians and RADUS interpretation by radiologists.

Agreement between the chart reviewers was expressed using Cohen's kappa, while agreement between results of PED POCUS and the final diagnosis was expressed as raw agreement (percentage). This outcome was also subanalyzed according to the POCUS experience level of the PED POCUS users. The study tertiary pediatric academic center has hosted a 1-year-long PED POCUS fellowship program for the past 7 years, and there is a wide range in POCUS user experience levels. Pediatric emergency department POCUS users were classified into 6 categories: residents, PEM fellows, PEM staff physicians, PED POCUS fellows during their first 6 months of fellowship, PED POCUS fellows during their second 6 months of fellowship, and POCUS-fellowship-trained PED POCUS staff physicians.

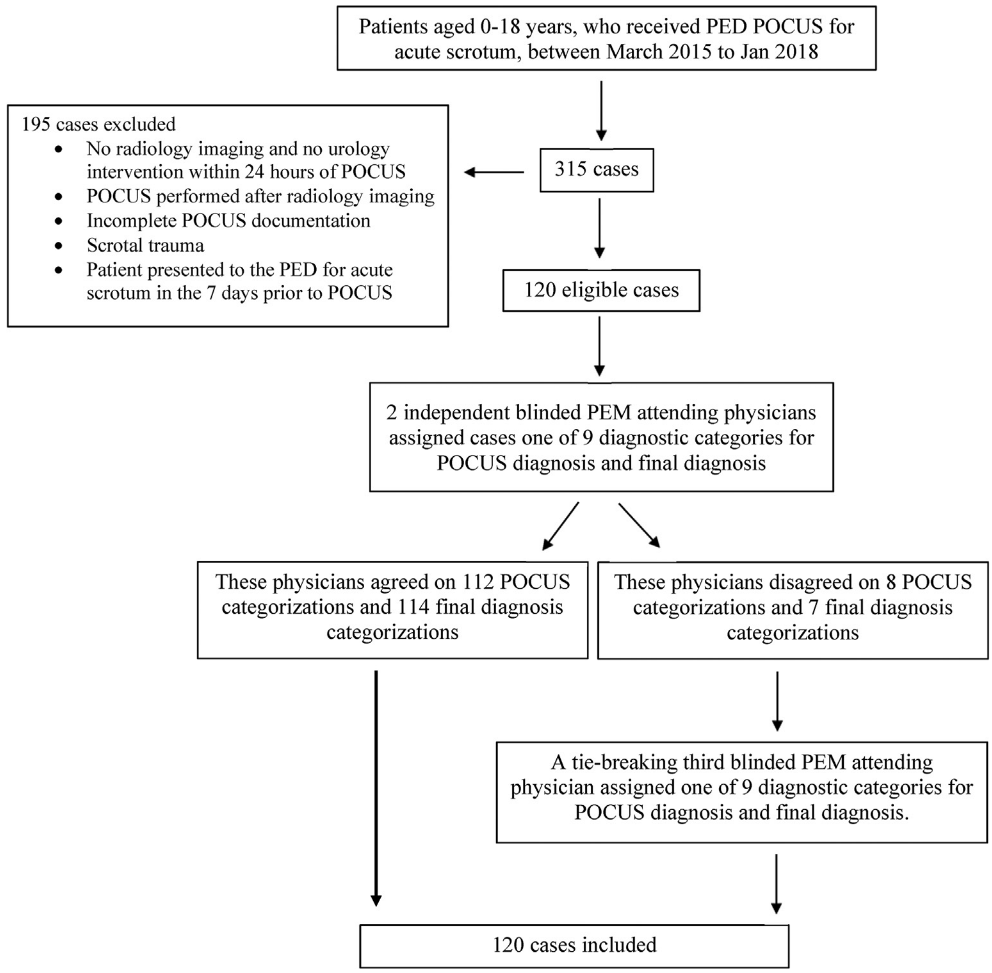

Fig. 1 Study flow diagram. PED, pediatric emergency department; POCUS, point-of-care ultrasound; PEM, pediatric emergency medicine.

For patients who received RADUS, the time difference between POCUS interpretation by the PED physician and RADUS interpretation of RADUS by the radiologist was also compared. As POCUS is interpreted as it is performed, the time stamp of the final POCUS image was used as the time of POCUS interpretation. For RADUS, the time of first documentation of interpretation (whether as a verbal report or the first written documentation in the chart) was used. Patients with a RADUS performed >24 h after PED arrival were excluded, as these cases do not reflect usual PED workflow.

Statistical analysis

Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (+LR), and negative likelihood ratio (-LR) were calculated for POCUS detection of testicular torsion. Agreement for all diagnostic categories was expressed as raw agreement. Time difference between POCUS interpretation and RADUS interpretation was calculated as a median and interquartile range. Calculations were performed using SAS, version 9.4.

Results

A total of 120 patients with a median age of 10 years (Q1 = 5 y, Q3 = 13 y) met the study criteria (Fig. 1). Point-of-care ultrasound examinations were all performed using a 5- to 14-MHz linear transducer and either a Zonare z.one machine (Mindray, Mahwah, NJ, USA) or a Zonare zs3 machine (Mindray, Mahwah, NJ, USA) using a soft-tissue setting. The two initial PED experts disagreed on 8 POCUS diagnostic categorizations, resulting in a kappa of 0.94 (95% confidence interval [CI] = 0.90–0.99); they also disagreed on 7 final diagnosis categorizations, resulting in a kappa of 0.93 (95% CI = 0.89–0.98). The diagnostic categorizations of the tiebreaking third PED POCUS expert resolved these disagreements. Twelve patients (10%) had a final diagnosis of testicular torsion.

Table 1 reports the sensitivity, specificity, PPV, NPV, +LR, and −LR of POCUS by PED physicians for pediatric testicular torsion. There was one false-positive POCUS diagnosis of testicular torsion in a case with a final diagnosis of torsion of the appendix testis. There were no cases where POCUS missed a diagnosis of testicular torsion: All 12 true-positive cases in the study cohort were correctly

Table 1 Accuracy of POCUS by PED physicians in diagnosing testicular torsion in children with acute scrotum.

Sensitivity (%, 95% CI)	100 (73.5–100)
Specificity (%, 95% CI[a]	99.1 (95.0–100)
PPV (%, 95% CI)	92.3 (63.0–98.8)
NPV (%, 95% CI)	100 (NC[a])
+LR (95% CI)	108.0 (15.4–759.8)
-LR (95% CI)	0 (NC[a])

CI, confidence interval; PPV, positive predictive value; NPV, negative predictive value; POCUS, point-of-care ultrasound; PED, pediatric emergency department.
[a] NC = non-calculable.

identified by PED POCUS. Eight of these 12 cases were identified by fellowship-trained PED POCUS staff physicians, 2 by PED POCUS fellows during their second 6 months of fellowship, and 2 by PED POCUS fellows during their first 6 months of fellowship.

In 6 of the 12 true-positive cases of testicular torsion, the urology service took the patient directly to the operating room after reviewing the POCUS images and examining the patient, without RADUS being performed. The case where POCUS was falsely positive for testicular torsion was diagnosed by RADUS as torsion of the appendix testis and did not receive urology intervention. Three testicular torsion cases presented >24 h after the onset of symptoms: One case underwent an immediate orchiectomy.

Table 2 reports the agreement between POCUS diagnosis and final diagnosis, overall and according to POCUS experience level.

Table 3 reports the agreement between POCUS diagnosis and final diagnosis according to the final diagnosis category.

There were 36 cases of disagreement between POCUS diagnosis and final diagnosis. Fifteen of these cases had a final diagnosis of torsion of the appendix testis but were erroneously diagnosed by the POCUS users as 10 cases of epididymo-orchitis, 2 normal exams, 2 cases of hydrocele, and 1 case of testicular torsion. Eleven of these cases had a final diagnosis of epididymo-orchitis but were erroneously diagnosed by the POCUS users as 6 cases of normal examination, 2 cases of hydrocele, 2 cases of scrotal edema, and 1 case of herniated bowel. Four of these cases had a final diagnosis of normal examination but were erroneously diagnosed by the POCUS users as 2 cases of hydrocele and 2 cases of epididymo-orchitis. Two of these cases had a final diagnosis of scrotal edema, but both were erroneously diagnosed by the POCUS users as epididymo-orchitis. Two of these cases had a final diagnosis of hydrocele but were erroneously diagnosed by the POCUS users as 1 case of normal examination and 1 case of epididymo-orchitis. One of these cases had a final diagnosis of varicocele but was erroneously diagnosed by the POCUS user as epididymo-orchitis. The final case had a final diagnosis of tumor but was erroneously diagnosed by the POCUS user as epididymo-orchitis.

Point-of-care ultrasound interpretations were made a median of 73 min (Q1 = 51, Q3 = 112) before RADUS interpretations.

Discussion

The study results suggest that scrotal POCUS performed by PED physicians is an accurate tool to detect testicular torsion in cases of pediatric acute scrotum. This agrees with prior reports that suggest this POCUS application can be used accurately by emergency physicians in a general emergency department setting [24,25].

There was variation in POCUS agreement with final diagnosis depending on POCUS user experience level, with PEM staff physicians without POCUS fellowship training exhibiting the lowest agreement with final diagnosis. There was also variation in POCUS agreement depending on the final diagnosis, with testicular torsion being the only diagnostic category where POCUS was in 100% agreement with final diagnosis, while cases of hydrocele also were accurately diagnosed by POCUS. Point-of-care ultrasound users did not correctly identify any of the 15 cases of torsion of

Table 2 Agreement between POCUS and final diagnosis for cases of pediatric acute scrotum, grouped according to POCUS user experience.

POCUS user experience level	Number of cases	Number of cases with agreement between POCUS diagnosis and final diagnosis	POCUS agreement with final diagnosis (%, 95% CI)
All users	120	84	70 (62–78)
Any degree of PED POCUS fellowship training	84	62	74 (64–83)
Completion of a PED POCUS fellowship	43	34	79 (67–91)
PED POCUS fellows during their second 6 months of fellowship	18	12	67 (45–88)
PED POCUS fellows during their first 6 months of fellowship	23	16	70 (51–88)
Pediatric emergency medicine fellows	24	18	75 (58–92)
Pediatric emergency medicine attending physicians without POCUS fellowship training	10	4	40 (12–74)
Residents	2	0	0 (0–78)

PED, pediatric emergency department; POCUS, point-of-care ultrasound; CI, confidence interval.

Table 3 Agreement between POCUS and final diagnosis according to final diagnosis category.

Final diagnosis	Number of cases	Agreement (%, 95% CI)
Normal examination	30	87 (69–96)
Testicular torsion	12	100 (74–100[a])
Epididymo-orchitis	34	68 (50–83)
Hydrocele	23	91 (72–99)
Torsion of the appendix testis	15	0 (0–22[a])
Varicocele	3	67 (9–99)
Scrotal edema	2	0 (0–84[a])
Tumor	1	0 (0–98[a])
Herniated bowel	0	NC[b]

POCUS, point-of-care ultrasound.
[a] One-sided 97.5% CI.
[b] NC = non-calculable.

the appendix testis and in fact did not apply this diagnosis in any of their cases. This likely reflects the study POCUS training program's lack of emphasis on this condition. Point-of-care ultrasound is frequently used not as comprehensive imaging but rather as a risk-stratification tool, and future work might examine whether POCUS can accurately distinguish acute scrotum cases requiring further inpatient management from cases that are safe for outpatient supportive treatment (i.e., rest, scrotal support, and analgesia, as in most cases of epididymo-orchitis and torsion of the appendix testis).

Radiology department ultrasound interpretations were reported a median of 73 min later than POCUS interpretation. This suggests a potential to decrease time to surgery in cases of testicular torsion, which is the focus of an ongoing study by the study authors. Future work should also investigate the potential for POCUS to decrease PED length of stay for other causes of acute scrotum.

Limitations

A multidisciplinary ultrasound oversight committee at the study institution sets credentialing and quality assurance standards for POCUS users and works to ensure that POCUS examinations are available in the study institution's electronic medical record. This allows qualified urology and emergency medicine POCUS users to collaboratively integrate scrotal POCUS findings into clinical decision-making for patients with acute scrotum. The results from POCUS users at the study site may not be generalizable to POCUS users at hospitals without such quality or image-sharing standards. It is also important to note that all cases of testicular torsion were identified by PED physicians with some degree of POCUS fellowship training.

The cases included in this analysis may also suffer from selection bias. By excluding patients who did not receive RADUS, cases performed by the most experienced and accurate POCUS users may have been excluded while sampling cases that were either more diagnostically challenging or where the POCUS user was less experienced and less confidant. As such, the study results may underestimate the degree of agreement between POCUS users and final diagnosis for non-testicular torsion causes of pediatric acute scrotum.

The final diagnosis composite chart review reference standard is also imperfect. In many cases, the only diagnostic test included in the final diagnosis reference standard was RADUS, and follow-up details could not be provided for most patients as they did not have subsequent visits in their charts.

Our study was not structured to allow more than one diagnostic category to be selected. In reality, small reactive hydroceles are common in the inflammatory milieu of the acute scrotum, and hydroceles or varicoceles may be incidental findings rather than the true cause of acute scrotum.

The study cohort contained few cases of varicocele, scrotal edema, and tumor and no cases of herniated bowel, so any conclusions about the true ability of PED POCUS to detect these diagnoses could not be confidently drawn.

Owing to the retrospective nature of this study, other potential impacts of POCUS, such as patient outcomes, cost-effectiveness, and patient satisfaction, could not be measured. While POCUS by surgeons and emergency physicians has the potential to limit unnecessary downstream testing and healthcare expenses when used accurately [20,30], inaccurate POCUS use may accomplish the opposite.

Conclusions

Point-of-care ultrasound by pediatric emergency physicians may be accurate in diagnosing testicular torsion of the children with acute scrotum. Further studies are needed on the ability of PED POCUS to detect other causes of acute scrotum and on whether PED POCUS can improve outcomes and resource utilization in these children.

Author statements

Ethical approval

The study was approved by the Research Ethics Board of The Hospital for Sick Children.

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Presentations

None.

Author contributions

M.O.T. conceived and designed the study and revised the manuscript. N.F. supervised the conduct of the study, performed data collection and data management (including quality control), and drafted the manuscript. Z.P., R.S., and F.T. performed data acquisition. M.S.L. and L.M. provided statistical advice on study design and analyzed the data. M.O.T. takes responsibility for the article as a whole.

Competing interests

None declared.

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Duration of symptoms is the only predictor of testicular salvage following testicular torsion in children: A case-control study

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ABSTRACT

Objective: Testicular torsion (TT) is an emergency requiring a prompt diagnosis and surgery to avoid irreversible changes and a complete loss of testis. The present study aimed to identify potential factors that may be predict a testicular salvage after TT in pediatric patients.
Methods: Consecutive medical records of all children ≤16 years old with surgically confirmed TT over a period of five years (2011–2016) were collected. Patients were divided into 2 groups according to testicular viability and the type of treatment: Orchidectomy and orchidopexy. The differences between the two groups and potential predictors of testicular salvage were analyzed.
Results: Thirty-one boys with TT met the inclusion criteria and were included in the study. The mean age was 13.6 years (range, 10 days - 15.8 years). Testicular salvage was possible in 18 (58.1%) patients. The duration of symptoms and a lesser degree of torsion indicated a testicular salvage in children and adolescents with testicular torsion, but in multivariate analysis only duration of symptoms (time to surgical detorsion) was significantly associated with the risk of non-salvage. At follow-up, testicular atrophy affected 73.3% of the patients treated with orchidopexy.
Conclusion: Duration of symptoms is the only predictor of successful testicular salvage following testicular torsion in children. It is associated with a substantial risk of testicular loss and atrophy.

1. Introduction

Testicular torsion (TT) is a surgical emergency affecting 1 in 4000 boys below the age of 25 and accounting for up to 25% of acute scrotal disease in pediatric population [1]. TT is defined as a suddenly occurring spermatic cord twisting along a longitudinal axis resulting in occlusion of the blood supply to the testis that untreated ultimately leads to testicular ischemia. An accurate and timely diagnosis and urgent surgery are necessary to avoid irreversible changes and loss of testis with eventual impairment of fertility and psychological trauma as long-term complications [2,3]. Therefore, the time-sensitive nature of TT is of utmost importance to pediatric surgeons and urologists as well as to emergency physicians and primary care providers who refer patients with TT for the treatment. In addition, malpractice cases of TT resulting in testicular loss are often a subject of medical malpractice litigation [4,5]. In addition to the aforementioned difficulties, a lack of defined objective criteria for an adequate assessment of testicular viability during exploration is the next potential challenge for involved clinicians [6].

Various studies have identified some predictors of testicular viability after surgical detorsion including duration of symptoms before surgery and degree of twisting [7-10]. However, there is still no agreement on whether both of these factors are relevant predictors.

The present study aimed to identify factors predicting testicular viability during scrotal exploration in patients with TT.

2. Materials and methods

We conducted a retrospective study using a cohort of pediatric patients with a surgically confirmed diagnosis of TT in the period between March 2011 and March 2016. TT was defined as a twisting of the spermatic cord and its contents with resultant ischemia due to compromised blood flow to the testicle. All patients underwent testicular ultrasonography with color-Doppler ultrasonography (CDUS) before surgery. The surgical procedure was never delayed more than 45 min from the hospital admission.

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The medical records of 33 consecutive patients were reviewed, including their medical histories, physical examination notes, and adjuvant colored Doppler ultrasonography (CDUS) results. The patients were divided into two groups according to testicular viability and the type of treatment: orchidectomy and orchidopexy groups. Inclusion criteria for the study were confirmed diagnosis of TT and age below 16 years. Those with incomplete or missing data were excluded from the study. Finally, 31 patients who were eligible for the study were selected for further review.

The primary outcome of the study was the restoration and maintenance of testicular blood flow during and immediately after surgery. Manual testicular detorsion was not attempted in any case. The access for surgical exploration of the testis in all cases was through the midline scrotal incision. After determining the type and degree of testicular torsion, all patients underwent a three-grade bleeding test as proposed by Arda and Ozyaylali [11], where grade I indicated an immediately sufficient arterial bleeding from the cut edge; grade II absent bleeding immediately after incision, but starting within 10 min, and grade III with no bleeding after 10 min. Based on the results of the bleeding test, the decision to perform orchidectomy or orchidopexy was made. All removed testes after orchidectomy underwent histopathological examination for final confirmation.

For all patients with primary performed orchidopexy, postoperative follow-up consisted of CDUS evaluation performed 1, 3, 6 and 12 months after surgery to asses testicular blood flow and volume. Testicular volume was calculated using formula 0.71 x length x width x thickness of the testicular ellipsoid [12]. Testicular atrophy was defined as a postoperative testicular volume $<$ 50% of the volume of the contralateral testis, based on measurement by ultrasonography [13]. In cases of presence of testicular atrophy, the duration of time before atrophy was identified and recorded.

All patient medical records were de-identified and anonymized for the current study. This study was approved by the local institutional review board (Ethical Committee of the Clinical Center, University of Sarajevo, number: 0901–2-678/18) and informed consent was waived due to its retrospective nature.

2.1. Statistical analysis

Mean and median were used as a measure of central tendency and standard deviation and range as measures of dispersion for continuous variables. The values of categorical variables were presented as numbers or percentages. The normality of data distribution for each of the variables was tested by the Kolmogorov-Smirnov test. The significance of the difference in continuous variables among the study groups was tested by the Mann Whitney *U* test because the data was not normally distributed. The association of study variables with the study outcome was tested by univariate and multivariate logistic regression. The quality of the multivariate logistic regression model was checked using the Hosmer and Lemeshow Test and coefficients of variation (R Square) by Nagelkerke and Cox & Snell. All statistical assays were performed using the Statistical Package for the Social Sciences (SPSS) IBM Version 26 (SPSS) (UNICOM Systems, Inc.).

3. Results

The demographic and clinical characteristics of the two cohorts are presented in Table 1.

Thirty-one patients met the inclusion criteria. Thirteen patients (41.9%) had undergone orchidectomy (orchidectomy group) and 18 (51.8%) had orchidopexy (orchidopexy group). The median age at presentation was 13.5 $\pm$ 2.6 years (range, 10 days - 15.8 years). The scrotal approach was performed in all patients. Preoperative CDUS showed absent/weak arterial and venous flow in 27/31 patients (87.1%).

The presenting symptoms associated with TT included testicular pain (27, 87.1%), erythema of scrotal skin (20, 64.6%), swelling (17, 54.8%), nausea or vomiting (12, 38.7%), abdominal pain (6, 19.4%), and fever (2, 6.5%).

The two groups did not differ significantly concerning the age [except in the age group <1 year old in which all patients underwent orchidectomy ($p = 0.045$); however, the number of events was small, $n = 4$], laterality (left sided TT was more common than right with a L:R ratio of 1.8:1), and seasonality of TT (Table 1). Interestingly, all patients that were treated in the spring underwent orchidopexy ($p = 0.002$), but more significant differences were observed with respect to the duration of symptoms and degree of torsion (Table 1).

A multivariate logistic regression model was constructed using a backward conditional deletion method and explained 59.2% and 44.3% of the dataset variability (Table 2). Univariate logistic regression analysis revealed a significant association between the duration of symptoms before surgery and degree of torsion with salvageability of the surgery, but multivariate logistic regression confirmed only the duration of symptoms before surgery as a significant variable (Table 2). Running logistic regression model with interaction between duration of symptoms before surgery and degree of torsion did not show an increase in the extent of association.

Table 1
Demographic and clinical characteristics of the two groups of children affected by the testicular torsion

Variable	Total n (%)	Orchidectomy group n (%)	Orchidopexy group n (%)	*P*-value*
n (%)	31	13 (41.9%)	18 (58.1%)	0.37
Mean age ± SD (years)	13.5 (6–14.5)	13.1 (0.1–14.1)	13.1 (1.2–15.8)	0.89
Age (years)				
<1	4 (100%)	4 (100%)	0 (0%)	**0.045**
2–3	1 (100%)	1 (100%)	0 (0%)	0.32
4–6	1 (100%)	0	1 (100%)	0.32
7–10	3 (100%)	1 (33.3%)	2 (66.7%)	0.56
11–16	22 (100%)	7 (31.8%)	15 (68.2%)	0.09
Laterality (Right vs. left)	Right 11 (35.5%)	Right 2 (18%)	Right 9 (50%)	**0.03**
	Left 20 (64.5%)	Left 11 (80%)	Left 9 (50%)	0.65
Duration of symptoms	48 h	96 h	24 h	
	Range, 24-96 h	Range, 64-96 h	Range, 18-24 h	**0.0001**
Degree of twisting	563.22 ± 349.2	775.44 ± 235.8	410.04 ± 342	**0.003**
Season				
Spring	5 (100%)	0	5 (100%)	**0.03**
Summer	13 (100%)	8 (61.5%)	5 (34.5%)	0.41
Autumn	6 (100%)	1 (16.7%)	5 (83.3%)	0.10
Winter	7 (100%)	4 (57.1%)	3 (42.9%)	0.71

* Only significant *p*-values are bolded.

Table 2
Results of univariate and multivariate logistic regression.

Variable	Crude odds ratio with CI*	Adjusted odds ratio with CI
Age	1.008 (0.882–1.151)	0.794 (0.578–1.091)
Duration of symptoms until surgery	0.950 (0.910–0.992)**	0.952 (0.911–0.995)**
Pain as the first symptom	N/A	N/A
Visibility of testicular blood flow on Doppler ultrasound scan	N/A	N/A
Degree of torsion	0.996 (0.993–1.000)**	0.997 (0.994–1.001)
Level of torsion (intravaginal or supravaginal)	0.714 (0.143–3.579)	0.414 (0.019–8.842)

* CI = 95% confidence interval.
** $p < 0.05$.

Among the eighteen patients that were treated by orchidopexy, 15 (83.3%) had a follow-up scrotal ultrasonography performed a median 91 days after surgery (range, 79–125 days). The remaining three patients were lost to follow-up. Testicular atrophy occurred in eleven patients (73.3%) while the total absence of the testis was found in one patient (6.6%).

4. Discussion

Among the variety of diseases in the differential diagnosis of the acute scrotum, (traumatic, ischemic or inflammatory origin), clinical suspicion of TT must be promptly proven or disproved due to the well-known fact that testicular tissue is particularly susceptible to ischemic/reperfusion injury due to torsion [14]. However, physical examination cannot reliably differentiate TT from other scrotal pathologies causing acute scrotum as confirmed in our and several previous studies [15-17]. In addition, our data indicate that a shorter duration of symptoms, a lesser degree of twisting, and the older age may be predictors of testicular salvage in children and adolescents affected by TT. We observed a bimodal age distribution of TT in children and adolescents; one in the neonatal period and the other in early puberty. Both peaks were the time of appearance of primary and secondary sex characteristics. These findings are in line with previous reports [18].

Despite the great efficacy of the existing radiological tools (e.g. CDUS), to distinguish TT from other causes of acute scrotum [19], there is still no harmonized treatment algorithm, and some clinicians advise surgical exploration in all cases of the acute scrotum to ensure a maximal testicular salvage [20,21]. Thus, a retrospective study of Molokwu et al. using this approach, diagnosed TT in only 51% of the cases [21]. The diagnostic accuracy of CDUS in our study was 87.1%, which was in accordance with several previous studies [22,23]. The reason for the preserved flow on CDUS in cases of TT in our study and a false negative CDUS finding for TT potentially can be explained by the different cord thicknesses that in the same degree of twisting shows a complete breakdown of blood flow in some testes but preserved in others [6]. Interpreting that the different cord thickness can contribute to a false negative CDUS finding for TT may be explained by a gradual blood flow impairment with obstruction of first venous drainage and impairment of arterial inflow occurring secondarily. Another reason for false-negative CDUS finding may be caused by a partial testicular torsion, which can be difficult to diagnose due to either subtle decrease in blood flow or flow that appears to be symmetrical with the contralateral testis [24]. Because of the design of this study and limited sample size, we decided not to analyze the diagnostic utility of CDUS in TT.

In our study, testicular salvage was possible in 58% of the cases; consequently, the orchidectomy was performed in ~42% of the cases. These results are in line with the findings of other studies, in which orchidectomy was done in ~40% of the cases [18,25]. The decision to perform orchidectomy or orchidopexy was based on the actual condition of the testis after detorsion and the results of a three-grade bleeding test proposed by Arda and Ozyaylali [11]. It should be noted here that the prediction of long-term viability and spermatogenesis of the affected testis is extremely difficult due to insufficiently clear effects of ischemia and ischemia/reperfusion injury on the testicular structures.

Two predictive factors of testicular viability during surgical exploration have been proposed including duration of symptoms before surgery and degree of twisting [7-10]. Due to clinical findings that a similar degree and duration of symptoms of TT can result in testicular infarction or salvage, Sessions et al. suggested the importance of other factors that may be involved in determining a vascular compromise in any degree of torsion [10]. These authors observed that thinner spermatic cords might tolerate better significant rotation of longer duration in comparison with more substantial cords under similar conditions [10].

In addition to the undoubted fact that the duration of ischemia has the greatest impact on the survival of a testicle following torsion [7-10,26], there is a lack of evidence on the impact of the degree of twisting on the vitality of the affected testis. While relevant data regarding the influence of the degree of twisting in the spermatic cord on ultimate testicular outcomes in TT cases were obtained from animal studies [27-29], the results on this topic are limited in humans. Dias et al. recently reported a correlation between the length of symptoms and degree of twisting with the testicular survival rates, noting that the degree of twisting between 360 and 540° during TT is the point where a significant occlusion to arterial flow occurs with the risk of damage to the testis [9]. Howe et al. found that the viability of the affected testis could be determined by the duration of symptoms along with the degree of twisting, with 15 h of symptoms duration and 860° of torsion leading to a 50% probability of non-salvage [7]. They also found that about 1 out of 4 testes undergoes atrophy after orchidopexy, concluding that duration of symptoms appeared to be the primary predictor of outcomes [7]. Our study revealed that the duration of symptoms was the only predictor of testicular salvage following TT. In our study, the testicular atrophy rate was slightly higher (~70%) than previously reported (~55–60%) [13,30], but this can be due to the small sample size.

In conclusion, testicular torsion is the most frequent testicular emergency in infants and adolescents that is associated with a high risk of testicular loss or atrophy. Older age, a shorter duration of symptoms, and a lesser degree of torsion may be predictors of testicular salvage in children and adolescents with testicular torsion, but the duration of symptoms appears to be the only predictor of testis salvage.

Availability of data and materials

The datasets presented in the current study are available by the corresponding author on reasonable request.

Declaration of Competing Interest

The authors declare no conflict of interest.

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Pediatric Testicular Torsion

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KEYWORDS

• Testis • Torsion • Acute scrotum • Epididymitis/orchitis

KEY POINTS

- Testicular torsion is a surgical emergency and requires prompt surgical exploration and management.
- The diagnosis of testicular torsion can be made by history and physical examination alone. When suspected, surgical management should not be delayed in an effort to obtain imaging.
- When unilateral testicular torsion is discovered, a contralateral orchidopexy should be performed to reduce the risk of asynchronous testicular torsion.

OVERVIEW AND HISTORY

The pediatric patient presenting with acute scrotal pain requires prompt evaluation and management given the likelihood of testicular torsion as the underlying cause. Although other diagnoses can present with acute testicular pain, it is important to recognize the possibility of testicular torsion because the best chance of testicular preservation occurs with expeditious management.

The first published report of testicular torsion was by Delasiauve in 1840, and Taylor first described newborn torsion in 1897. Torsion of a testicular appendage was recognized in 1922 by Colt.

EPIDEMIOLOGY

Although torsion of the spermatic cord and torsion of the testicular appendages can occur at any age, it is more common to see the former in postpubertal boys and the latter in prepubertal boys.[1,2] Adolescent boys are most commonly affected, with a smaller increase in frequency seen in newborns as well.[3] There is evidence to suggest that the risk of torsion can be inherited, particularly in cases of bilateral torsion.[4] The annual incidence of torsion is estimated at 3.8 per 100,000 (0.004%) for boys age 18 years and under.[5]

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DIFFERENTIAL DIAGNOSIS

- Spermatic cord torsion
- Torsion of appendix testis/epididymis
- Tumor
- Hernia/hydrocele
- Epididymitis/orchitis
- Trauma/abuse
- Cellulitis
- Vasculitis
- Varicocele

PERINATAL TORSION

Torsion can occur during the prenatal or postnatal period and is collectively referred to as perinatal torsion. Establishing the timing of the torsion can have implications on future management but is often difficult to determine. Classically, prenatal torsion involves a twisting of the spermatic cord that occurs proximal to the tunica vaginalis—extravaginal torsion. It typically is identified at birth with a firm, discolored, and non-tender hemiscrotal mass. It is often difficult to palpate the testicle separate from the scrotal skin as the inflammation causes fixation of the skin to the inflamed testicular mass. Postnatal torsion, by comparison, appears with more classic signs of torsion: acute inflammation, erythema, and tenderness. The key clinical finding that suggests postnatal torsion is the report of a previously normal scrotum and testicle at birth. Understanding this, timing is critical given that postnatal torsion should be treated as a surgical emergency with immediate exploration, detorsion, and orchidopexy of the contralateral testicle to prevent later torsion.

The management of true prenatal torsion remains debated.[6] The decision about the need for exploration, timing of exploration, and management of the contralateral testicle varies widely among practitioners. Factors that influence the decision include the age at which the torsion is diagnosed and overall health of the child. The debate exists because salvage of a prenatally torsed testicle is extremely unlikely,[7] the risk of neonatal anesthesia is higher than in older children,[8] and there is a risk of iatrogenic injury to the contralateral testicle. The age of the child at diagnosis influences the decision primarily because the tunica vaginalis becomes adherent to the surrounding dartos around 4 to 6 weeks of life. When the torsion is discovered after this 4- to 6-week age period, there is theoretically no longer a risk of asynchronous torsion and thus no need for prophylactic orchidopexy on the contralateral side. A prenatal (extravaginal) torsion event does not predispose the child to a future postpubertal (intravaginal) torsion event. **Fig. 1** outlines the authors' preferred management algorithm for perinatal torsion.

CLINICAL PRESENTATION

Testicular torsion classically presents with the sudden onset of severe unilateral scrotal pain. This pain is usually accompanied by nausea and vomiting. The pain is usually unrelenting and leads the child to immediately notify a caregiver, although very stoic children will often delay reporting the pain. Delays in recognition can also be seen in children who are unable to communicate with their caregivers.

Within hours of the torsion event, the scrotum will begin to show varying degrees of erythema, swelling, and induration. In cases where the evaluation occurs long after the

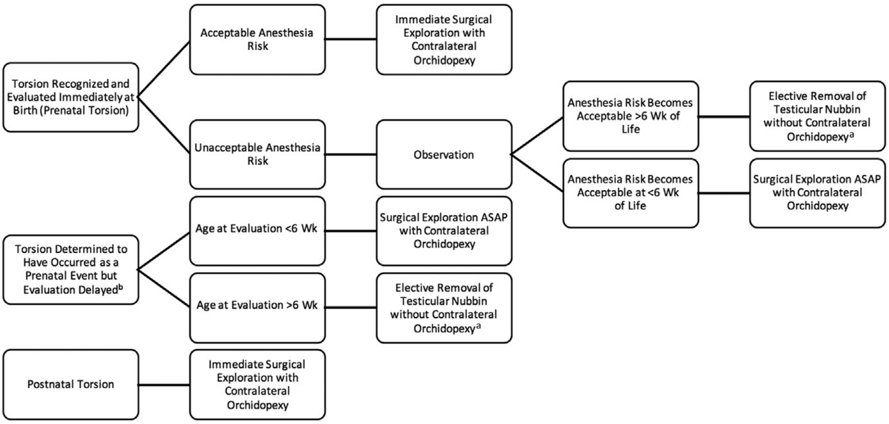

Fig. 1. Management algorithm for perinatal testicular torsion. [a]Observation is reasonable when the history and examination do not raise any concern for the presence of an intra-abdominal testicle. [b]When torsion timing is unclear, the decision of management needs to be based on a comprehensive discussion with the caregivers. ASAP, as soon as possible.

onset of symptoms, the severity of the scrotal edema can be quite severe and can make examination of the underlying testicle quite difficult.

INITIAL EVALUATION

The 2 most important components of the initial evaluation are the history and physical examination. These 2 elements alone are enough to establish the diagnosis and prompt treatment. It is important to recognize that any boy presenting with abdominal pain associated with nausea and vomiting requires a scrotal examination to evaluate for testicular torsion. Key components of the history that suggest acute testicular torsion include the following:

- Immediate onset of severe, unilateral scrotal pain
- Unrelenting pain
- Associated nausea/vomiting
- Described change in the position of the testicle

The physical examination should include a thorough investigation of the abdomen, inguinal region, penis, and scrotum. Key components of the physical examination include the following:

- Unilateral testicular tenderness
- Elevation (high-riding) of the testicle
- Transverse testicular orientation
- Palpation of the epididymis anteriorly
- Absent cremasteric reflex

The presence or absence of the cremasteric reflex is a classic teaching point in the evaluation of the acute scrotum. It is elicited by lightly stroking the inner thigh on the side of the suspected torsion. The resultant reflex occurs due to stimulation of the sensory fibers of the femoral branch of the genitofemoral nerve. This afferent input ascends to the brain, where there are superimposed cortical pathways that allow the signal to cross over and connect with motor centers that result in the efferent stimulation of the genital branch of the genitofemoral nerve, which innervates the cremaster muscle.[9] Although the cremasteric reflex is frequently absent in cases of acute torsion, the presence of the reflex does not exclude torsion.[10] The reflex is more reliable when absent on the side of pain but present on the normal side. It is less reliable when absent on both sides.

INITIAL MANAGEMENT

When the history and examination suggest testicular torsion, surgical exploration should immediately follow. If surgical care is not immediately available, an attempt at manual detorsion can be performed. Classically, this maneuver is instructed to be done in a fashion that rotates the testicle from medial to lateral, colloquially referred to as the "open book" rotation. From the perspective of the provider standing face to face with the patient, this means rotating the right testicle counterclockwise and rotating the left testicle clockwise. The success of this technique is hampered by patient discomfort, incomplete (or partial) detorsion, as well as the possibility of rotating the testicle in the wrong direction. Around one-third of testicles will be found to have rotated from medial to lateral, a situation that is only worsened when a classic "open book" detorsion maneuver is attempted.[11] In addition, the number of testicular rotations can range from 180° to 1080°, leaving open the possibility of only partial untwisting the testicle with a manual detorsion maneuver.

If manual detorsion is successful, the patient will typically have immediate relief of their pain. Although this relief may result in a longer window for testicular salvage, it should not delay prompt surgical management and fixation.

IMAGING AND LABORATORY TESTS

As stated throughout this article, clinical suspicion for acute testicular torsion mandates immediate surgical exploration. The acquisition of confirmatory imaging is generally unnecessary and typically only results in a delay in definitive management.[1] Although currently this principle remains unchanged, the advent of point-of-care ultrasound in the emergency department may ultimately lead to an environment where bedside imaging may almost be considered an extension of the physical examination with almost no delay in further management.[12]

Imaging is generally recommended only in cases where the cause of the acute scrotum is not thought to be due to acute torsion. Ultrasound with color-flow Doppler and radionuclide imaging are the 2 most commonly used imaging modalities. Although radionuclide imaging has been the historical examination of choice, the use of ultrasound with Doppler is now widely favored because of its excellent visual resolution, ability to detect the presence or absence of blood flow, availability, and lack of ionizing radiation. Ultrasound has a sensitivity and specificity of 89.9% and 98.8%, respectively, with a false-positive rate of 1% when performed by experienced providers.[13] The integration of any radiologic study, however, still needs to include the other aspects of the evaluation because false negatives can occur.[14]

Laboratory investigation in cases of suspected torsion is rarely necessary. In cases where the individual's medical history of presentation raises concern for a serious abnormality that can be demonstrated with laboratory data (anemia, coagulopathy, severe electrolyte disturbance, and so forth), laboratory investigation can be pursued. As a general principle, however, this should not delay progression to the operating room unless the risk of anesthesia is thought to be much greater than the likelihood of testicular salvage. In this unusual scenario, accepting the risk of testicular loss and theoretic risk of contralateral torsion may warrant consideration. Once the anesthetic risk is deemed acceptable, however, urgent surgical management should be undertaken.

OPERATIVE MANAGEMENT

Once surgical management is decided on, it should occur as quickly as possible. Testicular salvage rates are associated with the duration of ischemia with a "golden" window of 4 to 8 hours from the time of torsion to time of detorsion. Although an inguinal or hemiscrotal approach is reasonable, most surgeons use a midline raphe incision. Access via the midline allows each hemiscrotum to be independently explored and, once healed, the surgical scar is typically imperceptible. The general steps in the operative management of torsion are as follows:

- Midline scrotal incision
- Cautery dissection through the dartos layers of the symptomatic hemiscrotum to expose the underlying testicle
- Delivery of the testicle through the dartos
- Inspection of the tunica vaginalis and spermatic cord for extravaginal torsion (unlikely outside of newborn period)
- Incision and eversion of the tunica vaginalis to allow inspection of the testicle and epididymis
- Detorsion of the testicle noting direction and degrees of torsion
- Placement of detorsed testicle in a warm gauze sponge
- Cautery dissection through the dartos layers of the contralateral hemiscrotum to expose the underlying testicle
- Delivery of the testicle through the dartos
- Incision and eversion of the tunica vaginalis to allow inspection of the testicle and epididymis
- Fixation of the contralateral testicle
- Repeat inspection of the symptomatic testicle
  - Obviously nonviable → orchiectomy
  - Obviously viable → orchidopexy
  - Questionably viable → orchiectomy or ochidopexy

The assessment of testicular viability is a relatively subjective aspect of the surgical management. When viability is questionable, additional investigation can be performed, including incision of the tunica albuginea to inspect for active bleeding and to assess the viability of the seminiferous tubules. When no bleeding is observed and/or the tubules appear densely ischemic, orchiectomy is generally favored. In the presence of active bleeding and/or viable-appearing tubules, however, orchidopexy should be considered.

More recently there has been emerging evidence to support a third approach to the questionably viable testicle. Decompression of the tunica albuginea via a wide longitudinal incision along its surface (fasciotomy) followed by coverage of the defect with a tunica vaginalis flap has shown encouraging results as an option for testicular salvage.[15] This approach still mandates testicular fixation but theoretically allows for relief and recovery of the testicular "compartment syndrome." Although the long-term success of this option is difficult to definitively assess, it is a potentially useful option for the questionably viable testicle. The surgical technique itself has been described by Kutikov and colleagues.[16]

In cases where a torsed gonad is preserved, there has been concern raised about the possibility of damage to the contralateral testicle because of antisperm antibodies.

This debate includes cases of testicular salvage using a tunica vaginalis flap. These concerns generally arise from animal studies with the physiologic significance in humans remaining a source of debate.[17] In cases of torsion of a solitary testicle however, it is obviously recommended to make every attempt to preserve the testicle regardless of its likelihood of future atrophy. Adjuvant procedures, such as the aforementioned tunica vaginalis flap, should also be considered as a means to potentially save a gonad that would otherwise be unlikely to survive.

The techniques used to perform orchidopexy vary widely among surgeons, including debate about the following:

- Number of points of testicular fixation (typically between 1 and 3)
- Use of permanent or dissolvable suture
- Use of suture fixation versus placement of testicle within a dartos pouch alone
- Placement of fixation sutures within scrotum (medial, lateral, inferior, or a combination of all 3)

At the authors' institution, orchidopexy, in the setting of testicular torsion, is typically done in 1 of 2 ways. The first technique is to place the testicle partially back within the tunica vaginalis, leaving the anterior one-third of the surface of the testicle exposed. The edges of the tunica vaginalis are then tacked to the testicle in several places with an absorbable suture (polydioxanone or polyglactin). The second technique uses polypropylene suture to tack the tunica albuginea to the interior surface of the scrotum. This tacking is typically done inferiorly, laterally, and either anteriorly or medially for 3 total points of fixation.

FOLLOW-UP

In general, children recover well after surgery and can typically be discharged to home from the recovery room regardless of the surgical outcome (orchidopexy or orchiectomy). Outpatient follow-up several weeks after the procedure allows for evaluation of delayed atrophy. In cases where orchiectomy was performed, it also allows for discussion about future placement of a testicular prosthesis, should one be desired. Recommendations to avoid specific activities or sports are generally not given, but emphasis is given regarding the utilization of appropriate protection. Finally, it allows an opportunity to discuss the importance of testicular self-examination, a valuable topic for all male adolescents regardless of the outcome of their torsed testicle.

When counseling patients and families about torsion, it is important to remind them that the fixation of the testicle does not rule out the potential for future torsion. Recurrent torsion has been reported and requires urgent evaluation identical to an initial torsion event.[18] Similarly, studies have shown that there may be a component of heritability with testicular torsion[4] as well as a lower likelihood of testicular salvage in boys who experience an acute torsion event after having a sibling with torsion.[19] The latter phenomenon is difficult to explain but thought to potentially be related to a form of "desensitization" regarding testicular pain from the perspective of the caregiver.

INTERMITTENT TESTICULAR PAIN

Intermittent testicular pain is a frequent complaint, particularly among male adolescents. Although a history of testicular pain with spontaneous resolution should raise concern for the possibility of intermittent testicular torsion, a detailed history and examination can often elicit an alternate cause, as described in the differential diagnosis section. Anecdotally, people frequently associate testicular pain with puberty and the testicular growth that accompanies the early stages of puberty. These so-called growing pains, however, are not well described in the literature.

Individuals thought to be most at risk for intermittent testicular torsion include those with a "bell-clapper" deformity. Normally the tunica vaginalis invests upon the length of the posterior side of the testicle and epididymis, effectively fixing the testicle within the scrotum and limiting the risk of testicular torsion. When the tunical investments attach more proximally on the spermatic cord, the testicle and epididymis are allowed to hang more freely and take on a horizontal lie (**Fig. 2**), creating a narrow point of rotation that may predispose one to developing testicular torsion. The incidence of the "bell-clapper" deformity has been reported to be as high as 12% and can frequently be a bilateral process.[20] Considering that testicular torsion occurs at an incidence far lower than 12%, it is clearly not an isolated risk factor for testicular torsion. When evaluating the child with intermittent testicular pain and a "bell-clapper" deformity, it is important to counsel the patient and family about its association with testicular torsion. The risk of torsion must be weighed against the risks of anesthesia, persistent or worsened pain, and iatrogenic testicular injury or loss.

MIMICKERS OF TESTICULAR PAIN

Inflammation of the testicle and/or epididymis can occur in response to infection (viral or bacterial), trauma, torsion of the appendages, and urinary reflux into the ejaculatory duct/vas deferens, which is commonly referred to as "chemical" epididymitis/orchitis. True bacterial infections in children are generally rare. When suspected, a urine analysis and culture can be obtained. Investigation of sexually active adolescents for Gonococcus and Chlamydia is often warranted. If a true bacterial infection is diagnosed, consideration should be given to obtaining imaging of the urinary tract (renal/bladder ultrasound and/or voiding cystourethrogram) once the infection has been treated. Other anatomic abnormalities such as ectopic ureter (to the vas, ejaculatory duct, or seminal vesicle), ejaculatory duct obstruction, or posterior urethral valves may need to be considered and ruled out. Viral infections are also a rare source of testicular/epididymal inflammation. Historically, mumps orchitis, in postpubertal boys, was a common cause, which is rare today because of immunization.

Fig. 2. Bilateral "bell-clapper" configuration of the testicles. Note the transverse testicular lie of the testicle relative to the spermatic cord. This patient underwent bilateral orchidopexy with complete resolution of his previously intermittent bilateral testicular pain.

Adenovirus, enterovirus, influenza, and parainfluenza viruses have all been implicated as infectious causes. Although viral culture and serology can be obtained, it is generally unnecessary because supportive treatment is typically all that is required.

When evaluating the child with testicular pain thought not due to acute torsion or infection, it is important to take a detailed voiding and stooling history. Children with significant constipation and/or voiding dysfunction are thought to be at an elevated risk of developing epididymitis/orchitis because of high urinary pressure that can develop in the posterior urethra. This pressure can lead to reflux of urine into the ejaculatory ducts and vasa and subsequent inflammation of the epididymis/testicle, commonly referred to as “chemical epididymitis.”[21,22] Occasionally, this urinary reflux will be seen during the voiding phase of a voiding cystourethrogram.

Torsion of the appendix testis/epididymis is a common cause of acute scrotal pain and is often referred to as “the great mimicker.” Embryologically, the appendages differ in origin with the appendix testicle being a Müllerian remnant and the appendix epididymis being a Wolffian remnant. It is more common to see an appendage torsion in the prepubertal boy.[23] Given the shared ischemic cause, torsion of an appendage can very closely mimic the symptoms of acute testicular torsion. Close physical inspection will occasionally reveal the ischemic and inflamed appendage to be visible through the skin. This so-called blue-dot sign is highly suggestive of a torsed appendix and is often accompanied by focal tenderness of the appendage itself (Fig. 3). This inflammation and tenderness can spread to the epididymis and testicle, however, depending on the duration of the appendiceal torsion. Ultrasonography can often demonstrate an enlarged and heterogenous appendage adjacent to the testicle, often with no demonstrable blood flow (Fig. 4). When being evaluated many hours after the onset of pain, it can be very difficult to distinguish between a torsed appendix and a

Fig. 3. Physical examination of the scrotum demonstrating a classic “blue-dot” sign.

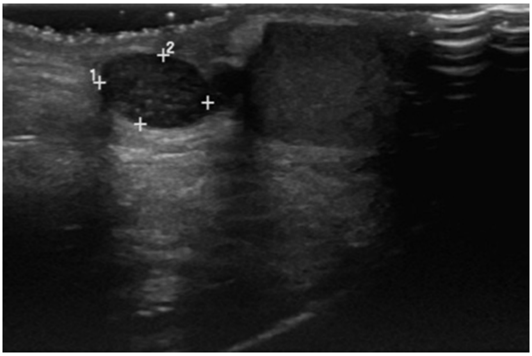

Fig. 4. Ultrasound image demonstrating torsion of the testicular appendage. Note the heterogenous appearance of the appendage relative to the normal-appearing testicle. This patient was found to have a classic "blue-dot" sign on physical examination.

torsed testicle. As with the physical examination, ultrasound can often identify a torsed appendage early on but has difficulty making this distinction later on when adjacent scrotal inflammation has progressed. Although the testis and epididymis are the most common places to find an appendage, there are potentially 5 anatomic sites where an appendage can exist (Fig. 5).[24,25] Surgical removal of a torsed appendage is not required because the appendage will ultimately necrose with relief of the pain. Surgical removal can occur, however, when exploration is undertaken because of concern about testicular torsion. If the torsed appendage is not removed, it may calcify

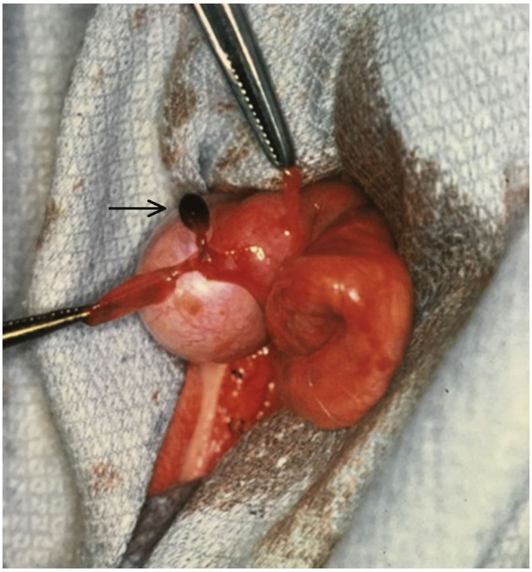

Fig. 5. Testicle with 3 distinct appendages. Normal appendix testis (held by hemostat on left side of image), torsed appendix epididymis (*black arrow*), and normal superior vas aberrans of Haller (held by hemostat at top of image).

and later be felt as a small “mass” within the scrotum. It can also end up free floating within the tunica vaginalis. When a testicular appendage is encountered incidentally in an otherwise normal testicle, most surgeons advocate for removal of all appendages to prevent the risk of future appendiceal torsion.

When counseling patients and families about a torsed appendage (or any other cause of scrotal pain), it is important to emphasize the potential of future torsion of the spermatic cord. It is critical that the patient and family understand that the diagnosis of scrotal pain due to appendiceal torsion or minor trauma may increase the risk of spermatic cord torsion during the recovery period.[26]

The appropriate management of epididymal/testicular inflammation and pain needs to include treatment of the acute inflammation as well as treatment of the underlying factors (if any) that led to development of the inflammation. Once testicular torsion and infection have been ruled out, children are often given little guidance as to how to manage their ongoing testicular pain. Repeat medical evaluation is frequently sought because of persistence of the pain. Antibiotics are frequently prescribed but rarely indicated in children in the absence of an abnormal urine analysis/culture. Similarly, narcotics can be used but are generally not required. Clinical improvement depends on relieving the inflammation. The key aspects of the management of the epididymal/testicular inflammation include the following:

- 48 to 72 hours of an age-/weight-appropriate dose of anti-inflammatory medication
- Corresponding 48- to 72-hour period of modified bed rest
- Aggressive oral hydration
- Timed voiding
- Management of constipation (if present)

The goal of the above recommendations is to help break the inflammatory cycle. Patients are recommended to limit all activities aside from normal activities of daily life (bathroom, meals, and so forth). Limiting activity has the benefit of reducing the physical movement of the scrotum and contents, which in turn allows the inflammation to subside, akin to elevating a sprained ankle. Hydration, timed voiding, and constipation management help to begin addressing any underlying issues that may have predisposed development of the inflammation. Long term, these issues may require additional directed management to fully address the problem.

Although most pediatric scrotal pain cases will be caused by one of the above issues, other less common causes exist. Vasculitic syndromes, such as Henoch-Schönlein purpura (HSP), can lead to pain, erythema, and swelling of the scrotum in up to two-thirds of patients.[27] Although rare, cases of HSP have been associated with acute testicular torsion, which reinforces the importance of always keeping torsion in mind when evaluating the acute scrotum.[28] Scrotal pain due to hernia, hydrocele, trauma, or neoplasia can also occur. Typically, a thorough history and physical examination are sufficient to differentiate these issues from acute testicular torsion.

SUMMARY

Despite being a common issue, acute scrotal pain in a child should be considered a surgical emergency until proven otherwise. History and physical examination are sufficient to confirm the diagnosis and prompt surgical exploration. When torsion is ruled out, aggressive management of the underlying cause or causes is important to provide relief of discomfort and limit the chance of recurrence.

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Controversies in the management of neonatal testicular torsion: A meta-analysis☆,☆☆

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ABSTRACT

Objective: This meta-analysis seeks to discern the optimal management strategy in neonatal testicular torsion (NTT).
Methods: Reviewed all English-language articles published between 2005 and 2015 in Medline/Pubmed that had a defined diagnosis of NTT within the first thirty days of life, and discussed specific surgical and nonsurgical management. Exclusion criteria were non-English literature, case reports, case studies, and failure to clearly describe the management of NTT. Data from 9 studies were analyzed, individually and together as pooled data, using a random effect model with a random intercept to estimate the pooled proportions of interest. Results are presented with 95% confidence interval. All analyses were done in SAS 9.4®.
Results: 9 publications met criteria for this analysis with a total of 196 patients. Bilateral testicular torsions (n = 14) were less common as compared to right/left testicular torsion (n = 85/97). Asynchronous NTTs (n = 9) were more common than synchronous NTTs (n = 2). There was a higher incidence of NTT in neonates delivered by vaginal delivery (n = 110) as compared to those delivered by c-section (n = 25). Extravaginal torsion (n = 54) is far more common than intravaginal torsion (n = 2). Full-term neonates (n = 122) have a higher incidence of NTT as compared to preterm neonates (n = 9). A total of 15 testicles were salvaged. Of the salvaged testicles 2 were documented as prenatal, 10 postnatal and 3 were undocumented. A strategy of bilateral exploration allows for salvage of about 7% of ipsilateral testicles and prevent asynchronous torsion in about 4% of neonates.
Conclusions: Based on our population, between 8–12% of patients would benefit from bilateral exploration at the time of diagnosis. We recommend urgent bilateral exploration with orchiopexy of the contralateral testicle in order to avert anorchia.
Type of study: Systematic review.
Level of evidence: Level 5 meta-synthesis (Evidence from systematic reviews of qualitative and descriptive studies).

Contents

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Testicular torsion management has plagued urologists and surgeons alike. With the incidence of neonatal testicular torsion (NTT) at 6.1 per 100,000 live births, prospective studies of management strategies are difficult to obtain [1–3]. Furthermore, the presumed need of prompt diagnosis has not allowed for proper prospective studies to identify the correct course of action when faced with a neonate with testicular torsion. NTT is defined as a torsion that occurs within the first thirty days of life which can occur in the prenatal period, or within 30 days of postnatal life. Torsion can be further broken down to extravaginal and intravaginal. Extravaginal, which is most commonly seen in neonates, is when the testis, epididymis, and tunica vaginalis twist on the spermatic cord [4–6]. In contrast, intravaginal torsion occurs secondary to a bell clapper deformity where the tunica vaginal inserts onto the spermatic cord higher than normal allowing the testes to rotate on itself [4–6]. Even with an early diagnosis, the salvage rate for torsions has been reported at about 5% [7]. As a result of this poor salvage rate, the necessity of urgent surgical intervention has been heavily debated. Owing to the perceived unlikely salvage, many surgeons have adopted a wait and watch approach. Others, however, feel that immediate exploration and orchiopexy of the contralateral side simultaneously or after a few months are prudent. This meta-analysis seeks to discern the optimal management strategy in NTT based on a review of recent results in the management of this condition.

1. Materials and methods

We reviewed all English-language articles published between 2005 and 2015 in Medline/Pubmed and SCOPUS that had a defined diagnosis of NTT within the first thirty days of life, and discussed specific surgical and nonsurgical management. Key words used for the search were: neonatal testicular torsion, neonatal testicles, neonatal orchiopexy, and perinatal torsion. Exclusion criteria were non-English literature, case reports, case studies, unable to clearly define neonatal testicular torsion within the first thirty days and failure to clearly describe the management of NTT (Fig. 1).

The main characteristics of the studies evaluated were the mode of delivery, laterality, gestational age, and management of ipsilateral and contralateral testes. Treatment strategies were classified into 4 groups to facilitate comparison (Fig. 2). Group 1: Bilateral exploration; Group 2: Exploration of affected side only; Group 3: Exploration of contralateral side only; and Group 4: Observation only. Other aspects reviewed were prenatal torsion, postnatal torsion, intravaginal torsion and extravaginal torsion. Data from selected studies were analyzed using a random effect model with a random intercept to estimate the pooled proportions of interest. Results are presented with 95% confidence interval. Each study was evaluated separately as well as pooled together to form combined data. All studies included in the meta-analysis were

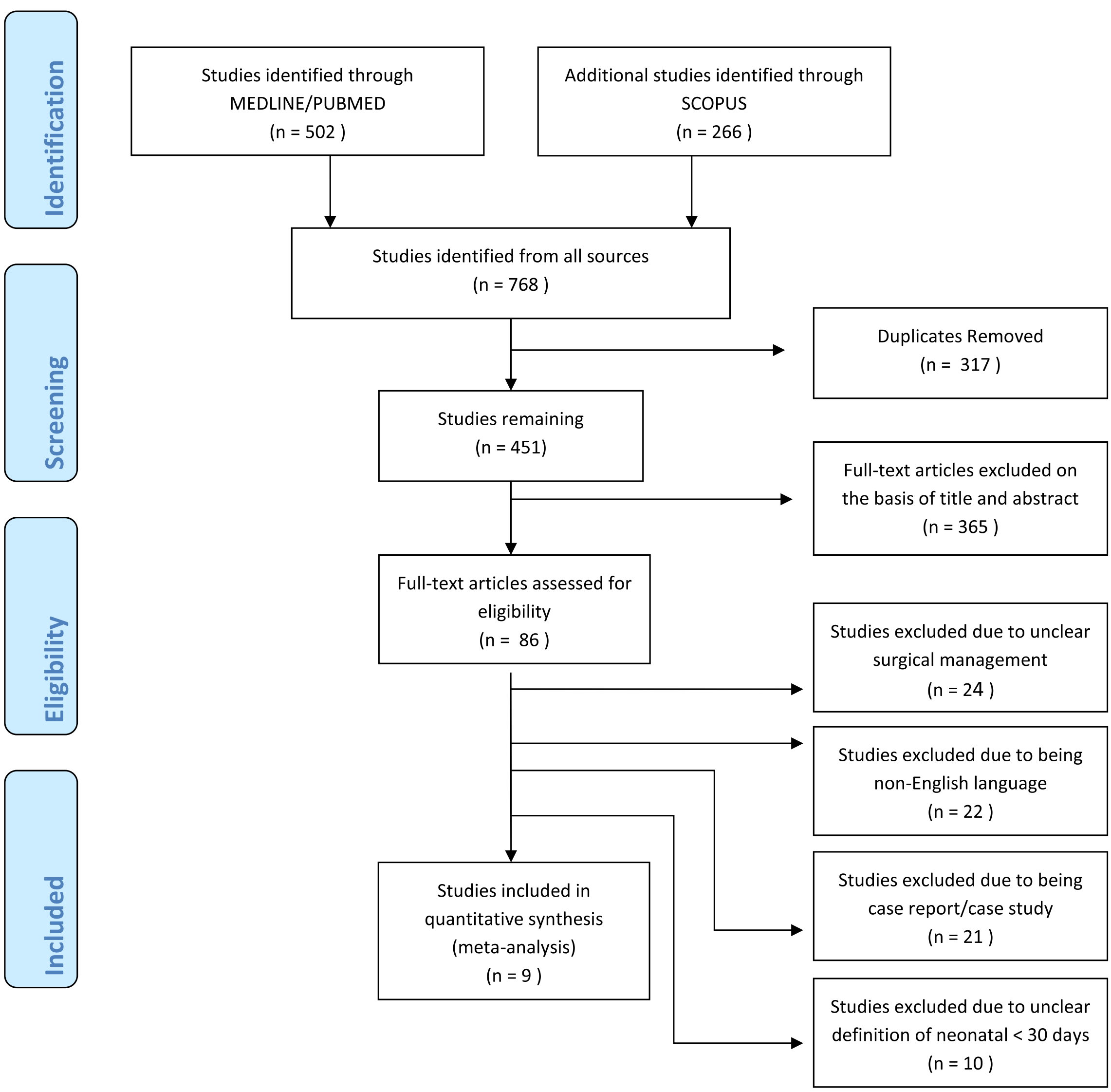

Fig. 1. Study selection flowchart.

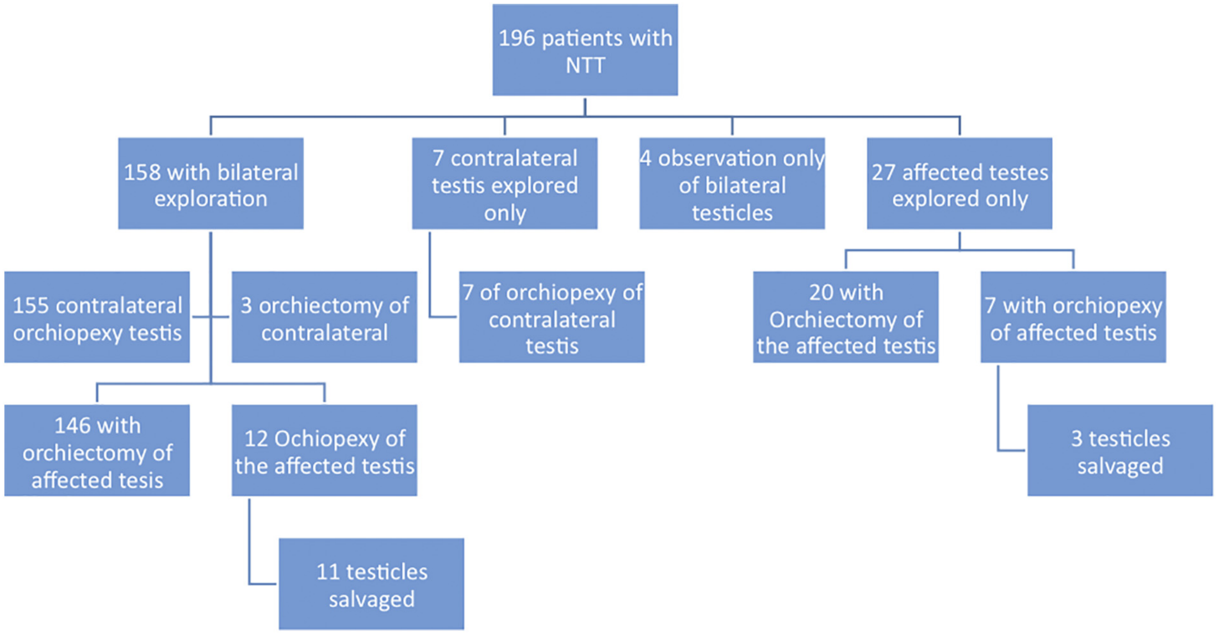

Fig. 2. Flowchart of NTT systematic review treatment strategies and outcomes.

used to estimate pooled confidence intervals (CI). The 95% CI discussed throughout the results represents the upper and lower limit of the estimated proportion. That is we are 95% confident that the proportion of patients who had the result/procedure is between the upper and lower limits set by the CI. The wider the CI the lower is the possibility of a Type 1 error; however, narrower CIs have a better accuracy. No p-value calculations were possible. All analyses were done in SAS 9.4®.

2. Results

9 publications met criteria for this analysis with a total of 196 patients (Table 1). Results are summarized in Tables 2 and 3. Of these 196 patients, there were torsion of the right testicle in 85 patients [pooled proportion 0.43; Confidence Interval (CI) (0.34–0.53)], 97 patients on the left [pooled proportion of 0.49; CI of (0.39–0.59)] and 14 bilaterally [pooled proportion of 0.7 and CI (0.03–0.15)]. A total of 15 testicles were salvaged. Of the salvaged testicles 2 were documented as prenatal, 10 postnatal and 3 were undocumented.

Of the 196 patients 110 of these infants were born via vaginal delivery [pooled proportion 0.54; CI (0.17–0.87)], 25 via c-section [pooled proportion 0.12; CI (0.06–0.23)], and 61 unknown. There were 122 term infants; defined as greater than 37 weeks [pooled proportion 0.70; CI (0.07–0.99)] vs 9 preterm infants; less than 37 weeks [pooled proportion 0.02; CI (0.01–0.10)] and 65 unknown gestational age.

98 patients had a documented prenatal torsion [pooled proportion 0.56; CI of (0.13–0.92]; 35 patients had a documented postnatal torsion [pooled proportion 0.10; CI (0.03–0.31). There were 63 undocumented.

2 patients had documented intravaginal torsion [pooled proportion 0.01; CI (0.00–0.05)] and 54 patients had extravaginal torsion [pooled proportion 0.28; CI (0.03–0.85)]. 140 of the 196 had an undocumented type.

158 patients had bilateral testes explored (Group 1) while 27 only had the affected testicle explored (Group 2), 7 patients had only contralateral testicle explored (Group 3) and 4 were observed without surgical management (Group 4). In Group 1, 146 of these patients had an ipsilateral (I/L) orchiectomy and bilateral testes explored with a pooled proportion of 0.75 and confidence interval of (0.49–0.9). 12 patients had orchiopexy of the affected testicle with an exploration of the contralateral testicle with a pooled proportion of 0.06 and CI of (0.02–0.18). 11 of the patients who had ipsilateral orchiopexy and exploration of the contralateral testicle had the testis salvaged with a proportion of 0.06 and CI of (0.02–0.14). In Group 2, 20 patients had orchiectomy of the affected testicle only, with a pooled proportion of 0.1 and CI (0.07–0.15). 7 patients underwent orchiopexy of the affected teste with a pooled proportion of 0.03 and CI of 0.01–0.11. 3 of these testicles were salvaged in the group with ipsilateral explored only with a CI of 0.01 (0–0.6). 4 patients (Group 4) were observed without surgical management.

Table 1
Article demographics.

Author	Yr. Published	Journal	# of patients in study
Abraham et al.	2015	Journal of Maternal–Fetal and Neonatal Medicine	28
Al-Salem, Ahmed	2007	Journal of Pediatric Surgery	11
Arena et al.	2006	International Journal of Urology	7
Djahangirian et al.	2010	Journal of Pediatric Surgery	44
Jensen et al.	2015	Danish Medical Journal	13
John et al.	2008	Acta Paediatrica	24
Kaefer et al.	2015	Journal of Pediatric Urology	37
Kaye et al.	2007	Journal of Urology	15
Mano et al.	2013	Urology	17

Table 2
Data results.

	No. patients documented	Pooled Proportion	Pooled 95% CI
Left Testicular Torsion	97	0.49	0.39–0.59
Right Testicular Torsion	85	0.43	0.34–0.53
Bilateral Testicular Torsion	14	0.07	0.03–0.15
Asynchronous	9	0.04	0.00–0.05
Synchronous	2	0.01	0.01–0.11
Vaginal delivery	110	0.54	0.17–0.87
C-section	25	0.12	0.06–0.23
Full term	122	0.70	0.07–0.99
Preterm	9	0.02	0.01–0.10
Extravaginal	46	0.28	0.03–0.85
Intravaginal	2	0.01	0.00–0.05

Table 3
Surgical management characteristics.

	B/L Testes Explored	I/L Testis Explored Only	C/L Testis Explored Only	Observed
Number of patients	158	27	7	4
Pooled Proportion /(CI) of ipsilateral ORCHIECTOMY	0.75 (0.49–0.9) N = 146	0.1 (0.7–0.15) N = 20		
[proportion of documented]	[92.4%]	[74%]		
Pooled proportion/ (CI) of ipsilateral ORCHIOPEXY	0.06 (0.02–0.18) N = 12	0.03 (0.01–0.11) N = 7		
[proportion of documented]	[7.6%]	[35%]		
Pooled proportion/ (CI) of SALVAGED Testicles	0.06 (0.02–0.14) N = 11	0.01 (0–0.06) N = 3		N = 1
[proportion of documented]	[91.2%]	[42.9%]		

Of the 15 testicles that were salvaged 2 of those were in a documented prenatal torsion with a pooled proportion of 0.01 (0.00–0.07) and 10 were documented postnatal torsion CI (0.05–0.12). 3 were unknown.

3. Discussion

Owing to neonatal testicular torsions rarity, the proper management has been difficult to ascertain. Currently, the most common practice currently is to perform bilateral exploration with orchiopexy of the unaffected testicle to prevent the devastating effects of anorchia, should asynchronous torsion occur. Based on this meta-analysis it appears that bilateral exploration (Group 1), by allowing effective comparison of the affected testicle with the opposite normal side leads to lower orchiopexy rates (12/158) but higher ipsilateral salvage rates (11/12). In Group 2, where only the affected testicle is explored, there appears to be a tendency to perform a higher rate of orchiopexy (7/27) with lower salvage rates (3/7). Based on these findings we recommend a bilateral exploration in NTT. Our study found 7%; 14 of 196 patients, had bilateral torsions with 9 or 4% reported as asynchronous. This is an interesting finding based on the fact that other studies have found synchronous torsion to be much more common [4]. Abraham et al. had similar findings in their single-center experience with all of their 5 bilateral torsions being asynchronous events [8]. This finding may push towards orchiopexy of the unaffected testicle in order to prevent a catastrophic event of anorchia. Yet, as described in various other studies the risks of urgent surgical intervention in the neonate, especially anesthetic risk, must be heavily weighed prior to proceeding with surgery [8–10]. With a Group 1 strategy of bilateral exploration, there would be a 7% salvage of the ipsilateral testicle and insurance against the 4% chance of asynchronous torsion. Overall this strategy would benefit between 7% and 12% (15 ipsilateral torsion salvage and 9 asynchronous torsion prevention of the total of 196) of neonates prone to developing NTT.

There have been multiple theories regarding why torsion would occur in the first place. It appears that intrauterine stress may be a significant risk manifested by prolonged or difficult labor, high birth weight, breech presentation, preeclampsia, or vaginal delivery to name a few described in previous studies [5,6,10]. Similar to other studies we found vaginal delivery to be associated NTT. It has been postulated that hypermobility of the tunica vaginalis within the scrotal sac when exposed to an extreme cremasteric reflex during delivery or in utero, may induce a torsion [5,6,10,12]. This may also explain why the meta-analysis population, which is consistent with other reports, presented with extravaginal torsions as opposed to intravaginal. Based on our data NTTs occurred most commonly in those born vaginally. This could also be explained by the fact that most of our study population were born vaginally as opposed to c-section. Factors around these deliveries such as prolonged rupture of membranes or other health risks were not adequately described to comment and therefore no firm stance can be provided on their role in NTT. Further study should be done on high-risk pregnancies and intrauterine stress as a possible contributing factor for NTT.

In our population, we found that no statistical difference in the occurrence of torsion in the left as opposed to the right. This is in-line with more recent studies in which there was no difference in torsion occurring on one side greater than the other [5,11]. It had been previously reported that NTT occurred more frequently on the left possibly owing to differences in the testicular vasculature [5]. This statement was not confirmed via this meta-analysis.

In contrast to many other studies two of the salvaged testes were documented as prenatal leading us to believe that increased surveillance of testicles at time of delivery coupled with early surgical intervention may actually increase the salvagibility [10]. This is, however, a hypothesis not based on literature evidence.

It has been postulated that removal of the affected testicle may not be best practice as there is some evidence that the testicle may maintain endocrine function even when the spermatogenic function has been adversely affected [4,11]. Yet, other studies have suggested that leaving the torsed testicle may be a nidus for infection, be a source of malignancy later in life, or become a source for testicular tissue antibodies; therefore, it is often recommended that the nonviable torsed testicle should be removed [4,13,14]. This aspect should be studied further to assess the true risk versus benefit. In our study, all of the testicles that were observed underwent atrophy suggesting that there is no significant benefit to surgically explore clearly, nonviable torsed testicles as the risk for formation of autoantibodies may be an overestimate.

Our study has its limitations. We relied on others' documentation as well as lack thereof for our data which also may be biased in nature. Also, the specific characteristics of torsed testicles that underwent an orchiopexy were not clearly defined which affects the ability to determine why certain testicles were salvageable and others were not. The timing of surgical intervention was lacking further affecting the ability to establish salvage rates based on the diagnosis of NTT to OR time. Owing to the rarity of neonatal testicular torsion prospective studies would be difficult to manage.

4. Conclusions

Any suggestion of viability urgent exploration should be considered not only in the attempt to salvage the affected testicle but to prevent the devastating effects of a bilateral torsion with subsequent anorchia. It appears that exploration of the contralateral testicle is the current standard of care. Based on our population, 8–12% of patients would benefit from bilateral exploration at time of diagnosis. We recommend urgent bilateral exploration with orchiopexy of the contralateral testicle in order to avert anorchia.

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Paternity, erectile function, and health-related quality of life in patients operated for pediatric testicular torsion

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Fertility; Paternity; Testicular torsion; Quality of life; Erectile function

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Summary

Introduction
Spermatic cord torsion (SCT) may lead to organ loss and can potentially influence fertility. Long-term effects of SCT are not fully investigated.

Objective
The purpose was to evaluate paternity rates in adults who have had SCT in childhood and to compare the results to those of a control population. The secondary purposes were to compare paternity rates after testis-preserving surgery with those after orchiectomy and to evaluate erectile function and health-related quality of life (HRQoL).

Study design
Questionnaires concerning paternity, erectile function (International Index of Erectile Function [IIEF]-5 questionnaire), and HRQoL (15D questionnaire) were mailed to 74 men who had been treated for SCT and to 92 controls treated for testicular appendage torsion in 1977–1995 and who were currently older than 30 years.

Results
Thirty-five of the 74 (47%) patients with SCT and 58 of the 92 (63%) controls responded. A same-aged control was selected for each patient with SCT. The median age at investigation was 41 (interquatile range [IQR]: 36 to 46) years in the SCT group and 41 (IQR: 38 to 46) years in the control group ($p = 0.81$). The paternity rate was 23 of 35 (66%) in the SCT group and 26 of 34 (76%) in the control group ($p = 0.43$). Nine percent of patients and controls suffered from infertility. Of the 30- to 50-year-old patients with SCT, 9 of 16 (56%) had children after orchiectomy, and 13 of 16 (81%), after detorsion ($p = 0.25$). Significant or moderate erectile dysfunction (IIEF-5 total score <12) was observed in 3 of 32 (9%) patients and in 1 of 35 (3%) controls ($p = 0.34$). Erectile dysfunction was similarly rare in both the orchidopexy and orchiectomy group. Total HRQoL scores were similar in the SCT and control groups ($p = 0.69$) as well as in patients with orchidopexy and orchiectomy ($p = 0.50$).

Discussion
Paternity, erectile function, or HRQoL was not impaired in the general level in the patients with SCT in comparison with controls. Both the modes of treatment, orchiectomy or detorsion, had no significant impact on the results. However, the results cannot be generalized to the individual level. The limitations were a small sample size and inability to investigate maternal factors to the paternity. However, the results are encouraging for the patients and families.

Conclusion
Paternity rate and HRQoL were similar in patients with SCT and controls. The type of surgery (orchiectomy vs. detorsion) did not affect paternity rates statistically. Moderate or significant erectile dysfunction was rare in both groups.

Summary Table

	SCT (median, IQR)	Controls (median, IQR)	p-value
Age (years)	41 (36–46)	41 (38–46)	0.81
Number of fathers	23/35 (66%)	26/34 (76%)	0.43
IIEF-1	4 (4–5)	5 (5–5)	0.01
IIEF-2	5 (4–5)	5 (5–5)	0.05
IIEF-3	5 (4.5–5)	5 (5–5)	0.26
IIEF-4	5 (4–5)	5 (5–5)	0.08
IIEF-5	5 (4.5–5)	5 (5–5)	0.14
IIEF-total	24 (22–25)	25 (24–25)	0.02
IIEF-total <22	7/32	3/35	0.18

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Introduction

Spermatic cord torsion (SCT) is a sporadic phenomenon, which may result in organ loss and can potentially influence fertility. Testicular torsion occurs when the spermatic cord becomes twisted and the circulation of blood to the testicle is prevented. Spermatic cord torsion can be either extravaginal, typically among neonatal patients, or intravaginal, more commonly found among prepubertal and pubertal boys and young adult men [1]. The incidence of SCT is 1:4000 in men younger than 25 years [2]. Clinical experience has revealed that the duration of the symptoms is a crucial factor when evaluating the vitality of the affected testicle [2,3].

A lot of attention has been given to improved diagnostics of SCT to get the patients sooner to a detorsion operation and to save as many testicles as possible. By contrast, there have been fewer articles focusing on the long-term effects of testicular torsion [4]. Arap et al. [5] have reported that SCT may have an effect on sperm quality. Laboratory tests after SCT indicate that germ cell function may be reduced in some patients, especially if the affected testicle had been removed [6]. However, the clinical significance of these findings is unclear, and as far as the authors know, paternity rates or erectile function has not been previously evaluated in adults after SCT in childhood. Because lack of gonadal tissue may lead to hypogonadism in some cases, the authors wanted to evaluate if erectile function is affected in patients with SCT.

The primary purpose of this study was to evaluate paternity rates in adults who have had SCT in childhood and to compare the results to those of a control population. The secondary purposes of the study were to compare paternity rates after testis-preserving surgery with those after orchiectomy and to evaluate erectile function and health-related quality of life (HRQoL) in the patients and controls.

Materials and methods

The database of the Children's Hospital, University of Helsinki, was retrospectively reviewed for patients treated for SCT between 1977 and 1995. Patients treated for testicular appendage torsion (TAT) during the same time span formed the control population. A total of 166 patients were identified. All 74 patients and 92 controls who were currently older than 30 years were invited to the study. Thirty-five of the 74 (47%) patients with SCT and 58 of the 92 (63%) patients with TAT responded. For all patients with SCT, a matched control of similar age was selected from the control group. The final sample size in both groups was 35 men aged 31–54 years.

Questionnaires concerning male fertility, erectile function (International Index of Erectile Function [IIEF]-5 questionnaire), and HRQoL (15D©) were mailed up to three times. In addition, the patients were asked if they had fathered or attempted to father children and if they had chronic illnesses. The patient was considered to have an infertility problem if he had attempted to father a child without success for more than one year. The paternity rate in the general Finnish population was obtained from Statistics Finland (https://www.stat.fi/) for comparison. In addition, satisfaction concerning the appearance of the testicles or prosthesis was asked: Are you satisfied with the prosthesis? yes/no, and if the answer was no, the men were asked to describe what kind of problems they had with the prosthesis.

Erectile function was evaluated by using a Finnish translation of the 5-item version of the IIEF-5 questionnaire. Less than 22 of 25 points on that questionnaire indicates mild and less than 12 of 25 points indicates moderate or significant erectile dysfunction [7]. Health-related quality of life was evaluated using the 15D questionnaire. It measures 15 dimensions of health: mobility, vision, hearing, breathing, sleeping, eating, speech, excretion, usual activities, mental function, discomfort and symptoms, depression, distress, vitality, and sexual activity. Each dimension has five levels (1–5), with 1 indicating perfectly normal function and five indicating very serious problems. A change in the total 15D score of 0.015 or more is considered clinically important in the sense that, on average, a person can feel the difference [8].

International Index of Erectile Function-5 scores are expressed as medians and interquartile ranges (IQRs), and 15D scores, as means. Paternity rates between the patients and controls were compared using Fisher's exact test; IIEF scores between the groups were compared using the Mann–Whitney test, and 15D scores were compared using the independent samples *t*-test (SPSS and Statview® 5.0.1, SAS Institute Inc.). A P-value less than 0.05 was considered significant.

Results

The median age at surgery was 13 years (IQR: 1–14 years) in patients with SCT and 10 years (IQR: 6–12y) in the controls with TAT ($p = 0.26$). The median age at investigation was 41 years (IQR: 36 to 46) in the SCT group and 41 years (IQR: 38 to 46) in the control group ($p = 0.81$). The paternity rate was 23 of 35 (66%) in the SCT group and 26 of 34 (76%) in the control group ($p = 0.43$). Of the 30- to 50-year-old patients with SCT, 9 of 16 (56%) had children after orchiectomy, and 13 of 16 (81%), after detorsion ($p = 0.25$). Three men with SCT were not included, because of age less than 30 years. The median time for surgery from the beginning of the symptoms for patients with SCT was 6 h (IQR: 4–11h) in the orchidopexy group and 27 h (IQR: 17–48h) in the orchiectomy group ($p < 0.01$).

Three of 33 (9%) patients with SCT and 3 of 34 (9%) patients with TAT suffered from infertility. Two patients did not answer the question. The paternity rate among the study patients and controls was comparable with the population-based paternity rate (65%) of similar-aged men in Finland 2016.

The IIEF-5 total score was lower in patients with SCT than in the controls (median: 24 [IQR: 22 to 25] vs. 25 [IQR: 24 to 25]; $p = 0.02$). The most significant difference was seen in confidence to get and keep an erection (Q 1) ($p = 0.005$). One man in the SCT group and one in the TAT group had not been sexually active in the last six months. However, significant or moderate erectile dysfunction (score <12) was rare in both groups, in 3 of 32 (9%) patients in the SCT group and in 1 of 35 (3%) controls ($p = 0.34$) (Table 1). Erectile

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Table 1 Paternity, age and IIEF scores of SCT patients and TAT controls.

	SCT (median, IQR)	Controls (median, IQR)	p-value
Age (years)	41 (36–46)	41 (38–46)	0.81
Number of fathers	23/35 (66%)	26/34 (76%)	0.43
IIEF-1	4 (4–5)	5 (5–5)	0.01
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IIEF-3	5 (4.5–5)	5 (5–5)	0.26
IIEF-4	5 (4–5)	5 (5–5)	0.08
IIEF-5	5 (4.5–5)	5 (5–5)	0.14
IIEF-total	24 (22–25)	25 (24–25)	0.02
IIEF-total <22	7/32	3/35	0.18

IIEF, International Index of Erectile Function; SCT, spermatic cord torsion; IQR, interquartile range.

dysfunction was similarly rare in both the orchidopexy and orchiectomy groups.

Health-related quality of life (15D) total scores were similar in both the patients and controls. There were also no statistically significant differences between the groups on any of the 15 dimensions of the 15D instrument (Fig. 1). Health-related quality of life was also similar in patients with both testicles (median age: 41 years among responders) and in those who had only one testicle left (median age: 37 years among responders; 15D scores: 0.953 vs. 0.936, respectively; p = 0.50). However, somewhat lower scores were found in the orchiectomy group in usual activities (p = 0.06) and vitality (p = 0.05), although the differences did not reach statistical significance.

Patients who had lost a testicle because of torsion in childhood or adolescence were offered an opportunity to have a testicular prosthesis. Sixty-seven percent (14 of 21) had chosen to have a prosthesis, and 71% of those with the prosthesis were satisfied. Most complaints concerned about the size of the prosthesis (four patients, 29%), and one of these patients was unsatisfied with the position of the prosthesis. Patients who had a prosthesis (median age: 39 years) reached similar total 15D scores (0.93) to those of patients without a prosthesis (median age: 34 years) (0.95) (p = 0.43).

Discussion

In this study, the paternity rate and HRQoL were similar in patients with SCT and the controls with TAT. The paternity rate was also comparable with that of the same-aged Finnish general population. The type of surgery (orchiectomy vs. detorsion) did not affect paternity rates significantly either. Moderate and significant erectile dysfunction was rare in both groups. However, a slight non-significant tendency was found in reduced paternity (56% vs. 81%) and erectile function in patients with SCT, especially after orchiectomy.

In late postoperative series, testicular atrophy has been reported to take place in 60–68% of surgically untwisted testicles [9]. There are also a few studies on testicular hormonal function (luteinizing hormone (LH), follicle-stimulating hormone (FSH), inhibin B, and testosterone) after testicular torsion, which show that testicular function is often compromised in patients with SCT [6,10,11]. Arap et al. [5] studied the vitality and morphology of the sperm in patients with SCT and found that patients who had undergone detorsion and orchidopexy had more sperm abnormalities than those who had undergone orchiectomy or controls, respectively. However, sperm concentration was similar in both the groups in that study.

In a previous study conducted in Israel, Gielchinsky et al. [12] interviewed 63 patients (41 who underwent detorsion and 22 who underwent orchiectomy) who had been treated for SCT, mostly in adulthood, and who had been in a stable relationship for at least one year. In that study, the paternity rates were similar to those in the general population in both the orchidopexy and orchiectomy group (90.2% vs. 90.9%, respectively). The numbers are in line with the incidence of infertility problems in this study (9% in both groups). Although paternity rates were not compromised in this patient group as a whole, it does not mean that fertility may not be impaired on the individual level. One hypothesis could be that the slightly lower paternity rate in this

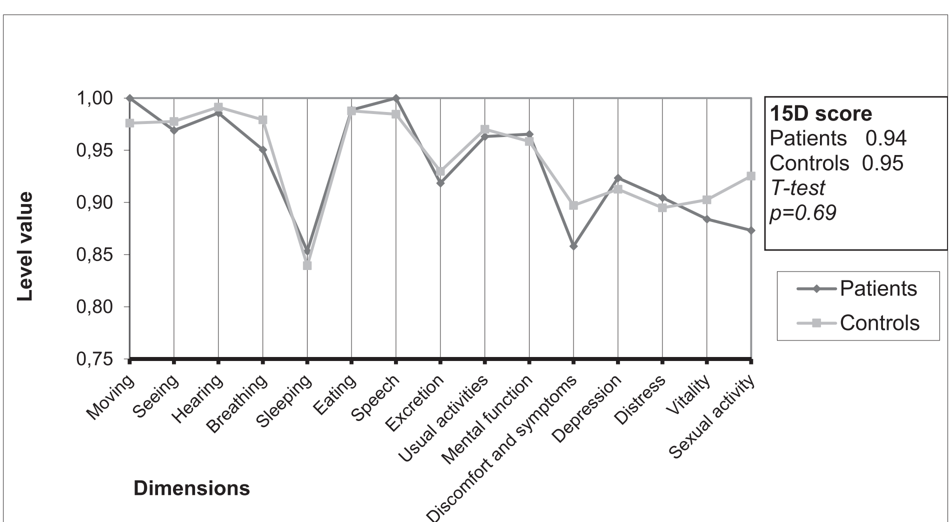

Fig. 1 HRQoL (15D) total scores. HRQoL, health-related quality of life.

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orchiectomy group may be related to smaller total testicular volume [6]. Unfortunately, the authors were not able to perform testicular volume measurements in this study. In earlier fertility studies, testicular torsion has only accounted for 0.5% of infertility [13].

The reason to evaluate erectile function in the study patients is that in some rare cases, erectile dysfunction may be associated with hypogonadism [14]. Although the IIEF-5 total score was lower in patients with SCT than in the controls statistically, it might not be clinically important. Among the study patients, erectile dysfunction was rare and not more common than in the controls. Erectile dysfunction and infertility may have a negative influence on the quality of life [15,16]. However, the authors were not able to evaluate these associations among the study patients because of the rarity of erectile dysfunction and fertility problems.

Health-related quality of life (15D) scores were similar in the study patients and controls. In a previous study, 33 of 40 patients were satisfied with the testicular prosthesis after radical orchiectomy. The satisfaction rate among the study patients with testicular prosthesis was comparable (71%).

This study has several limitations. First, only about half of the patients and of the controls responded to the study invitation, and there were no physical examination or testicular volume measurements available. Second, the authors were not able to focus only on the men who had attempted to have children. Third, the authors were not able to exclude possible female reasons in the cases reporting infertility problems. In addition, the number of subjects in each group was rather small, and it is not possible to estimate whether the non-significant differences in paternity and erectile dysfunction rates resulted from the small sample size and insufficient power of this study. As far as the authors know, the possible effect of torsion of the appendix testis on paternity has never been investigated. However, the authors think that it is suitable that the control group has had supposedly non-harmful scrotal operation. In addition, paternity rates were also compared with the normal population in registry data, which supported the study findings. Despite the limitations, this is the only study focusing on the long-term results after pediatric treatment for SCT. In addition, the study patients' material is rather large, considering the rarity of the condition.

Conclusions

In conclusion, paternity, erectile function, or HRQoL is not usually compromised in the long term in patients treated for testicular torsion in childhood.

Author statements

Ethical approval

The board of ethical issues has approved the study, and the study conforms to the principles of the Declaration of Helsinki.

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None.

Competing interests

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpurol.2019.10.008.

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Do repeat ultrasounds affect orchiectomy rate in patients with testicular torsion treated at a pediatric institution?

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Keywords
Testicular torsion; Outcomes assessment; Repeat ultrasound; Hospital transfer

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Summary

Introduction
Testicular torsion is a urological emergency; as the testicular salvage rate decreases with time, prompt intervention is required to restore the blood flow. Interhospital transfers and ultrasound examinations, while clinically essential to proper treatment and diagnosis, may adversely affect outcomes by delaying surgical intervention. Patients transferred to another institution for treatment of testicular torsion may experience a further time delay by undergoing two ultrasound examinations: one at the initial admitting institution and one at the receiving institution. To the knowledge of the authors, no study has yet explored the time delays and outcomes associated with these repeat ultrasounds.

Objective
The objective was to investigate the impact of repeat ultrasound imaging on time to treatment and patient outcomes in patients with testicular torsion.

Study design
A retrospective chart review of 133 patients, aged 0—20 years, treated at the authors' institution for testicular torsion was conducted. Neonate patients and patients who did not receive ultrasound were excluded. Demographic and clinical variables were collected from the electronic medical record. Pearson Chi-squared and *t*-tests were used for univariate comparisons, and multivariate logistic regression analysis was performed to measure the relationships between variables.

Results
Forty-nine percent of patients were primary patients, and 51% were transfer patients. Fifty-two percent of transfer patients received repeat ultrasounds. In comparison to salvaged patients, those who underwent orchiectomy experienced a greater delay between presentation at the institution and surgical intervention (229 min vs 177 min, $p = 0.048$). The transfer status does not appear to be related to the outcome, i.e. orchiectomy versus salvage. Patients who underwent orchiectomy were more likely than salvaged patients to have received repeat ultrasounds ($p = 0.008$). Repeat ultrasound patients had three times the likelihood of orchiectomy of single ultrasound patients. In a subset analysis of transfer patients, repeat ultrasound patients were more likely than single ultrasound patients to receive an orchiectomy ($p = 0.03$).

Discussion
In agreement with previous studies, patients who underwent orchiectomy were found to experience greater treatment delays and trend toward transfer. Specifically, repeat ultrasound and time between presentation and intervention appear to influence patient outcomes. The effect of repeat ultrasound on outcomes appears to be independent of the transfer status. The study was limited by its retrospective nature and small sample size.

Conclusion
The analysis suggests that efforts to prevent repeat ultrasounds and minimize the time between presentation and intervention would improve patient outcomes. It is proposed that standardized clinical decision-making procedures, such as the TWIST scoring system, be incorporated into hospital protocols.

Logistic regression model of the relationships between orchiectomy and significant treatment variables. Bold values indicate a statistically significant association between the treatment variable and the likelihood of orchiectomy.

Treatment variable	Coefficient	Pr(>|Z|)	Odds ratio	95% confidence interval
Intercept	0.0673	0.8744	1.0696	(0.7108, 1.6095)
No repeat ultrasound	−1.0977	**0.0075**	0.3336	(0.2250, 0.4948)
Time between presentation and intervention	0.0027	**0.0435**	1.0026	(1.0014, 1.0039)

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Introduction

Testicular torsion can occur at any age; its incidence in the pediatric population has a binomial distribution with the first peak during the first year of life and the second peak between the ages of 13 and 16 years [1]. While testicular torsion is fairly rare, occurring in 3.8 per 100,000 boys annually [2], its outcomes impact patients' long-term quality of life as testicular loss is associated with reduced fertility and psychological trauma [3]. Intraoperative salvage has been shown to be time dependent, with a 90–100% salvage rate if operation occurs within 6 h after torsion. This salvage rate decreases significantly as time delay increases [4]. Consequently, processes that affect time to treatment and consequently the likelihood of orchiectomy have significant implications for patient outcomes.

Color Doppler ultrasound imaging is the standard technique for evaluating the acute scrotum [5]. As the symptoms of testicular torsion overlap with other conditions that do not require surgical intervention, an ultrasound examination can help patients avoid unnecessary surgical exploration. However, ultrasound imaging can also delay time to treatment.

Interhospital transfer is another aspect of care that delays time to treatment. Additionally, transfer patients may experience a further time delay because of repeat ultrasounds. As emergency departments often order ultrasound to diagnose scrotal pain, it is possible that patients transferred to another institution for treatment of testicular torsion may undergo two ultrasound examinations: one at the initial admitting institution and one at the receiving institution.

While interhospital transfers and ultrasound can be essential to proper treatment and diagnosis, the time delays incurred by these measures may adversely affect outcomes. Previous studies have suggested that the inherent delay associated with interhospital transfer [3,6,7] may contribute to likelihood of orchiectomy; however, to the knowledge of the authors, no study has explored the delays associated with repeat ultrasound imaging. In this study, the latter concern was addressed by investigating testis outcomes associated with repeat ultrasound in patients with testicular torsion. The effects of secondary variables on this primary outcome, including symptom onset, presentation at the institution, and total time between presentation and surgical treatment, were also studied. It was hypothesized that repeat ultrasounds increase the likelihood of orchiectomy.

Methods

A retrospective chart review of 133 patients, aged 0–20 years (mean age 12.1 years), treated at the Monroe Carell Jr. Children's Hospital at Vanderbilt (VCH) for testicular torsion between January 2008 and July 2017 was conducted. Neonatal torsion patients were excluded from this study. Two patients, both of whom were successfully salvaged, did not receive any ultrasound examinations before surgical intervention and were excluded from the analysis. Data on patients' demographic information, transfer status, time of presentation at the VCH emergency room, time of surgical intervention, and ultrasound imaging performed were collected from the electronic medical record and stored in a clinical REDCap database. Surgery consisted of scrotal exploration and three-point fixation with non-absorbable sutures. Tunical fasciotomy was not used in any patient in this series. A Shapiro–Wilks test showed that the data were normally distributed; therefore, parametric statistics were conducted. Pearson Chi-squared and *t*-tests were used for univariate comparisons, and a multivariate logistic regression analysis was performed to measure relationships between variables. The significance level was set *a priori* at 0.05.

Results

The mean age of the patient cohort was 12.1 years, with the majority ($n = 105$, 79%) being 8 years or older. As indicated in Fig. 1, about one-half ($n = 65$, 49%) were primary patients and about one-half ($n = 68$, 51%) were transfer patients. More than half ($n = 73$, 55%) were salvaged, while 45% ($n = 60$) received an immediate orchiectomy. A 0% rate of negative exploration was found.

The mean time between presentation at VCH and surgical intervention was 3 h and 20 min. More than one-third ($n = 52$, 39%) of the patients presented at VCH less than 6 h after symptom onset, and about one-third ($n = 48$, 36%) presented at VCH more than 24 h after symptom onset.

As shown in Table 1, patients who underwent orchiectomy generally experienced a longer delay in treatment than salvaged patients. In comparison to salvaged patients, patients who underwent orchiectomy experienced a significantly longer mean time between presentation at the institution and surgical intervention ($p = 0.048$) and were more likely to experience longer times between symptom onset and presentation ($p < 0.001$). More than one-half of patients who underwent orchiectomy ($n = 35$, 58%) were transfer patients; however, the transfer status did not differ significantly between orchiectomy and salvaged patients. Patients who underwent orchiectomy were significantly more likely than salvaged patients to have received repeat ultrasounds ($p = 0.008$).

Logistic regression analysis was performed to investigate the associations of the treatment variables found to be statistically significant in the preceding analysis with the likelihood of orchiectomy (see Table 2). Receiving a single ultrasound is associated with a lower likelihood of orchiectomy than receiving repeat ultrasounds: patients who do not receive repeat ultrasounds have one-third the likelihood of orchiectomy of patients who do receive repeat ultrasounds. Time between presentation and intervention was, to a lesser degree, positively associated with the likelihood of orchiectomy.

As all repeat ultrasound patients are also transfer patients, it is possible that the effects of repeat ultrasound on time to treatment and outcomes that were observed may arise from some effect of transfer instead. Therefore, the effect of repeat ultrasounds was analyzed within transfer patients to eliminate this potential bias. While repeat ultrasound patients experienced a longer mean time between presentation and intervention (193.1 ± 108.2 min) in

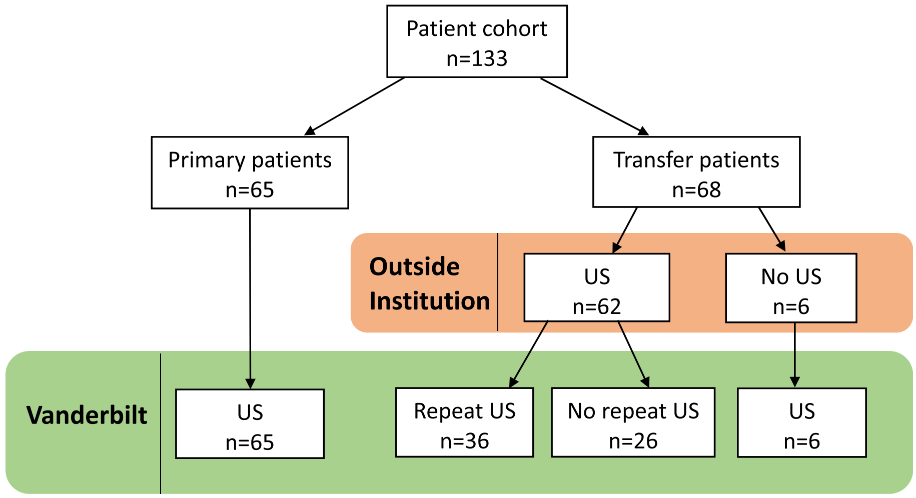

Figure 1 Flowchart depicting patients' course of treatment. US indicates ultrasound examination; outside institution indicates the transferring institution; Vanderbilt indicates the receiving institution for transfer patients (VCH).

Table 1 Differences in treatment between patients who underwent orchiectomy and salvaged patients.

Patient characteristics	Orchiectomy (n = 60)	Salvaged (n = 73)	p-value
Transferred from outside institution	58% (35)	45% (33)	0.132[a]
Primary patients	42% (25)	55% (40)	
Repeat ultrasound	38% (23)	18% (13)	**0.008**[a]
Single ultrasound	62% (37)	82% (60)	
Time between symptom onset and presentation	12% (7)	62% (45)	**<0.001**[a]
<6 h			
6–12 h	15% (9)	27% (20)	
12–24 h	5% (3)	1% (1)	
>24 h	68% (41)	10% (7)	
Time between presentation and intervention (minutes)	229 ± 162	177 ± 133	**0.048**[b]

SD, standard deviation. Bold values indicate p-values corresponding to a statistically significant difference in outcomes. x ± s represents X ± 1 SD. Numbers after proportions are frequencies.
Tests used: [a]Pearson Chi-squared test.
[b]*t*-test.

comparison to transfer patients who received a single ultrasound (153.0 ± 134.8 min), this difference was not significant (p = 0.185). Repeat ultrasound patients were significantly more likely than single ultrasound patients to receive an orchiectomy (p = 0.03): almost two-thirds (64%, n = 23) of repeat ultrasound patients received an orchiectomy while one-third (38%, n = 12) of single ultrasound patients received an orchiectomy.

Discussion

It is critical that diagnosis of torsion is accurate and prompt, to both avoid unnecessary surgical intervention and increase chances of testicular salvage. The clinical benefits of interhospital transfer and ultrasound imaging may be outweighed by the negative effects of the time delay that these measures introduce. Repeat ultrasound imaging, in particular, has apparently limited clinical benefit as reconfirming the torsion diagnosis, at the expense of further time delay, is unlikely to change the patient's treatment plan. Additionally, repeat ultrasounds are generally avoidable, while transfer may be necessary if the initial admitting institution lacks urology coverage or, in the case of pediatric patients, feels unequipped for managing the surgical and anesthetic challenge of operating on younger patients [7].

Time to treatment is one of the most important factors in the viability of the affected testicle [8,9]. Accordingly, patients who underwent orchiectomy were found to be more likely than salvaged patients to experience a longer time between symptom onset and presentation at the institution. The results also suggest that delays occurring between presentation and intervention may contribute more to patient outcomes than transfer-related delays, indicating a need to reevaluate the hospital protocol. In comparison to salvaged patients, patients who underwent orchiectomy experienced

Table 2 Logistic regression model of the relationships between orchiectomy and significant treatment variables.

Treatment variable	Coefficient	Pr(>|Z|)	Odds ratio	95% confidence interval
Intercept	0.0673	0.8744	1.0696	(0.7108, 1.6095)
No repeat ultrasound	−1.0977	**0.0075**	0.3336	(0.2250, 0.4948)
Time between presentation and intervention	0.0027	**0.0435**	1.0026	(1.0014, 1.0039)

Bold values indicate a statistically significant association between the treatment variable and the likelihood of orchiectomy.

a significantly greater mean time between presentation and intervention and, while they trended toward transfer, did not significantly differ in terms of the transfer status. Previous studies have similarly found that transfer patients were more likely to have an orchiectomy but not to a significant degree. Bayne et al. [6] found that while mean transfer delay was greater in patients who underwent orchiectomy, transfer did not significantly predict the orchiectomy rate. In Preece et al.'s [7] analysis, the rate of orchiectomy in transfer patients was double that of primary patients; however, this difference was insignificant. It is possible that the sample size has limited the statistical power of these analyses, which used samples of 97 and 133 patients, respectively. A much larger, statewide sample of nearly 2800 patients also failed to find a significant relationship between the transfer status and orchiectomy—while transfer and orchiectomy were associated with univariate analysis, multivariate analysis revealed that patient age may have confounded this association [3]. It is possible that time delays outside of transfer, such as delayed patient presentation at the admitting institution, may irreversibly compromise testicular viability, meaning that transfer-related delays would not affect outcomes [3].

The results indicate that repeat ultrasounds also adversely affect patient outcomes. Patients who underwent orchiectomy were found to be significantly more likely than salvaged patients to have repeat ultrasounds. Patients who received a repeat ultrasound were about three times as likely to receive an orchiectomy as patients who received one ultrasound. The effect of repeat ultrasound on patient outcomes appears to be independent of any potential effects of the transfer status. While repeat ultrasound patients tended to experience a greater time between presentation and intervention than single ultrasound patients, this difference was not significant. It is possible that statistical significance was not found because of the small sample size of this subset analysis as there were 68 transfer patients in the study population.

More than half (52%) of the transfer patients in the sample received repeat ultrasounds, indicating that repeating ultrasounds is a consistent practice and therefore an important area to address that could affect patient outcomes. Repeat ultrasounds have been indicated in a few specific circumstances: McLario and Kendall [10] recommend performing repeat ultrasound examinations in patients with suspected torsion-detorsion at intervals of 1—4 h if the clinician suspects torsion yet the initial ultrasound is normal; Sung et al. [11] suggest considering repeat ultrasounds in case of false-negative evaluations. However, reconfirming the torsion diagnosis after transfer does not fit these specifications. Ultrasound imaging may also be performed and/or repeated to defend against potential malpractice litigation. However, ultrasound examinations have not been found to be protective during legal defense during testicular torsion cases [12]. Therefore, repeat ultrasounds offer little clinical or medicolegal benefit. It is also possible that the receiving institution may repeat the ultrasound because clinicians are unaware that an ultrasound has already been performed. While ultrasound may be important in ruling out other causes of testicular pain, the urologist's diagnosis tends to be accurate. In agreement with Bayne et al. [6], the surgeon's ability to discern testicular viability was found to at least match the final histologic diagnosis of a non-viable, necrotic testis. One must be aware that intraoperative 'viability' truly refers to leaving the testis *in situ* as some testes may still develop atrophy on postoperative follow-up. In most cases, patient history, physical presentation, and clinical judgment may be sufficient for diagnosing testicular torsion, regardless of whether the patient is transferred from a less experienced institution. According to both the American Academy of Family Physicians and the American Academy of Pediatrics, surgical exploration should not be postponed to perform imaging if patient history and physical examination suggest torsion [13,14].

The study was limited by its retrospective nature. While the time between symptom onset and intervention is likely the most representative measure of patients' time to treatment, the subjective reporting of time of symptom onset and the potential absence of such information in the electronic medical record hindered the ability to accurately determine this time interval. The time of symptom onset is obtained solely from the report of the patient and/or his parents and, therefore, may be influenced by recall bias or patient age. For example, younger patients may have difficulty in articulating their symptoms, making the determination of the time of symptom onset uncertain. Additionally, because the patients in the sample were selected based on their diagnosis of testicular torsion, it was unable to determine whether a repeat ultrasound changed the diagnosis for a transfer patient with suspicion of torsion presenting at the authors' institution. Orchiectomy has been found to be associated with age, meaning that the patients' ages may have affected the results [2]. However, the study sample was primarily composed of older patients yet displayed similar rates of orchiectomy and salvage; therefore, it was believed that patient age has not confounded the results. The sample size may have also limited the ability to detect statistically significant differences in patient outcomes.

The analysis suggests that efforts to prevent repeat ultrasounds and minimize the time between presentation and intervention would improve patient outcomes. It was proposed that such considerations be incorporated into emergency department and other hospital protocols for patients presenting with suspicion of torsion. Toward this end, the institution a protocol to standardize clinical decision-making regarding patients with torsion is currently being implemented at the authors' institution. Standardized risk assessment procedures such as Barbosa et al.'s [15] TWIST scoring system, which indicates either ultrasound or immediate intervention based on patients' physical signs of torsion, may help decrease unnecessary ultrasounds and reduce patients' time between presentation and intervention. An NIH clinical trial found that more than 50% of high-risk patients avoided ultrasound under the TWIST system [16]. Patient and parental education on the symptoms of testicular torsion and their urgency may also help decrease time to presentation. Improving testicular salvage rates in pediatric patients with torsion likely requires a multifaceted approach, of which standardized clinical protocols are a crucial component.

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Ethical approval

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Competing interests

The authors have no competing interests to declare.

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Direction of Rotation in Testicular Torsion and Identification of Predictors of Testicular Salvage

Todd Yecies, Jathin Bandari, Francis Schneck, and Glenn Cannon

OBJECTIVES To identify the rate at which testicular torsion occurs in a lateral direction and identify any predictors of direction of testicular rotation and orchiectomy.

MATERIALS AND METHODS We performed a retrospective review of 104 cases of emergent scrotal exploration performed for testicular torsion by 3 pediatric urologists from 2003 to 2017. Patients with neonatal torsion, negative scrotal exploration, or exploration for presumed intermittent testicular torsion were excluded. Univariable logistic regression was performed to assess if any factors predicted direction of testicular rotation. Univariable and multivariable logistic regression was used to identify predictors of testicular salvage.

RESULTS Of 104 cases of acute testicular torsion, information regarding the direction of testicular rotation was available in 81 patients. Lateral testicular rotation occurred in 38 cases (46%). No factors were found to be predictive of direction of torsion. Orchiectomy for testicular nonviability was performed in 50 of 104 cases (48%). On univariable analysis, younger age ($p = .002$), absence of gastrointestinal symptoms ($P = .02$), time to exploration ($P < .001$), testicular size differential on ultrasound ($p = .002$), absence of hydrocele ($P = .01$), abnormal ultrasound echotexture ($P < .001$), and degree of torsion ($P = .04$) were associated with orchiectomy. With the exception of absence of gastrointestinal symptoms, all predictors of orchiectomy remained statistically significant on multivariable analysis.

CONCLUSION Testicular rotation occurs in a lateral direction in 46% of cases. Lateral manual detorsion should be performed only with awareness of the potential for increasing the degree of testicular rotation. New independent predictors of testicular salvage were identified. UROLOGY 114: 163–166, 2018. © 2017 Elsevier Inc.

Testicular torsion is a relatively common surgical emergency in pediatric urology, with an estimated incidence of 1:4000 in men under the age of 25.[1] Management of suspected testicular torsion consists of emergent scrotal exploration and testicular detorsion with orchiopexy, in the case of a viable testis, or orchiectomy if the testicle is nonviable. The role of attempted manual detorsion with or without Doppler or ultrasound guidance is controversial, stemming from concerns over inadequate detorsion or exacerbating lateral torsion.

Traditionally it has been thought that testicular torsion occurs in a medial direction.[2] As such, when attempting manual testicular detorsion, one rotates the testicle in a lateral direction, commonly referred to as an "open-book" technique. As it has previously been established that degree of torsion correlates with degree of testicular ischemia and reduced salvage rates, this carries the risk of worsening the degree of testicular torsion if the initial testicular rotation was in a lateral direction.[3] Sessions et al in 2003 established that within their cohort of patients with testicular torsion, lateral rotation occurred in 33% of cases;[4] however, this finding has not been subsequently validated, and no predictors of direction of torsion were reported. We hypothesize that analysis of our cohort of patients with testicular torsion would confirm this finding that lateral testicular rotation occurs in a substantial minority of cases of testicular torsion.

MATERIALS AND METHODS

Study Population

We performed a retrospective analysis of 104 cases of emergent scrotal exploration performed for testicular torsion by 3 pediatric urologists from the years 2003 to 2017 at a single tertiary referral freestanding children's hospital. Only pediatric patients were included in this study. Exclusion criteria included neonatal torsion,

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negative scrotal exploration, or exploration for presumed intermittent testicular torsion. Institutional review board approval was obtained from our institution for purposes of this study (IRB #PRO17010041).

Data Analysis

Data collected included patient age, torsion laterality, time to exploration, presence of associated gastrointestinal symptoms, scrotal ultrasound characteristics, direction and degree of torsion, transfer from outside hospital, and whether testicular salvage occurred. Ultrasound characteristics analyzed included testicular size differential, parenchymal echogenicity, and presence of associated hydrocele. Independent *t* test and tests were performed to compare the testicular salvage and orchiectomy patient populations. Before usage of parametric statistical tests, all continuous variables were tested for normality using chi-square goodness-of-fit testing. Univariable logistic regression was performed to assess if any of the measured variables predicted the direction of testicular rotation. Univariable and multivariable logistic regression was used to identify predictors of testicular salvage. All statistics were performed using the Microsoft Excel statistical package using a 2-tailed $P < .05$ as the threshold for statistical significance.

RESULTS

A total of 104 patients who underwent scrotal exploration for acute testicular torsion during the study period were identified. Average patient age was 12.6 years. Of these 104 cases, information regarding the direction of testicular rotation was available in 81 patients. Lateral testicular rotation occurred in 38 cases (46 %) (Table 1). Symptoms were localized to the left in 69 (66%) and right in 35 cases (34%). Mean degree of rotation was 555 degrees (standard deviation, 257 degrees). Univariable analysis found that no measured factors were predictive of direction of torsion, including age ($P = .84$), laterality ($P = .15$), presence of gastrointestinal symptoms ($P = .12$), and ultrasound characteristics such as testicular size differential ($P = .14$), presence of hydrocele ($P = .54$), or abnormal echotexture ($P = .78$) (Table 2).

Testicular salvage occurred in 54 of 104 (52%) of cases. Of the 54 cases of testicular salvage, 2 patients developed subsequent testicular atrophy with approximately 50% volume loss of the affected testicle. On univariable analysis, younger age ($P = .002$), absence of gastrointestinal symptoms ($P = .02$), time to exploration ($P < .001$), testicular size differential on ultrasound ($P = .002$), absence of hydrocele ($P = .01$), abnormal echotexture ($P < .001$), and degree of torsion ($P = .04$) were associated with orchiectomy (Table 3). On multivariable analysis, younger age ($P = .03$), time to exploration ($P < .001$), testicular size differential ($P = .04$), absence of hydrocele ($P = .01$), abnormal echotexture ($P < .001$), and degree of torsion ($P = .03$) were associated with orchiectomy (Table 3).

DISCUSSION

This study demonstrates that the prevalence of lateral testicular torsion is higher than previously reported. Sessions et al in 2003 published their series demonstrating that lateral rotation occurred in 33% of cases.[4] Additional literature on the topic is sparse and limited to small sample populations, with 5 series demonstrating 8 of 28, 1 of 8, 5 of 8, 1 of 10, and 0 of 8 cases of testicular torsion occurred with lateral rotation.[2,5-8] When combining all available data, the pooled rate of lateral rotation is 107 of 377

Table 1. Clinical and radiographic characteristics of patients presenting with acute testicular torsion

	Total N = 104	Testicular Salvage N = 54	Orchiectomy N = 50	*P* Value
Age, y, mean (SD)	12.6 (3.9)	13.7 (2.1)	11.4 (4.9)	.002
Laterality				.73
Right	35	19	16	
Left	69	35	34	
Time from onset of symptoms to OR, h, median (IQR)	12.5 (6.9,50.3)	7 (5.5,9.9)	50 (20.5,70.8)	<.001
Presence of nausea or emesis				.02
Yes	76	45	31	
No	28	9	19	
Testicular size differential, %, mean, (SD)	68.3 (56.0)	48.5 (38.7)	96.5 (62.4)	<.001
Presence of hydrocele				.02
Yes	80	47	33	
No	24	7	17	
Abnormal echotexture				<.001
Yes	85	37	48	
No	19	17	2	
Transfer from external facility				.99
Yes	35	18	17	
No	69	36	33	
Degree of torsion, degrees, mean (SD)	555 (257)	505 (270)	608 (232)	.04
Direction of torsion	N = 81	N = 50	N = 31	.99
Medial	43	27	16	
Lateral	38	23	15	

IQR, interquartile range; OR, operating room; SD, standard deviation.

Table 2. Univariable analysis performed to identify predictors of direction of testicular torsion

	Direction of Testicular Torsion	
	Univariable Analysis	
Predictor	Odds Ratio [95%CI]	*P* Value
Age	1.00 [0.96-1.03]	.84
Laterality		
Right	0.88 [0.70-1.10]	.25
Left	Reference	
Time to OR	1.0 [0.99-1.01]	.42
Presence of nausea or emesis		.99
Yes	1.0 [0.76-1.31]	
No	reference	
Testicular size differential	1.0 [0.99-1.01]	.14
Presence of hydrocele		.58
Yes	0.93 [0.70-1.22]	
No	reference	
Abnormal echotexture		.79
Yes	0.96 [0.72-1.27]	
No	Reference	
Degree of torsion, degrees, mean (SD)	1.00 [1.00-1.00]	.49

CI, confidence interval; OR, operating room; SD, standard deviation.

(28%). Despite these findings, it is still commonly taught within textbooks of both urology and emergency medicine that testicular rotation occurs medially, and detorsion should always be performed in a lateral direction.[9,10] Combined with the available literature, our findings suggest that these teachings are misleading and may carry a high potential risk of exacerbating present torsion. Unfortunately, no independent predictors of the direction of testicular rotation could be identified to guide bedside decision-making on when to perform manual detorsion.

Despite our finding, prior studies have demonstrated high success rates with lateral manual detorsion before scrotal exploration. Filho et al report that manual detorsion was associated with improved rates of testicular salvage at exploration.[11] Cattolica, and Frazier and Bucy also have reported high rates of testicular salvage with preoperative manual detorsion.[7,12] Given that none of the aforementioned studies were prospective or randomized, it is possible that patients with lateral testicular rotation had physical examinations felt to be less favorable for manual detorsion and thus did not undergo attempted detorsion. Additionally, residual torsion at the time of orchiectomy has been found in 28%-32% of "successful" cases of manual detorsion.[2,9] Although this finding has typically been attributed to inadequate detorsion, another possibility is that pre-existing lateral torsion was exacerbated. Although manual detorsion can be a useful tool in restoring blood flow in a setting where scrotal exploration is not immediately available, the present study poses a strong argument for forgoing manual detorsion when surgery is imminent.

Multiple studies have evaluated predictors of testicular salvage in testicular torsion, with variable results. Our study confirms prior findings that time from onset of symptoms to surgical exploration is a key predictor of testicular

Table 3. Univariable and multivariable analysis of predictors of testicular salvage in acute testicular torsion

	Testicular Salvage			
	Univariable Analysis		Multivariable Analysis	
Predictor	Odds Ratio [95%CI]	*P* Value	Odds Ratio [95%CI]	*P* Value
Age	1.04 [1.01-1.06]	.003	1.02 [1.00-1.04]	.03
Laterality				
Right	1.03 [0.84-1.27]	.73		
Left	Reference			
Direction of torsion		.84		
Lateral	0.98 [0.79-1.21]			
Medial	Reference			
Transfer from external facility		.94		
Yes	0.99 [0.81-1.22]			
No	Reference			
Time to OR	0.92 [0.88-0.95]	<.0001	0.93 [0.90-0.96]	<.0001
Per 24-hour period				
Presence of nausea or emesis		.014		.92
Yes	1.31 [1.05-1.63]		0.92 [0.18-4.61]	
No	Reference		Reference	
Testicular size differential	0.92 [0.88-0.97]	.002	0.95 [0.91-0.99]	.035
Per 50% differential				
Presence of hydrocele		.01		.016
Yes	1.34 [1.07-1.68]		1.26 [1.05-1.52]	
No	Reference		Reference	
Abnormal echotexture		<.001		<.001
Yes	0.63 [0.50-0.80]		0.68 [0.56-0.84]	
No	Reference		Reference	
Degree of torsion	0.93 [0.87-0.99]	.04	0.94 [0.89-0.99]	.031
Per 180° rotation				

CI, confidence interval; OR, operating room.

salvage.[13] We also confirm previously reported findings that abnormal testicular echotexture on ultrasound and degree of testicular rotation are both associated with orchiectomy.[3,4,14] The impact of age on testicular salvage rates has been variable across studies, with our findings echoing the population-based studies by Cost et al and Bayne et al that younger age is associated with lower rates of testicular salvage.[15,16] In addition to these previously reported factors, we identified novel predictors of orchiectomy. The absence of a reactive hydrocele and greater than 50% testicular size differential were independently predictive of orchiectomy. A reactive hydrocele is commonly found in acute torsion as an inflammatory response to the ischemic insult, whereas the lack thereof may indicate a longer duration or subacute onset of testicular ischemia. Similarly, increased testicular size differential is likely related to reactive vasogenic edema, potentially indicating a greater degree or longer duration of testicular ischemia.

This study should be interpreted in light of its potential limitations. First, the retrospective nature of its design poses the potential for selection bias; in particular, it may be that surgeons reported lateral torsion at higher rates than usual because of perceived rarity. Given that direction of torsion was reported in 77% of assessed operative reports, this was unlikely to significantly affect our outcomes. Certain parameters that have previously been evaluated as a predictor for testicular salvage, such as ambient temperature or ethnicity, were not readily available for review and thus could not be verified. Ideally, physical examination findings such as testicular lie would have been assessed as a potential predictor of direction of testicular torsion; however, this was not included because of inconsistent reporting within the medical record. This was a single-institution study with unique referral patterns and demographics, which may limit generalizability. Lastly, manual detorsion is rarely attempted at our institution so the effect of attempted detorsion on testicular salvage could not be assessed. Future studies in this area could prospectively gather data to avoid the potential for recall bias and ensure standardization of data reporting. Nevertheless, despite these limitations, this study is one of the largest series to date on torsion direction and uniquely establishes that there are no preoperative predictors that would guide clinicians toward manual detorsion.

CONCLUSION

Testicular rotation occurs in a lateral direction in 46% of cases. No predictive factors for identifying direction of torsion were identified. Lateral manual detorsion should be performed only with awareness of the potential for increasing the degree of testicular rotation. New independent predictors of testicular salvage were identified.

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Optimal Predictor of Gonadal Viability in Testicular Torsion: Time to Treat *Versus* Duration of Symptoms

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ABSTRACT

Background: We hypothesize that in testicular torsion, the duration of symptoms (DoS) better correlates with predicting testicular viability than minimizing the "time-to-treat" (TtT) after presentation to a medical facility.
Materials and methods: Medical records of male pediatric patients treated for suspected diagnosis of testicular torsion in the emergency department (ED) from January 1, 2016, to December 31, 2018, were retrospectively evaluated. Forty-one patients met inclusion criteria. Statistical analysis compared testicular viability based on TtT, DoS, and site of initial presentation.
Results: Testicular salvage rates for patients presenting directly to our ED was 56.3% with an average TtT of 2.5 h *versus* 77.8% and 1.96 h, respectively, for transferred patients. Overall testicular survival was not statistically impacted by the difference in TtT. Comparing DoS, an 84% testicular salvage rate (DoS $<$ 24 h) *versus* a 15.4% salvage rate (DoS $>$ 24 h) was shown in patients presenting directly to our ED ($P \leq 0.0001$). Within the total population ($n = 41$), a significant difference was also shown ($P \leq 0.0001$) when comparing overall testicular salvage rates in patients presenting with $<$24 h *versus* $>$24 h total DoS (84% *versus* 25%).
Conclusions: These data reveal that an alternative predictor of testicular salvage rates is a DoS $<$ 24 h. This is a meaningful metric when providing accurate preoperating counseling to parents and may be a better focus of quality improvement efforts surrounding this topic.

Introduction

Testicular torsion is a well-described pediatric surgical emergency and accounts for 10%-15% of acute scrotum presentation.[1] Testicular torsion has an annual incidence of 3.8 per 100,000 pediatric patients and results in an orchiectomy rate of 42%.[1]

According to recent literature, the testicular viability rate is highest when surgical treatment is implemented within 6 h of presentation to the emergency department (ED).[2] This is known as the "time-to-treat" (TtT) or the interval starting when the patient arrives to the ED until the time they are surgically treated. Testicular viability beyond the 6 h TtT interval, even up to 24 h, is more significant than previously appreciated.[3] It has been demonstrated that in instances with a TtT interval of between 12 and 24 h, 54% of all testes will survive. However, these viability rates do sharply reduce to 18% at the 24 h TtT mark.[3]

To date, there has been no literature that studies a TtT interval shorter than 6 h. Despite this lack of evidence, there

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have been attempts to shorten the TtT below 6 h using differing scoring systems, educational programs, and protocols. An example of such a program includes implementing the TWIST scoring system into a protocol to shorten the time to surgery.[4,5] Some institutions have even vied for implementing a 2 h TtT interval.[5]

However, TtT is not the only focus of recent research efforts. It has been proposed that TtT may not be the ideal parameter to guide quality improvement efforts and hypothesized that duration of symptoms (DoS) might be a better focus for future research.[6] Few studies have analyzed the DoS as a metric that can predict testicular salvage rates. In one study by Ramachandra *et al.*, patients who had symptoms for <6 h had a salvage rate of 90% compared with 28.6% for those who presented later; median time to the operating room (OR) for all comers was 3.33 h, suggesting that time to surgery was less indicative of salvage rates when compared with DoS.[7]

Minimizing the TtT window to 2 h may be a costly and institutionally challenging benchmark for many hospitals and outpatient centers with yet unproven benefit. Furthermore, in many cases where a transfer is necessary, imposing a 2-h TtT window may disincentivize transfer to higher levels of care with pediatric surgical and anesthesia capabilities. Prioritizing DoS over the TtT interval may reveal a novel approach to treating patients presenting with symptoms of testicular torsion. Better predictors of gonadal salvage would not only improve surgical quality metrics but allow for surgeons to offer a more informed consent to parents with regards to need for orchiectomy *versus* salvage procedure, a source of significant family concern.

This novel approach formed the hypothesis that minimizing TtT has less impact on testicular salvage rates (within a 6-h window), and that patients' DoS better correlates with predicting testicular viability.

Materials and methods

Scientific Review Committee/Institutional Review Board approval was obtained through the University of Tennessee College of Medicine Chattanooga before the initiation of this study. Data were deidentified before inclusion in the database.

Medical records of all male pediatric patients treated for a suspected diagnosis of testicular torsion in the ED from January 1, 2016, to December 31, 2018, were retrospectively evaluated.

Inclusion criteria contained all pediatric males treated for a suspected diagnosis of testicular torsion on presentation to the ED. International Classification of Diseases, Tenth Revision (ICD-10) system went into use on January 1, 2016. The ICD-10 codes used for patient identification were N44.00 and N44.02. Patients were excluded if they were aged <6 mo, aged >18 y, or had incomplete charts. Forty-one patients met inclusion criteria at the time of our analysis. The utilization of ICD-10 codes was more specific for testicular torsion patients than other defining variables, such as Current Procedural Terminology codes. Current Procedural Terminology codes were not used because they included elective orchiectomy patients that would have had to be excluded. Using ICD-10 codes was specific for acute torsion in our dataset.

The pertinent data points that were collected include age, medical record number, insurance type, DoS on presentation to ED, time of presentation to ED, time of ultrasound, time of surgical consultation, time of surgical incision, operative finding (not twisted/twisted but viable/twisted and nonviable), and procedure performed (orchiopexy *versus* orchiectomy). Patient characteristics were included in Table 1.

Testicular viability was defined using surgeon assessment and by noting the type of surgery that was ultimately performed (orchiopexy = viable and orchiectomy = nonviable.) Pathology was not reviewed.

TtT was defined as the time the patient presented to an ED until the surgical incision was made in the OR. DoS was defined as reported onset of symptoms until the patient presented to an ED.

Statistical analysis compared testicular viability based on both TtT and DoS. Patients originating in our system *versus* transfers from outside hospitals (OSHs) were also compared. A statistician was used to analyze our data. Statistical analysis used to compare outcomes used the chi-square and the Fisher's exact tests. The Levene's test for equality of variances was used to compare outcomes across groups of patients (originating in our ED and from OSHs). Where a large skew was present, the Mann–Whitney U test was used to determine significance.

Results

Overall testicular viability of the total studied population of patients ($n = 41$) was 61%, regardless of TtT or DoS. Mean TtT and DoS for each patient category is shown in Table 2. Average TtT in the total population was 209 min (3.48 h). TtT was compared between the viable and the nonviable cases and was not found to be significantly different with a P value of ≤0.184 as shown in Table 3. Specifically, TtT was an average of 132 min (±58) in the viable group and 160 min (±69) in the nonviable group.

The average TtT within the group of patients presenting to directly to the ED was 150 min (±57) or 2.5 h with a viability rate of 56.3%. The average TtT within the group of patients presenting first to an OSH and requiring transfer was 117.8 min (±89) or 1.96 h with a viability rate of 77.8%. Both these metrics are well within the current 6-h standard of care.

Table 1 – Patients' characteristics.

Age (y)	
<10	3
>10	38
Insurance	
Commercial	23
TN medicaid	12
GA medicaid	3
Self pay	3

Table 2 – Mean TtT and DoS for each patient category.

Overall outcomes

Direct to ED ($n = 32$); viability = 56.3%

- Average TtT = 150 (±57) min (2.5 h)
- Symptoms < 24 h ($n = 19$)
  - DoS mean = 325 (±285.5) min (5.4 h)
  - TtT mean = 141.8 (±57) min (2.36 h)
- Symptoms >24 h ($n = 13$)
  - DoS mean = 3452.3 (±1331) min (59 h)
  - TtT mean = 161.9 (±57.2) min (2.69 h)

OSHs ($n = 9$); viability = 77.8%

- Average TtT = 117.8 (±89) min (1.96 h)
- Symptoms < 24 h ($n = 6$)
  - DoS mean = 380.3 (±89) min (6.33 h)
  - TtT mean = 127.5 (±96) min (2.1 h)
- Symptoms >24 h ($n = 3$)
  - DoS mean = 3000 (±264) min (50 h)
  - TtT mean = 98.3 (±88) min (1.64 h)

When using TtT as the primary variable for comparison in these two groups, the overall testicular viability was not impacted by the TtT. This is depicted in Table 4.

The data were then examined by TtT intervals. Within this dataset, 13 of the total 41 patients had a TtT of <2 h. Twenty-six patients had a TtT between 2 and 4 h. Only two patients had a TtT >4 h. Within the group with the TtT <2 h, the viability rate was 85%. Within the next group of patients with a TtT of between 2 and 4 h, the viability rate was 54%. Within the last group of two patients with a TtT of >4 h, one was in the viable group, and one was in the nonviable group.

These data do show an improvement in outcomes with a shorter TtT; however, it is also important to note that the mean DoS in the patients in the viable group was lower than those in the nonviable group in all three categories. However, the means for DoS are associated with a large standard deviation secondary to the wide range of data that is included. Because of this, the calculations were run in a binary fashion, comparing a DoS <24 h *versus* >24 h.

Within the first category of patients with a TtT of <2 h, 82% of the viable patients had a DoS <24 h, whereas 50% of the nonviable patients had a DoS <24 h. Within the next category of patients with a TtT of between 2 and 4 h, 86% of the viable patients had a DoS <24 h, whereas only 17% of the nonviable patients had a DoS <24 h. Within the group of patients with a TtT of >4 h, one patient with a viable outcome had a DoS <24 h, and one patient with a nonviable outcome had a DoS >24 h. These data are shown in Table 5.

Table 3 – Comparison of TtT between the viable and nonviable patients.

TtT comparison (total population)

	Number	Mean time	P value
Viable	25	132 min (±58.2)	
Nonviable	16	160 min (±68.6)	≤0.184

Table 4 – Viability rates and their corresponding average TtT between the two groups of patients.

Viability rate based on TtT

	Viability (%)	TtT (average), min
Direct to ED	56.3	150
Transfer from OSH	77.8	117.6

The data were then analyzed using the DoS as the primary variable, with 24 h as the "cut-off" time and calculated for the difference in viability of these patients. Within the total population of patients, a significant difference occurred (*P* value ≤0.0001) when comparing overall viability in patients that presented before 24 h DoS compared with those who presented after 24 h DoS (84% *versus* 25% viability as seen in Table 6).

The DoS was also used to compare outcomes between the two populations (ED *versus* OSH). Within the population of patients who presented directly to the ED, there was an 84% testicular viability in the patient who presented before 24 h DoS *versus* a 15.4% survival if the patient presented after 24 h (*P* value of ≤0.0001). A similar trend appeared if the patient first presented to an OSH and required a transfer, although this did not reach statistical significance. If the transferred patient in this scenario presented within 24-h DoS, the viability rate was 83.3% compared with 66.7% if the patient presented after 24 h.

The total DoS (which includes the DoS before presentation to an ED plus the TtT) was also significantly higher in the nonviable group. The mean total DoS was 49.6 h (±30) in the nonviable group, and only 13.6 h (±17) in the viable group. This showed significance with a *P* value of ≤0.0001 by Mann–Whitney *U* (nonparametric) test.

Discussion

The majority of literature that has been published thus far on testicular torsion focuses mainly on TtT after presentation for care and the subsequent testicular viability. The current

Table 5 – Number of patients who had a DoS <24 or >24 h and the number of viable *versus* nonviable outcomes.

TtT	Dos <24 h	DoS >24 h	DoS <24 h (%)
<2 h			
Viable	9	2	82
Nonviable	1	1	50
2-4 h			
Viable	12	2	86
Nonviable	2	10	17
>4 h			
Viable	1	0	100
Nonviable	0	1	0

Table 6 – Viability based on DoS.

Viability rates based on DoS

	DoS <24 h	DoS >24 h	P value
Direct to ED	84%	15.4%	≤0.0001
Transfer from OSH	83.3%	66.7%	≤0.375
Total population	84%	25%	≤0.0001

Significant differences are shown in the group of patients who presented directly to the ED and in the overall population of patients.

recommendation aims to minimize the TtT to as low as 2 h. This information led to the hypothesis that minimizing TtT has less impact on testicular salvage rates, and that DoS is also correlated with testicular viability outcomes. Based on the previously mentioned data, DoS is correlated with testicular viability in testicular torsion and can be used as a predictor of outcomes within the context of a TtT <6 h.

The average TtT during this period of investigation was <6 h, the most well-documented and researched standard. There is no research comparing a 2- and 6-h TtT. If 2 h is the new standard to be obtained, then future research in this area is warranted. These data did show an improvement in outcomes with a decreased TtT to 2 h; however, these patients typically presented with a shorter DoS, which this data has shown leads to an increased viability and must be considered as part of the equation.

In addition, these data suggest that referral centers should strongly consider transfer of testicular torsion patients to an experienced, tertiary care center with expert pediatric surgical or urologic capabilities even if transport might appear to increase the TtT. Particularly if the DoS is <24 h, these patients can have excellent outcomes and a high testicular viability rate. In addition, as shown by these data, the TtT can actually be shortened when patients are transferred from an OSH. This is because of the fact that the surgeons at the tertiary center are alerted before transport and can have the OR ready and the surgical team awaiting the arrival of the patient. When the patient arrives from the OSH, they can move efficiently through the system and proceed quickly to the OR.

Regarding the 24-h mark, this was chosen after reviewing previous literature. A metanalysis by Mellick *et al.* that culled 30 studies and more than 2000 patients showed that within a 24-h TtT, viability rates were 54%; however, after 24 h, viability rates dropped to 18%.[3] This study did not take into account the concept of DoS, but did, however, begin to show that there must be factors other than TtT, which contributed to testicular viability.

In one of the few studies where DoS was analyzed by Pogorelic *et al.*, the median DoS of patients with viable testicles was 6 h (1-72 h), and in patients with nonviable testicles, the median DoS was 46 h (12-120 h).[2] Based on these findings, a 24 h cut off was chosen because it appeared to be the "tipping point" in the previous literature.

Ultimately, these data can also help provide more precise informed consent to both the patients and their parents. By knowing the duration of the patient's symptoms, the surgeon can answer questions more confidently on the likelihood of orchiectomy *versus* testicular salvage. This is a source of significant stress on the family, and having more accurate statistics would help to ease anxiety.

In addition to providing more information, working to shorten the DoS (instead of working to shorten TtT) is likely a better focus for quality improvement efforts. The best way to continue to improve viability rates is to focus on how to raise public awareness surrounding the symptoms and urgency of a diagnosis of testicular torsion and prompt parents and children to present to the hospital at the earliest sign of these symptoms. Community outreach and educational programs are likely the next step in increasing testicular viability rates.

A limitation of this study is that it used a low sample size of patients presenting from an OSH. To be more generalizable, data from more patients presenting to an OSH is needed to assess the significance of the trend toward a higher viability rate with a shorter DoS that was seen in this population.

Conclusions

In this study of testicular torsion outcomes, these data support that an alternative predictor of increased testicular viability is a shortened DoS (<24 h). This is a novel approach to discussing and predicting the possibility of testicular viability on a case-by-case basis and is a meaningful metric when providing proper preoperative counseling to parents and their children.

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The authors of this article have nothing to disclose.

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Revisiting testicular torsion scores in an Asian healthcare system

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Summary

Introduction
Testicular pain is a common presentation amongst young boys. It is important to distinguish between testicular torsion and other testicular pathology as testicular viability is dependent on timely diagnosis and surgical intervention.

Objectives
The aim of this study was to evaluate the utility of the TWIST score in our population. Our second objective was to compare a new testicular torsion score (TT score) developed in a paediatric Asian population, with the TWIST score in risk stratification for testicular torsion. Duration of symptoms and delays after presentation were also correlated with testicular viability.

Methods
This is a prospective cohort study of children admitted with testicular pain from January 2016 to December 2018 at a tertiary care hospital in Singapore. Relevant findings such as age, nausea/vomiting, testicular swelling/firmness, absence of cremasteric reflex and abnormal lie were collected. Univariate and multivariate logistic regression was performed to identify significant predictive factors of testicular torsion to generate TT score.

Results
A total of 315 patients were involved in this study. Mean age of patients was 121.3 $\pm$ 44.2 months. There were 43 patients with testicular torsion. No patients with a TT score of $\leq$1 were found to have testicular torsion. In contrast, 10 patients with a TWIST score of $\leq$2 were found to have testicular torsion. Of the patients with testicular torsion, 16 had a TWIST score of $\geq$5 and 22 had a TT score of $\geq$6. In this study, the area under the curve was 0.87 for the TWIST score and 0.93 for the TT score.

Conclusion
In conclusion, the TT score is a reliable score for excluding testicular torsion in an Asian patient population with a sensitivity and negative predictive value of 100% at a cut-off value of $\leq$1. Both TWIST and TT score performed equally well in early presenters (<6 h) Further prospective validation studies are needed to evaluate the utility of the TT score. Delay in presentation to hospital is the most important determinant of outcome.

Summary Table Proposed testicular torsion score (TT score).

Risk factor	Score
Age group ($\leq$1 or $\geq$10 Years old)	1
Nausea or vomiting	2
Testicular swelling	2
Testicular firmness	1
Absent cremasteric reflex	1
Abnormal lie	2

The testicular torsion (TT) score. The score ranges from 0 to 9. A score of $\leq$1 indicates that, testicular torsion is unlikely while a score of $\geq$6 is predictive for testicular torsion.

[1] XL and MIA are joint first authors as both contributed equally to this paper.

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Introduction

Testicular pain is a common presentation of the acute scrotum in the emergency setting. Around 10%–15% of these children have testicular torsion which needs to be differentiated from non-torsion cases [1]. This is especially so as the rate of testicular viability or salvage is dependent on time [2–4]. The incidence of testicular torsion has been estimated to be around 1 in 4000 in males younger than 25 years old [4].

Testicular torsion is caused by the twisting of the spermatic cord along the vasculature of the testicle and requires prompt surgical intervention to prevent testicular loss form ischemia [5]. Studies have found that males treated within 6 h of onset of pain have a 90% testicular salvage rate [4]. However, this drastically falls to 18.1% after 24 h [6]. Therefore, detorsion of the testes should ideally be done within then 6-h window period.

Several studies have suggested that presence of nausea, vomiting, absent cremasteric reflex, abnormal lie and testicular swelling/hardness are highly associated with testicular torsion [7,8]. However, these signs could occur in other acute scrotal conditions as well, such as torsion of the cyst of Morgagni and epididymo-orchitis and may be difficult for junior doctors to pick up [5].

Scrotal ultrasound is an important tool in the evaluation of torsion with a specificity and positive predictive value of up to 90%–100% [9]. However, it takes time and may prolong pre-operative testicular ischemia. It may also be falsely negative in cases of subacute testicular torsion [10]. The testicular workup for ischaemia and suspected torsion (TWIST) score was previously developed for stratifying patients with testicular torsion between 3 months and 18 years of age [7]. The cut-offs for low- and high-risk scores were ≤ 2 and ≥ 5 respectively.

The initial study reported a negative and positive predictive value of 100% with a sensitivity of 76% and specificity 81% [7]. Barbosa et al. predicted that the need for ultrasound would be decreased to 20% with the TWIST score. Notably, this scoring system was done by trained urologists. The score was also validated in other studies by paediatric emergency providers using different cut-offs and addition of the Tanner staging [8,11].

Due to differences in the primary care setting and clinical systems, children with testicular pain in Singapore are often seen by junior doctors, general practitioners and emergency physicians before they are assessed by a urologist. At our institution, we found that the TWIST scoring system did not perform as well in our population, despite training of junior doctors.

Therefore, one of our objectives was to develop an alternative testicular torsion (TT) scoring system which was more inclusive to prevent any missed testicular torsions. The diagnostic value of the TT score was also compared against the TWIST score for patients presenting with acute scrotal pain. Subgroup analysis of the utility of both scoring systems was also compared in patients presenting early on (i.e. within 6 h of onset of testicular pain). Duration of symptoms and delays after presentation were also correlated with testicular viability, to better assess how to reduce duration of pre-operative ischaemia.

Methods

Study design

This is a prospective cohort study from January 2016 to November 2018 done at the KK Womens' and Childrens' Hospital in Singapore. Institutional review board (IRB) approval was obtained prior to the commencement of this study (CIRB 2015/29,686) All children below the age of 16 years old with acute testicular pain admitted to the Paediatric Surgery service in our hospital were included. Patients with scrotal trauma, prior scrotal abnormalities (e.g. existing hydrocoele or varicocele) or urinary tract infection/penile discharge were not included. Patients with delayed presentation (scrotal pain for $>$ 1 week) were also excluded from this study. Consent for the study was obtained from the patients' parents.

Data collection and selection of variables

Every child was evaluated by a medical officer on admission using a comprehensive data collection proforma which was completed by the clerking doctor. All medical staff were shown teaching slides on how to perform the clinical examination and scoring to ensure consistency, reliability and reproducibility of the scoring system.

Patient demographic and clinical data such as age, duration of pain, time to ultrasound or surgery, presence of nausea/vomiting and other examination findings such as testicular firmness on palpation, absence of cremasteric reflex, high riding testis, lie of the testis, scrotal erythema, localized tenderness, thickening of the spermatic cord, inguinal fullness and fixity of testis to scrotal skin were recorded. These criteria were included in our protocol based on studies by Barbosa et al. [7] and Shah et al. [12] as well as suggestions by senior consultants in our Department. Our aim was to include broad range of symptoms and signs to ensure that all testicular torsions were not missed.

Clinicians making treatment decision (conservative vs surgical) were blinded to the scoring system as it was done independently. Clinical outcomes were classified into salvaged testis, testicular atrophy or orchidectomy. Follow-up and evaluation was done in the outpatient setting three months after surgery.

Statistical analysis

All factors and outcomes investigated were evaluated using descriptive statistics. Percentages were used for categorical data and means with standard deviations were used for continuous data. Univariate analysis using Chi-square test of predictive factors for testicular torsion was done to ascertain which individual factor was significantly associated with testicular torsion. Factors which were found to be significantly associated with testicular torsion were then included in the multivariate analysis using logistic regression. Selection of factors to be included in the scoring system and score weightage was done using statistically significant outcomes derived from the multivariate and receiver operating characteristic (ROC) analysis.

Hosmer–Lemeshow test was used to evaluated goodness of fit for the logistic regression.

After the testicular torsion score was derived, area under the curve (AUC) of the ROC analysis was calculated and compared between the TT score and TWIST score. All statistical analysis was done using the IBM SPSS Statistics for Windows software, version 23 (IBM Corporation, New York, USA). A p-value of <0.05 was considered to be statistically significant.

Results

Patient demographics

315 children with acute testicular pain participated in this study. Mean age of the patients was 121.3 ± 44.2 months. Mean duration of testicular pain was 41.3 ± 40.1 h. Number of patients with testicular torsion was 43 of 315 patients (13.7%) (see Table 1). 86.3% (272/311) patients had negative scrotal ultrasounds while 12.5% (39/311) had positive scrotal ultrasounds for testicular torsion. The remaining 4 patients with testicular torsion were brought straight to theatre for surgical exploration without ultrasound due to high index of suspicion by senior clinicians.

Univariate analysis

Out of all the factors analyzed, only age group (OR 6.18, 95% CI 2.36, 16.19), presence of nausea/vomiting (OR 14.17, 95% CI 6.11, 32.87), testicular swelling (OR 13.33, 95% CI 4.03, 44.14), firm testes (OR 7.58, 95% CI 3.71, 15.50), absence of cremasteric reflex (OR 14.78, 95% CI 6.88, 31.79), high riding testes (OR 7.19, 95% CI 2.84, 18.22), abnormal lie of testes (OR 15.66, 95% CI 6.28, 39.03), thickened spermatic cord (OR 6.28, 95% CI 2.43 16.25), inguinal fullness (OR 13.85, 95% CI 2.45, 78.12) and fixity of scrotal skin (OR 10.13, 95% CI 1.64, 62.47) were associated with likelihood of testicular torsion (see Table 2).

Multivariate analysis

On multivariate analysis, only age group (OR 6.21, 95% CI 1.79, 21.44), presence of nausea/vomiting (OR 11.49, 95% CI 3.35, 39.45), testicular swelling (OR 8.29, 95% CI 1.71, 40.18), testicular firmness (OR 3.60, 95% CI 1.28, 10.15), absence of cremasteric reflex (OR 3.27, 95% CI 1.08, 9.91) and lie of testes (OR 7.60, 95% CI 1.93, 29.97) were found to be significantly associated with likelihood of testicular torsion (see Table 2). Of all factors, presence of nausea/vomiting with concomitant testicular pain was highly suggestive of testicular torsion. The Homer–Lemeshow test for goodness of fit of the logistic regression was 0.910.

Selection of variables and score weightage

Based on the multivariate analysis, a total of six factors ($p < 0.05$) were selected to be included in the testicular torsion (TT) score: age group (i.e. $\leq$ 1 years old or $\geq$10 years old), nausea/vomiting, testicular swelling, testicular firmness, absence of cremasteric reflex and abnormal lie of testes. Score weightage was done using the odds ratio of each factor with age group, absence of cremasteric reflex and testicular firmness being given a score of 1. Meanwhile, nausea/vomiting, testicular swelling and abnormal lie being given a score of 2 as these factors were more strongly indicative of presence testicular torsion. The minimum score is 0 and the maximum score is 9.

Table 1 Comparison of TT score and TWIST score with respective sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) at each cut-off value.

TT Score	Torsion	No torsion	Sensitivity	Specificity	PPV	NPV
0	0	47	100.00%	17.28%	16.04%	100%
1	0	74	100.00%	44.49%	22.16%	100%
2	1	61	97.67%	66.91%	31.82%	99.45%
3	7	58	81.40%	88.24%	52.24%	96.77%
4	4	18	72.09%	94.85%	68.89%	95.56%
5	9	11	51.16%	98.90%	88.00%	92.76%
6	9	0	30.23%	99.26%	86.67%	90.00%
7	9	1	9.30%	99.63%	80.00%	87.42%
8	2	1	4.65%	99.63%	66.67%	86.86%
9	2	1	0.00%	100.00%	NA	86.35%
TWIST Score	**Torsion**	**No torsion**	**Sensitivity**	**Specificity**	**PPV**	**NPV**
0	1	115	97.67%	42.28%	21.11%	99.14%
1	1	12	95.35%	46.69%	22.04%	98.45%
2	8	110	76.74%	87.13%	48.53%	95.95%
3	6	12	62.79%	91.54%	54.00%	93.96%
4	11	15	37.21%	97.06%	66.6.7%	90.72%
5	7	7	20.93%	99.63%	90.00%	88.85%
6	8	1	2.33%	100.00%	100.00%	86.62%
7	1	0	0.00%	100.00%	NA	86.35%

Table 2 Univariate and multivariate analysis of predictive factors for testicular torsion. Only 6 factors were significantly associated with testicular torsion on multivariate analysis, which were included in the TT scoring system.

Factors	Frequency	Univariate analysis		Multivariate analysis	
		Odds ratio	95% Confidence interval	Odds ratio	95% Confidence interval
Age group (≤1 or ≥10 years)	188/315	6.18	(2.36, 16.19)	6.21	(1.79, 21.44))
Nausea/vomiting	29/315	14.17	(6.11, 32.87)	11.49	(3.35, 39.45)
Testicular swelling	176/315	13.33	(4.03, 44.14)	8.29	(1.71, 40.18)
Testicular firmness	48/315	7.58	(3.71, 15.50)	3.60	(1.28, 10.15)
Absent cremasteric reflex	40/315	14.78	(6.88, 31.79)	3.27	(1.08, 9.91)
High-riding testes	21/315	7.19	(2.84, 18.22)	0.93	(0.15, 5.56)
Abnormal lie	24/315	15.66	(6.28, 39.03)	7.60	(1.93, 29.97)
Scrotal erythema	130/315	1.59	(0.83, 3.03)		
Local tenderness	260/315	1.71	(0.64, 4.57)		
Thickened spermatic cord	20/315	6.28	(2.43, 16.25)	1.46	(0.33, 6.44))
Inguinal fullness	6/315	13.85	(2.45, 78.12)	33.36	(0.83, 1345.14)
Fixity of scrotal skin	5/315	10.13	(1.64, 62.47)	0.32	(0.02, 4.56)

Sensitivity and specificity

The TT score was able to exclude testicular torsion without the need of ultrasound in 121 patients and was hence better than TWIST score in our patient population. Sensitivity, specificity, positive predictive value and negative predictive value for each score is presented in Table 1. No patient with a TT score of ≤1 was found to have testicular torsion (see Table 1). In contrast, 10 patients with a TWIST score of ≤2 were found to have testicular torsion, indicating that the sensitivity and negative predictive value of the TWIST score was not as high in our patient population [7,8,11]. (see Table 1).

At a cut-off value of 1, the sensitivity and negative predictive value of the TT score was 100% with specificity of 44.49% and positive predictive value of 22.16%. In contrast, the TWIST score at a cut-off value of 2, had a sensitivity of 76.74% and a negative predictive value of 95.95% with specificity of 87.13% and positive predictive value of 48.53%. Meanwhile, the TT score had a specificity of 99.26% and positive predictive value of 86.67% with sensitivity of 30.23% and negative predictive value of 90.00%, at a cut-off value of 6. In comparison, the TWIST score had a specificity of 99.63% and a positive predictive value of 90% with a sensitivity of 20.93% and negative predictive value of 88.85%, at a cut-off value of 5 (see Table 1).

Comparison of TT score vs TWIST score

ROC curves were constructed for both scoring systems using our prospective patient cohort. The AUC for the TT score was higher than the TWIST score (0.93 vs 0.87 respectively) (see Fig. 1).

Performance of the TT score and TWIST score in early presenters (<6 h)

Subgroup analysis of patients who presented within 6 h of onset ($n = 68$) was also performed. ROC analysis for both the TWIST score and TT score suggested that both scores were comparable at diagnosis of early testicular torsion (AUC of 0.87, 95% CI 0.78, 0.95 for TWIST and AUC of 0.91, 95% CI 0.84, 0.98 for TT score). 100% sensitivity was achieved for both the TT score and the TWIST score at a cut-off of 2.

Surgical outcomes

A total of 6 patients underwent orchidectomy due to non-salvageable testis while 37 patients had salvage surgery. For all cases of orchidectomy, orchidopexy of the contralateral testes was performed.

Long term outcomes

At three months, viability of the salvaged testis was checked by physical examination or repeat testicular ultrasound. 11 patients were found to have testicular atrophy on follow up (29.7% of salvaged testes). 18 were confirmed to have no atrophy with normal sized testes (48.6% of salvaged testes). 8 patients were not re-evaluated as they defaulted on follow-up while the remaining 6 had orchidectomy done.

Testicular viability stratified by time to presentation

Analysis of the time of presentation from onset of pain is shown in Table 3. Only 21% patients with testicular torsion present within 6 h of onset of pain. Testes salvaged after 6 h of onset of pain have a very high atrophy rate. The delay in getting an ultrasound is comparatively less in our setting.

Meanwhile, testicular viability was highest in patients presenting within 6 h of onset of pain (75%), despite a delay of about 2.5 h for ultrasound confirmation and a further surgical delay of 2 h (see Table 3) Testicular viability drops to 50% in patients presenting between 7 and 12 h, and further down to 20% in patients presenting between 13 and 24 h. Testicular viability is dismal in patients presenting after 24 h (14%).

In patients who were brought directly for surgical intervention on the basis of clinical presentation, only 1 patient who presented within 6 h was shown to have viable testes on follow up while the rest were atrophic. Mean time

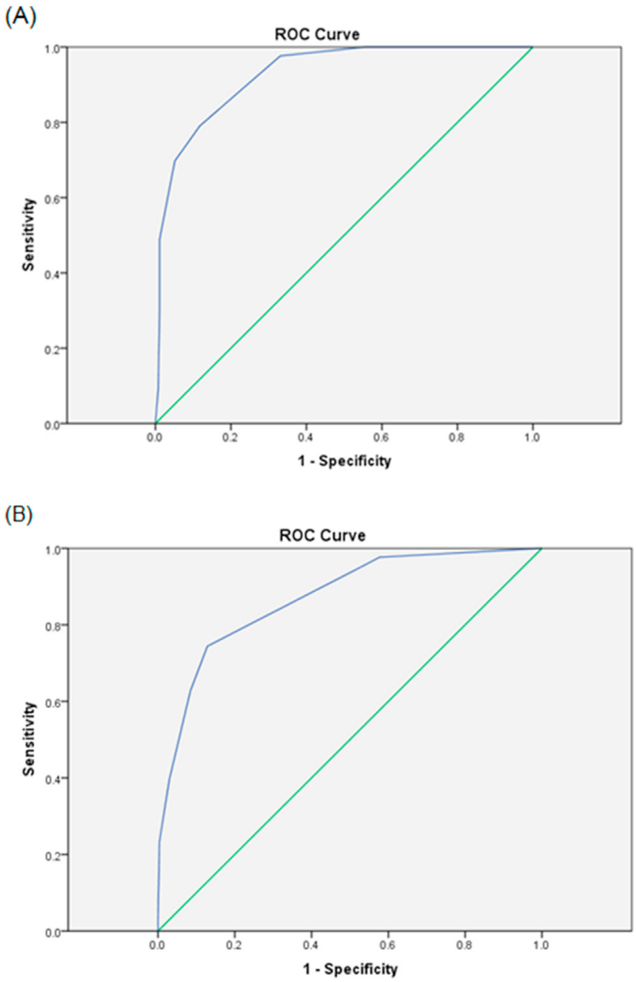

Figure 1 ROC analysis comparing TT score (A) and TWIST score (B). For TT score, the area under curve (AUC) value was 0.93, 95% CI (0.89, 0.96) while the AUC value for the TWIST score was 0.87, 95% CI (0.81, 0.93).

delay for ultrasound diagnosis was about 2.5–3.9 h, while mean time delay for surgery was about 1–2 h.

Discussion

Testicular torsion is a urological emergency which needs to be urgently differentiated from other causes of testicular pain in order to salvage the testis [13]. However, delay in presentation and lack of awareness of the time-sensitivity of this condition may result in delayed diagnosis and treatment, resulting in non-salvageable testicular necrosis. In one study, testicular salvage rate dropped to 20%–50% when treated between 6 and 12 h, and to 10% when treated between 12 and 24 h [14].

Barbosa et al. developed a scoring system for distinguishing testicular torsion in children presenting with the acute scrotum by risk stratification [7]. We found that the TWIST score did not perform as well in our population as there were cases of testicular torsions despite a low score and therefore developed a more sensitive score to prevent missed torsions. Also, although diagnostic ultrasound scrotum has a sensitivity of between 85% and 100% and specificity of between 75% and 100%, it may prolong testicular ischemia time and delay surgery [15,16]. However, this will affect the outcome only if the patient arrives before 6 h of onset of pain.

In our study, we found that the diagnostic utility of the TT score to be better for risk stratification compared to the TWIST score in our population. This may be due to a lower cut-off value which resulted in a more inclusive scoring system to avoid misdiagnosis by junior doctors. There were no missed testicular torsions in our patient cohort based on the TT score, while 10 cases were missed using the cut-off value of 2 based on the TWIST score. The TT score was also found to perform better at detecting testicular torsion cases with 22 positive cases at a cut-off of $\geq$6, while there were only 16 positive cases at a cut-off of $\geq$5 for the TWIST score.

Another reason for the difference between the efficacy of the TT and TWIST score in evaluating patients with testicular pain is that our patients tend to present earlier with less classical signs suggestive of testicular torsion. For example, in our study, the strongest predictor of testicular torsion was nausea and vomiting, where some of these patients had normal testicular examination apart from mild scrotal tenderness or abnormal lie. In some instances, patients with equivocal ultrasounds were subsequently reviewed by senior consultants labelled as testicular torsion. Moreover, the mean time to presentation was about 41 h in our study while mean time to presentation was about 67 h in the study by Barbosa et al. [7] Patients who present earlier may have equivocal signs on assessment due to twisting and untwisting of testes, which may result in higher likelihood of missed torsions.

Furthermore, one other reason for reduced utility of the TWIST score, as compared to the TT score was the clinical experience and training of junior doctors. Although all medical staff were taught how to perform the clinical examination and scoring, high turnover of staff at our institution (our junior doctors undergo three to six monthly rotations) meant that there was a steep learning curve when examining the first few patients presenting the testicular pain. Therefore, a lower threshold was set for our scoring system to prevent cases of missed torsion.

We also decided to include age group into the scoring system as we found close correlation between patient age group ($\leq$1 years old and $\geq$10 years old) and presence of testicular torsion. This may be due to the bimodal incidence of testicular torsion in the neonatal period (extravaginal torsion) and adolescent period (intravaginal torsion). This is also easier than using the Tanner classification system as described by Sheth et al. [8] We also chose abnormal lie (i.e. transverse lie) rather than high-riding testes as one of the criteria for scoring as there was higher association of between abnormal lie and testicular torsion. Also, a retractile testis may be misinterpreted as a high-riding testis amongst non-specialist doctors.

In some instances, abdominal pain may be the only presenting symptom of testicular torsion as well [17]. Also, in a study by Shah et al. a clinical decision tool with only three variables (abnormal lie, nausea or vomiting, age of 11–21 years old), showed a sensitivity and negative

Table 3 (A) Outcomes of patients stratified by time from symptom onset to presentation (B) Time log of patients with testicular torsion who had pre-operative ultrasound. (C) Time log of patients with testicular torsion who were taken for surgical exploration without US. (D) Surgical delay after diagnosis.

(A) Time from symptom onset to presentation (hours)	Torsion	Not torsion
0–6	17	50
7–12	4	27
13–24	6	74
>24	16	121

(B) Duration of pain (hours)	Number of patients	Viability of testis on follow-up	Mean delay in ultrasound (hours)
0–6	16	12	2.5
7–12	4	2	2.25
13–24	5	1	2.8
>24	14	2	3.9

(C) Duration of pain (hours)	Number of patients	Viability of testis on follow-up
0–6	1	1
7–12	0	0
13–24	1	0
>24	2	0

(D) Surgical delay after diagnosis (hours)	Number of patients
<1	11
1–2	21
>2	11

predictive value to 100% which corresponds with findings in our study [12]. Another point to consider is the use different cut-off values for patients presenting early vs late as clinical signs are likely to become more obvious of patients present late.

The main objective of this study was to develop a scoring system which would aid the diagnosis of testicular torsion amongst junior healthcare professionals and prevent any missed torsions. The TT scoring system has been shown to have a 100% sensitivity and negative predictive value for testicular torsion in our patient cohort which we found was better than the TWIST score introduced by Barbosa et al. Even at a cut-off of 0, there was 1 case of missed torsion using the TWIST score whereby this patient presented with only testicular tenderness and abnormal lie. In a study by Sheth et al. there were 3 patients with testicular torsion despite a TWIST score of 1 [8]. Similarly, Frohlich et al. reported 5 cases of testicular torsion at a TWIST cut-off of 2 or less [11]. We found the Tanner staging very complex and therefore, simply used the age criteria.

One interesting point to note is that the TT score and TWIST score appear to perform equally well in patients who present early (<6 h). This is because most early presenters are patients who have classical signs of testicular torsion such as significant scrotal pain or significant testicular swelling or firmness which were capture by both TT and TWIST score. The symptoms of nausea/vomiting (OD 12 vs 5.1), absent cremasteric reflex (OD 9.8 vs 3.8) and abnormal lie (OD 14 vs 5.9) are more common in late (>6hr) than early presenters. TT score places higher weightage on these later factors and demonstrated higher diagnostic value in detection of torsion with late presentation compared to TWIST score.

One other important distinction to also note is that testicular salvage does not equate to testicular viability. In this study, only 30% of salvaged testes were found to be viable on subsequent follow up at 3 months. Some of the factors predictive of testicular atrophy include pain for greater than 1 day and heterogenous echogenicity on ultrasound [2]. Another study reported degree of twisting and duration of symptoms as main factors predictive of testicular viability in torsion cases [18].

In this study, prehospital delay of >6 h was found to correlate with decreased testicular viability. Although this factor cannot be controlled, a multi-pronged approach of reducing time to surgery and reducing need for ultrasonography for testicular torsion cases may improve outcomes. For instance, up-triaging patients presenting with an acute scrotum as a Priority 2+ (where patients are seen within 15 min) to streamline assessment of patients with testicular torsion helps expedite diagnosis and surgical intervention.

Further validation studies are needed to evaluate the robustness of this scoring system for excluding or diagnosing testicular torsion and whether or not it improves testicular viability. We are currently in midst of setting up our prospective validation study for the TT score in conjunction with our emergency department. Nevertheless, we feel that the TT score is a useful adjunct in assessment of patients presenting with scrotal tenderness in the paediatric population.

Conclusion

The TT score is a good alternative to the TWIST score for use amongst junior doctors (non-specialists) and has a sensitivity and negative predictive value of 100% for excluding testicular torsion in the Asian population. It has a high sensitivity, specificity, positive predictive value and negative predictive value as a clinical diagnostic tool for testicular torsion. Further multi-center, prospective validation studies are needed to evaluate the utility of this scoring method.

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Conflicts of interest

None.

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Review Article

Frontiers in pediatric testicular torsion: An integrated review of prevailing trends and management outcomes

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Summary
Testicular torsion remains the most frequent cause of testicular ischemia, especially in adolescents and young adults. Timely diagnosis and intervention are keys to saving the affected testicle. This review presents current trends in the diagnosis and treatment of torsion, potential pitfalls and consequent outcomes. Additionally, other salient issues surrounding testicular torsion are also discussed, including: pathogenesis of injury, legal ramifications, fertility outcomes, novel management techniques, and recent advances in diagnostic technology.

Introduction

Testicular torsion is an emergent condition caused by sudden twisting of the spermatic cord around its axis within the scrotum. This in turn cuts off blood supply to the affected testis, resulting in ischemic damage that is often irreversible. It is a disorder primarily affecting the pediatric population worldwide. It is estimated that 5 of every 100,000 males aged <25 years experience testicular torsion every year, the greatest incidence being in perinatal and pubertal age boys [1,2]. Prompt diagnosis and surgical intervention are required to restore blood flow to the affected testis, with a very narrow window of opportunity to prevent testis loss. Yet, complete recovery of testicular viability is often impossible, as delays in presentation, recognition, and treatment are frequent and lead to suboptimal outcomes [3].

Although studies on the development of testicular torsion and best treatment algorithms are still debated, new information continues to surface in the literature. Thus, this review discusses current perspectives on the etiology, risk factors, and pathogenesis of injury. Novel diagnostic technology and temporal trends in management and outcomes are also presented. Legal ramifications and long-term fertility prognoses in affected patients are summarized.

Etiology and pathophysiology

Testicular torsion occurs when the testis rotates about its spermatic cord attachments, preventing blood flow and resulting in tissue ischemia. With prolonged ischemia time, the involved testis can suffer irreversible injury, atrophy and loss of function [4,5]. The spermatic cord can rotate either within the tunica vaginalis (intravaginal torsion), or in association with the tunica vaginalis (extravaginal torsion) [6]. The majority of cases are intravaginal; extravaginal cases are seen almost exclusively in the antenatal or early postnatal period (perinatal testicular torsion), and are associated with poor outcomes for testis viability even with prompt surgical intervention [7]. In either case, the relationship between the testis and the tunica vaginalis plays an important role in the pathogenesis of torsion. In the perinatal period, the totality of the testis is not tethered to the scrotal wall; in turn, the spermatic cord and tunica vaginalis collectively rotate within the scrotal sac [8]. In contrast, the majority of testicular torsion cases outside the perinatal period are associated with an anomaly where high insertion of the tunica vaginalis prevents full descent of the testicle into the scrotum. This allows the testis and the spermatic cord to rotate freely within the tunica vaginalis, predisposing to torsion (the so-called bell-clapper deformity). The severity of testicular torsion is dependent on both degrees of rotation and duration of torsion. The spermatic cord can be rotated anywhere from 180° to >720°, with increased rotation resulting in a more rapid onset of ischemia, greater orchiectomy risk, and higher atrophy rates [4,9,10]. Prenatally torsed testes are almost never viable at the time of

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exploration; however, some authors have reported successful salvage in a small number of cases. Outcomes of postnatal testis torsion are less bleak, but reported salvage rates have greatly varied from as low as 0.06% to as high as 21.7% [11–13]. In older patients, testicular salvage rates can be as high as 90% when correction of torsion is achieved within 6 h, but this falls rapidly to 50% at 12 h, and $<10\%$ at 24 h [4]. Unfortunately, the combination of delays in patient presentation, diagnosis, and intervention can often lead to suboptimal outcomes.

Epidemiology

Testicular torsion affects 5 in 100,000 males between the ages of 1 and 25 years every year [1]. The age distribution is bimodal, with the first peak occurring during the perinatal period and the second peak occurring during the pubertal period [6]. Some evidence suggests a potential genetic predisposition to the development of testicular torsion [14,15]. About 10% of cases are associated with a positive family history, and the bell-clapper deformity is bilateral in up to 80% of cases [6]. The pattern of inheritance is not clearly defined, and no clear genetic mechanisms have been elucidated to date. However, Shteynshlyuger and Yu drew attention to 'age-related clustering' in familial testicular torsion, which is the tendency of torsion to occur in the same age range across generations within a family. The authors demonstrated that mean ages at torsion occurrence were unique to families. Notably, their findings remained statistically valid when applied to perinatal testicular torsion, leading to authors to suggest that the underlying genetic components of familial testicular torsion may extend to perinatal testicular torsion [16].

Sozubir et al. investigated the potential role of insulin-3 (*INSL3*) mutations in the pathogenesis of testicular torsion in mice. The *INSL3*-knockout mice were affected by gubernaculum dysgenesis, which in turn resulted in bilateral, intraabdominal cryptorchidism secondary to impaired testicular descent [17]. Their testes were freely mobile within the retroperitoneum, and accordingly a significant percentage (32%) of *INSL3*-knockout mice demonstrated vanished, torsed, or atrophied testes. This led the authors to hypothesize that abnormalities in *INSL3* function predispose to testicular torsion. Unfortunately, genomic DNA testing of 39 human patients with testicular torsion failed to identify any functionally significant mutations in *INSL3* or its receptor *RXFP2* [17].

Presenting signs and symptoms

Testicular torsion classically presents as sudden onset of severe unilateral scrotal pain [5,6]. Although the absence of scrotal pain can rule out acute testicular torsion in most cases, the specificity is quite poor (sensitivity 91%; specificity 27%) [18]. Conversely, perinatal testicular torsion is typically identified at the time of delivery, but may occur up to 30 days after birth. The majority of cases are unilateral, and the affected testicle is enlarged, firm, discolored, and non-tender [3].

Conventionally, differential diagnoses for the pediatric acute scrotum include epididymitis, orchitis, torsion of the testicular appendix, scrotal trauma, varicocele, malignancy, and incarcerated inguinal hernia [4,6,9]. Barbosa et al. [19] developed the TWIST score, a validated scoring system based on five other signs and symptoms commonly seen with testicular torsion: testicular swelling (2 points); hard testicle (2 points); absent cremasteric reflex (1 point); nausea/vomiting (1 point); and high riding testis (1 point) [19]. Retrospective validation with two patient cohorts allowed the investigators to achieve 100% positive predictive value with scores ≥ 5, and 100% negative predictive value with scores ≤ 2.

If the patient's history and physical exam findings are highly suggestive of testicular torsion, immediate surgical exploration is warranted. Awaiting diagnostic confirmation with imaging is not advised, as the delay can prolong testicular ischemia and may increase the likelihood of testicular loss. In indeterminate cases, color Doppler sonography (CDS) is the diagnostic imaging modality of choice [4–6]. In contrast to orchitis, where normal or increased blood flow to the affected testicle is observed, testicular torsion demonstrates decreased or absent blood flow. If the diagnosis is questionable based on history and physical exam, yet CDS reveals absent blood flow to the testis, immediate surgical exploration is warranted.

Trans-scrotal near-infrared spectroscopy: emerging alternative to diagnostic sonography

Aside from history and physical exam, CDS is currently the preferred modality for diagnosis of testicular torsion [20]. However, it has its shortcomings. Heavy dependence on operator expertise, unavailability of ultrasound technicians after-hours in some hospitals, as well as the potential for false negatives even in experienced hands significantly impair the reliability of CDS in acute settings [21]. Additionally, sonographic features used to differentiate partial, complete, and intermittent torsion are highly variable and may mislead diagnosis with potentially perilous outcomes. The whirlpool sign (WS), a spiral-shaped mass visualized along the spermatic cord on CDS or gray-scale ultrasonography, has been reported as a reliable finding for differentiating intermittent from partial and complete torsion [22]. Kalfa et al. reported visualizing the WS on high-resolution ultrasonography (HRUS) in 96% (199/208) of children with surgically confirmed testicular torsion. However, accurate identification of the WS was dependent on level of advanced radiology training [21]. Recently, McDowall et al. conducted a meta-analysis of 10 studies that determined the sensitivity and specificity of the WS to be 73% (95% CI 65–79%) and 99% (95% CI 92–99%), respectively [23]. However, these findings were tempered by the small number of selected studies and variability in study design. The formation of a pseudomass distal to the torsion nidus on the spermatic cord is another sonographic feature highlighted for its diagnostic promise; however, the ubiquity of this finding may limit its utility [24].

Near-infrared spectroscopy (NIRS) has recently been investigated as a potentially more reliable alternative. With wavelengths in the 700–1000 nm range, near-infrared light can penetrate superficial body layers (3–4 cm deep) with relative ease. Hemoglobin and other tissue chromophores absorb and emit pulses of light delivered by NIRS oximetry units via a probe; light particles returned to the device are detected, and the O_2-dependent absorbance spectra are translated into concentration changes corresponding to the tissue oxygen saturation (%StO_2) of the probed area. Although it shares a similar design with pulse oximetry, NIRS estimates %StO_2 mainly from interpreting venous oxygen saturation (i.e. the amount of oxygen remaining after tissue demand is met) [25]. Regarding torsion, the %StO_2 of the affected testicle is predicted to be markedly lower than the unaffected, contralateral testicle. NIRS oximetry devices are small, readily bedside accessible, and easily interpreted without specialty training, the latter of which may give it a distinct advantage over CDS.

Near-infrared spectroscopy has shown promise in several animal studies of acute torsion [26–28]. Thus far, there have been four studies examining NIRS for the diagnosis of acute torsion in human patients (Table 1) [29–32]. All these studies had small sample sizes and significant variance in results. In a prospective study of 16 adult torsion cases, Burgu et al. found that the mean %StO_2 values of the affected testes were significantly lower than those of the unaffected contralateral testes (mean Δ%StO_2[1] 16.1%; $P < 0.001$) [30]. They used a cutoff Δ%StO_2 value of 11.5% (sensitivity 100%, specificity 100%) as the threshold to initiate surgical exploration. Schoenfeld et al. reported a mean Δ%StO_2 value of 3% (range −1 to 9%, 95% CI −2 to 8%, $P = 0.17$) in five adult patients with torsion [32]. However, their findings were not statistically significant. Schlomer et al. conducted the largest of these studies ($n = 36$) in an exclusively pediatric cohort. The authors reported significant diagnostic value in some patient subgroups (median Δ %StO_2 2.0%; $P < 0.004$). However, this significance was tempered by the low overall accuracy (AUC 0.66, 95% CI 0.55–0.78), its dependence Tanner stage, and the presence or absence of scrotal edema [29].

Shagdan et al. reported use of spatially resolved NIRS (SR-NIRS) to accurately diagnose testicular torsion in a 14-month-old boy [31]. Spatially resolved NIRS factors in the distance traveled by the emitted light particles to obtain an absolute tissue saturation index (TSI). Because the SR-NIRS technique accounts for the depth of superficial tissue in its calculating algorithm, TSI values between patients of different ages and/or physical features are expected to be directly comparable [33]. Obviously, this hypothesis needs to be tested with a much larger patient cohort.

Based on currently published data, the potential role for NIRS in the management of acute torsion remains an experimental modality. Well-designed clinical trials with large patient samples are necessary to determine whether NIRS may eventually supersede CDS as the diagnostic imaging modality of choice.

Ischemia/reperfusion injury

When testicular torsion is diagnosed or strongly suspected, urgent scrotal exploration and detorsion of the spermatic cord are indicated. Paradoxically, however, restoration of blood flow to the testis following prolonged ischemia may in

Table 1 Clinical studies on near infra-red spectroscopy for diagnosing testicular torsion.

Study	NIRS oximetry device/probe	Number of patients[a]	Mean age±SD, (range)	Mean duration of pain, hours (range)	Mean NIRS δ%StO_2 (range)[b,c]	Predictive model cutoff δ%StO_2[d]	*P*-value[e]
Burgu et al. (2013) [30]	Invos 5100C/OxyAlert NIRSensor	16	18.3±– years (16–29)	12 (4–16)	−16.1% (−28.0–5.0)[f]	−11.5% (sensitivity 100%; specificity 100%)	<0.001
Schoenfeld et al. (2013) [32]	Inspectra 650/NR	5	16.8±– years (NR)	– (0.8–291.3)	+3.0% (−1.0–9.0)	NR	0.174
Shadgan et al. (2014) [31]	PortaMon SR-NIRS/Wireless Probe	1	14 months	24	+6.8%	NR	NR
Schlomer et al. (2017) [29]	Inspectra 300 Spot Check/Inspectra Thenar Clip 1315	36	12.9 ± 3.8 years (1 month–18 years)	12.0[g] (0.6–129.3)	+2.0% (−19.0–56.0)	+20% (sensitivity 22.2%; PPV 100%)	0.004

NIRS, Near infra-red spectroscopy; NR, not reported; PPV, positive predictive value.
[a] Torsion patients only.
[b] %StO_2 measured at presentation.
[c] Δ = %StO_2 unaffected testis − %StO_2 affected testis.
[d] Diagnostic cut-points and performance analysis assessed via Receiver Operating Characteristic (ROC) curve analysis.
[e] Statistical significance was set at $P < 0.05$ in all studies.
[f] Δ%StO_2 = %StO_2 affected testis − %StO_2 unaffected testis.
[g] Median duration reported.

[1] Δ%StO_2 = %StO_2 (affected testis—unaffected testis).

fact exacerbate the injury [5,14,34,35]. This concept of ischemia/reperfusion injury holds significance in numerous conditions, including myocardial infarction (MI), stroke, and graft failure after solid organ transplantation [36]. As oxygen supply is restored to ischemic tissue, excess reactive oxygen species (ROS) are generated. These ROS overwhelm protective antioxidant mechanisms, and cause endothelial dysfunction and vascular leakage, inflammation, lipid peroxidation, disruption in cellular architecture, and ultimately apoptosis [35,36]. In testicular torsion, the apoptosis of germ cells can lead to loss of spermatogenesis and reduced fertility [37].

Numerous preclinical studies have investigated the role of pharmacologic agents in reducing the burden of ischemia/reperfusion injury following surgical correction of testicular torsion [14]. These have included: phosphodiesterase (PDE) inhibitors (e.g. vardenafil, sildenafil, trapidil, dipyridamole); vitamins and minerals (e.g. vitamin C, vitamin E, selenium); hormones (e.g. melatonin, erythropoietin, DHEA, PPAR agonists); angiotensin-converting-enzyme (ACE) inhibitors (lisinopril, zofenopril); plant extracts (e.g. ternatin, lycopene, ginseng, Ginkgo biloba); calcium channel blockers (verapamil); non-steroidal anti-inflammatory drugs (ibuprofen, diclofenac); anesthetics (propofol); statins (rosuvastatin); PARP inhibitors (3-aminobenzamide); and other antioxidative agents (e.g. DMSO, N-acetylcysteine) [35]. Many of these agents exert their protective effects through mitigation of oxidative stress and/or tissue inflammatory response. For example, several studies have shown that the administration of sildenafil in a rat model of testicular torsion seems to reduce the degree of cell damage, oxidative stress, and apoptosis compared to placebo [38,39]. Although these studies did not investigate the underlying mechanism, a similar study in a rat model of renal ischemia/reperfusion injury demonstrated that sildenafil treatment increases the expression of antioxidant and anti-apoptotic genes, while decreasing the expression of pro-inflammatory genes [40]. Sildenafil and many of the above-mentioned agents have shown promise in animal models, with significant reductions in testicular cell damage and apoptosis. Unfortunately, none of these agents have been tested in human subjects to date [35]. The emergent nature of testicular torsion makes the coordination and administration of the agents difficult, especially if they are to be given prophylactically before surgical detorsion and restoration of blood flow.

Treatment modalities

Manual detorsion

Manual detorsion of the acutely torsed testicle, either as a bridge to or in place of definitive surgical management, has recently regained interest. Dias-Filho et al. observed lower orchiectomy rates among young adults with torsion ($n = 133$; median age 16.3 years, interquartile range (IQR) 14.4—19.3 years) who successfully underwent preoperative manual detorsion, compared to patients who either failed or did not undergo manual detorsion (2.8% vs 24.6%, OR 11.23, 95% CI 2.43—105.82, $P < 0.001$) [41]. Demirbas et al. also reported promising outcomes in a similar series ($n = 20$; mean age 20.2 years, SD 8.4 years) [42]. Interestingly, these patients were given a choice between immediate orchiopexy after manual detorsion, or delayed orchiopexy at a later date of their choosing (median 10 days, IQR 0—45 days). Notably, no episode of acute scrotum was reported by any patient who chose to delay orchiopexy, and no clinical evidence of atrophy was found in any patient after continued evaluation for nearly 2 years (range 2—40 months).

Manual detorsion requires minimal technical skill and may be utilized as a temporizing measure. It is generally held that when torsion occurs, the affected testis usually rotates counterclockwise or towards the midline (medial) along the axis of the spermatic cord. Manual detorsion should therefore be performed by a clockwise twisting of the affected testis, in a manner likened to 'opening a book' [6]. However, torsion can, in reality, occur in either direction. Hence, patient and anatomic response should guide detorsion attempts [43,44]. Color Doppler sonography should be performed after manual detorsion, to document restoration of blood flow. As the degree of torsion is variable, manual detorsion may be incomplete. Surgical exploration and orchiopexy remain the standard of care, and manual detorsion should not be attempted at the cost of delay in surgery.

Tunica albuginea incision

In addition to a conventional surgical approach, Kutikov et al. suggested an incision to the tunica albuginea combined with a tunica vaginalis flap (TVF) to relieve elevated testicular compartment pressures [45]. Reperfusion after detorsion generates an overabundance of reactive oxygen and nitrogen species from ischemic testicular tissue. Viable testicular tissues spared from the initial ischemia sustain free radical damage, subsequent edema, and a rise in testicular pressure leading to additional infarction and tissue injury. Incision of the tunica albuginea conceivably lowers the intracompartmental pressure of the testis, thus attenuating further vascular compromise [46].

Figueroa et al. reported improved testis salvage after employing tunica albuginea decompression with TVF at their institution [47]. In their series, the frequency of orchiectomy for nonviable testes was observed to significantly decrease (35.9% vs 15%, $P < 0.05$) after routinely decompressing the affected testes following surgical detorsion. Recently, Chu et al. reported successful preservation of orchiectomy-bound testes after tunica albuginea incision with TVF in a matched pediatric series [48]. Despite the prospect of this technique to preserve viable testes, the potential for a surgical incision to worsen oxidative stress cannot be overlooked [49]. Moreover, these studies involved a small number of cases and high rates of testicular atrophy; further studies examining benefit are warranted before considering this technique for managing acute torsion.

Testicular prosthesis

Bush et al. proposed testicular prosthesis placement and contralateral orchiopexy at the time of orchiectomy in adolescent torsion patients with nonviable testes. From the study of 12 adolescent patients (mean age 14.5 years, range

12–16), the authors reported surgical feasibility with excellent cosmesis, and no significant complications perioperatively or at long-term follow-up (median 4.8 months; range 1.5–16) [50]. However, the decision to implant the testicular prosthesis at the time of orchiectomy in the pediatric population remains a controversial matter. The psychosexual benefits of a combined orchiectomy and prosthesis implantation in tandem among infants and adolescents have not been investigated.

Turek et al. found improved body and self-esteem in a monorchid cohort ($n = 73$; mean age 12.8 years, range 0–17) surveyed 1 year after prosthesis implantation [51]. However, baseline body and self-esteem scores of the patients (i.e. prior to prosthesis insertion) were significantly above the average and the upper limit of normal in the quality of life assessment scales used in the study. In addition, the pediatric patient subgroup had been monorchid for a median of 9.1 years at the time of baseline assessment. More recently, Mohammed et al. reported a higher desire for prosthesis implantation among postpubertal males who had undergone an orchiectomy during early childhood or prepubertal years. This suggests that a heightened awareness of body image and self-esteem issues stemming from testis loss does not manifest until the postpubertal and adult ages are reached [52].

Testicular prosthesis placement is not a harmless procedure. The aforementioned study by Turek et al. reported a 14.5% complication rate directly related to the prosthesis; a similar study in a pediatric cohort reported a 10.5% complication rate [51,53]. Complications from the procedure included extrusion and implant migration. Significantly higher complication rates were seen when testis loss occurred secondary to inflammatory conditions (e.g. torsion, epididymitis) in the scrotum, compared to other etiologies (Fig. 1) [54].

Finally, testicular prostheses are considered to be medical devices, and as such are subject to regulation by local statutes. State-based or federally backed insurance may not deem their placement to be medically necessary [55], and patients and their parents may incur the full cost of this procedure ($15,000–20,000 or greater) [56].

Testicular torsion and infertility risk

It is not entirely clear whether, and through which mechanism, testicular torsion can lead to infertility, even with timely intervention. The leading hypotheses are ischemia/reperfusion injury and autoimmunization, but neither schema has gained widespread acceptance [57]. Additionally, different studies vary in how they measure fertility indices (e.g. via semen or hormonal analyses), and the reliability of these indices is controversial. Puri et al. evaluated a series of adult patients ($n = 18$) who experienced torsion in their prepubertal years (mean age at torsion 9 years, SD 3.6 years) and concluded that prepubertal testicular torsion did not compromise subsequent fertility in the adult years [58]. Arap et al. similarly reported no significant differences in the endocrine profiles and seminal analyses of 24 patients with a history of torsion when compared to controls [59]. In contrast, Thomas et al. concluded that a unilateral torsion event markedly decreased overall fertility potential after a study of 67 patients with history of torsion. In their series, 64% of patients had at least one abnormality on seminal analysis. Specifically, 39% had sperm counts <20 million/ml and 67% had abnormalities of sperm motility or morphology. Notably, in a 20-patient subgroup who were attempting to conceive, three were successful and six had been deemed infertile after extensive investigation. Interestingly, >90% of participating patients in their series had hormone levels within normal limits [60].

Recently, Gielchinsky et al. evaluated pregnancy rates in 63 heterosexual couples, where the males (age >25 years) had experienced unilateral torsion an average of 5 years prior to marriage [61]. They reported no differences in pregnancy rates or time to conception in these couples compared to the general population.

Effects of hospital transfer on salvage outcomes

Numerous studies have demonstrated that the time interval between symptom onset and treatment is the most critical

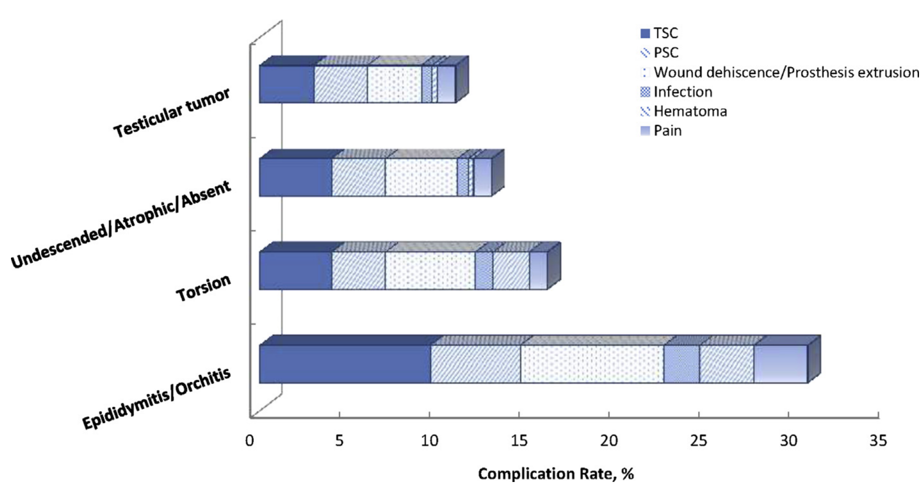

Figure 1 Relationship between underlying diagnosis for testis loss and complication rate after testicular prosthesis implantation. $n = 2533$ patients [54]. Many patients had >1 symptom. TSC, transient scrotal contraction; PSC, persistent scrotal contraction.

prognostic factor affecting testicular viability [14,62]. Unfortunately, a significant number of patients are transferred to other institutions for management, which delays treatment [63,64]. Unavailability of a local urologist, or inadequate surgical facilities and personnel are understandable justifications for patient transfer. However, recent trends in referral practices by general urologists to pediatric urologists and pediatric subspecialty certified hospitals have raised concern.

Bayne et al. [63] reported a significant increase in referred cases of acute torsion in otherwise healthy adolescents to their institution after it received subspecialty certification in pediatric urology. The authors also found that the majority (71.1%) of these transfers occurred during weeknights and weekends. If all pediatric torsion patients were indiscriminately transferred to their institution, the frequency of torsion patients who presented during this period should not be different between the transferred and non-transferred cohorts. This difference among patients with suspected torsion who were transferred to their institution versus those who presented directly (71.1% vs 43.7%, $P = 0.01$) suggests that the tendency among general urologists to refer pediatric torsion patients to pediatric urologists may be based on convenience rather than necessity. Preece et al. [64] corroborated these findings after observing similar temporal trends in transferred pediatric torsion patients to their institution versus those who presented directly during nights and weekends (77.8% vs 51.7%, $P = 0.009$). Both studies reported overall duration of symptoms as the most significant predictor of testis loss in transferred and non-transferred patients alike [63,64]. Undue transfers delay definitive management and may increase the likelihood of testis loss [64]. Socioeconomic factors, such as insurance and household income, have also been suggested determinants of outcomes, but further studies validating these findings are warranted [65,66].

It is not unusual for adult urologists to refer the treatment of pediatric torsion patients to pediatric urologists, despite adequate surgical facilities [67]. All American Board of Urology (ABU)-certified urologists are trained to treat testicular torsion in children and adolescents. Perinatal torsion is a distinct entity, and appropriate pediatric anesthesia and perioperative facilities must be available for neonates undergoing surgery. Unless an inter-hospital transfer of pediatric patients with torsion is absolutely necessary, it is recommended that general urologists should initiate timely intervention for this urologic emergency.

Medicolegal considerations in testicular torsion

For urologists and emergency physicians, testicular torsion remains a highly litigious area in much of the developed world. Several studies in the United States, United Kingdom, Canada, and Europe have reported high rates of malpractice litigation for these cases, with many ending in substantial settlements [68—71]. In a review of litigation proceedings stemmed in pediatric acute care, torsion was ranked third among the most common causes of malpractice lawsuits in male plaintiffs between the ages of 12 and 17 years [72]. Many efforts have been made to examine the specifics resulting in adverse outcomes and eventual legal action. In a review of 52 cases (53% minors), Colaco et al. reported incorrect diagnoses as the reason for 96% of claims against physicians [73]. Gaither et al. had similar findings after reviewing a national database [70]. The authors reported ‘missed diagnosis/negligence’ as grounds for litigation in 98% of claims made by 53 patients (mean age 15.4 years, SD 10.4 years, range 2—47; orchiectomy rate of 88%) against a physician. Of note, 31% of these patients presented with an atypical symptom of torsion (abdominal pain only). In fact, atypical torsion represented 31—46% of cases leading to litigation, according to two studies [70,74]. Matteson et al. [74], after examining claims made to a malpractice insurance company, reported that 18 (46%) of 23 patients (mean age 24.3 years, range 5—25) presented with a chief complaint other than acute testicular pain. These cases were also less likely to result in monetary settlements (average settlement $491,421, median $305,678) by the defendant physician [74].

Failure to obtain timely ultrasonography in cases where torsion is suspected is another potential legal hazard. Color Doppler sonography has a reported sensitivity and specificity of 97.3% and 99%, respectively, and is thus the imaging modality most commonly utilized to rule out torsion. Unfortunately, many missed cases of torsion are associated with use of ultrasound without color Doppler, or without any imaging performed at all. In aforementioned studies, 19—72% of patients did not undergo an ultrasound or other imaging modality at presentation [70,73,74]. With that said, there was no significant association between initial imaging and rulings in the physician’s favor (OR 0.99, 95% CI 0.33—2.95, $P = 0.99$) [70,73].

Conclusion

Testicular torsion is a critical condition often affecting the pediatric population. Testicular salvage is principally affected by duration of symptoms and time to intervention. The true consequence of torsion on fertility has not been ascertained. Torsion remains a highly litigious, diagnostic and management dilemma. Emerging diagnostic tools and surgical techniques show promise but warrant extensive studies demonstrating benefit. Further studies of torsion pathophysiology may pave the way for additional treatment modalities.

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Predictors of testicular viability in testicular torsion

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Children

Abstract *Aim:* Testicular torsion (TT) requires prompt diagnosis and treatment to avoid testicular loss. Most studies have focused on the ideal work up to rule TT out in cases of acute scrotum. We attempted here to define objective criteria to select between orchidopexy and orchidectomy in patients undergoing surgery for TT.

Patients and methods: Fifteen boys with a median age at presentation of 7.8 (range 6.4—12) years undergoing surgical treatment for TT underwent color-Doppler ultrasound (CDU) preoperatively, and a bleeding test intraoperatively. Duration of preoperative history, degree of torsion, CDU findings and degree of bleeding were analyzed.

Results: Salvageability was independent of the degree of torsion. In patients with a history longer than 10 h, no flow on CDU and no bleeding, after orchidectomy all the testicles were necrotic on pathology. When all these variables were negative, all the testicles did well during follow up. In the group of patients with no agreement among the analyzed variables, the outcome was unpredictable. Five out of six underwent orchidopexy, but in two cases the testicle atrophied (in spite of flow on CDU in one).

Conclusions: No predictive parameters were found for testicular salvageability. Taken as a whole, the parameters studied can be of help in treatment choice. In patients with no agreement among the parameters, orchidopexy seems the appropriate option, but parents should be informed of the risk of testicular atrophy during follow up.

Introduction

Testicular torsion (TT) accounts for only about 25% of all cases of acute scrotum in children [1], but requires prompt diagnosis and treatment in order to avoid ischemic necrosis of the testis. Misdiagnosis or delayed diagnosis of TT with subsequent testicular loss is a relatively common subject of litigation [2].

Given such a need for prompt differential diagnosis with respect to other non-surgical conditions, it is not surprising that most studies have so far focused on the ideal diagnostic work up to rule out TT in the face of an acute scrotum [3]. Once the diagnosis has been established, the clinician can be faced with another dilemma, i.e. whether or not to remove the testicle. This decision is usually taken during surgical exploration, and the problem resides in the

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fact that no objective criteria exist to assess testicular viability.

In the present study, we analyzed some major indicators of TT to determine whether they could also serve as objective criteria to discern, intraoperatively or even preoperatively, between need for orchidectomy and testicular salvageability in patients with TT.

Materials and methods

Fifteen boys with a median age at presentation of 7.8 (range 6.4–12) years undergoing surgical treatment for TT at our institution from January 2002 to December 2005 were studied prospectively. Cases of neonatal torsion were excluded. All underwent ultrasound scan with color-Doppler ultrasound (CDU) preoperatively. This never delayed surgery by more than 30 min.

In no case was manual detorsion attempted before surgery. Surgical exploration was carried out through a scrotal incision. After detorsion all patients underwent a bleeding test, as follows. The tunica albuginea was incised and the onset of active arterial bleeding (bright blood) from the cut edge within 10 min evaluated. The following grading was used: grade I, bleeding observed immediately after incision; grade II, bleeding absent immediately after incision, but starting within 10 min; grade III, bleeding absent after 10 min.

Orchidectomy was carried out based on the apparent viability of the testicle after detorsion, and orchidopexy was performed in the remaining cases. All removed testes underwent histopathological examination. No biopsies were performed on the testicles of patients undergoing orchidopexy.

These patients underwent a median follow up of 2.6 (0.8–4.1) years. CDU was performed 1, 3, 6 and 12 months after surgery to assess testicular blood flow and volume. The latter was calculated using the formula 0.52 $\times$ length $\times$ width $\times$ thickness of the testicular ellipsoid. Testicular atrophy was defined as a difference >50% between the affected and the contralateral testes.

The following parameters were taken into consideration for the purposes of this study: (1) duration of symptoms before surgery; (2) testicular blood flow on CDU; (3) degree of torsion on intraoperative exploration; and (4) grade of bleeding on the bleeding test. For the statistical analysis, duration of symptoms was categorized as either longer or shorter than 10 h, testicular blood flow on CDU as absent or present, and degree of rotation as smaller or greater than 360 degrees. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of the parameters were computed as appropriate. The four parameters were compared in two groups of patients: those undergoing orchidectomy or developing testicular atrophy during follow up vs those undergoing orchidopexy without atrophy during follow up. To compare the two groups, Mann–Whitney *U*-test was used for non-paired continuous values and Fisher's exact test for categorical variables. A $p < 0.05$ was considered significant.

Results

Of the 15 enrolled boys, nine underwent orchidopexy and six orchidectomy (orchidectomy rate 40%). Patients' characteristics are summarized in Table 1. Pathology showed necrotic infarction in all the removed testes. Of the nine patients who underwent orchiopexy, two developed testicular atrophy during follow up. Of these, blood flow was absent in one and normal in the other on preoperative CDU. Both cases had a history of longer than 10 h and grade II testicular bleeding.

Interval between the onset of symptoms and surgical exploration

A history longer than 10 h was a very specific sign of testicular non-viability, and all the cases with this feature required orchidectomy (Table 1). Sensitivity and NPV were only 62% and 70%, respectively (Table 2). Hence, although all patients with a long history lost their testicles, this happened in some with a short history as well.

Table 1 Characteristics of patients undergoing surgery for testicular torsion

Pt	History >10 h	Flow on CDU	Degree of torsion	Bleeding grade	Surgical treatment	Outcome
1	Yes	No	540°	III	Orchidectomy	Single testis
2	Yes	No	540°	III	Orchidectomy	Single testis
3	Yes	No	360°	III	Orchidectomy	Single testis
4	Yes	No	540°	III	Orchidectomy	Single testis
5	Yes	No	540°	III	Orchidectomy	Single testis
6	No	No	720°	III	Orchidectomy	Single testis
7	No	No	360°	II	Orchidopexy	Atrophy
8	No	No	540°	II	Orchidopexy	Testes OK
9	No	Yes	360°	II	Orchidopexy	Atrophy
10	No	Yes	360°	II	Orchidopexy	Testes OK
11	No	Yes	540°	II	Orchidopexy	Testes OK
12	No	Yes	360°	I	Orchidopexy	Testes OK
13	No	Yes	540°	I	Orchidopexy	Testes OK
14	No	Yes	360°	I	Orchidopexy	Testes OK
15	No	Yes	540°	I	Orchidopexy	Testes OK

Table 2 Comparison of four parameters in predicting testicular viability

	Orchidectomy/ testicular atrophy ($N = 8$)	Orchidopexy ($N = 7$)	p value	Sensitivity	Specificity	PPV	NPV
History >10 h	5	0	<0.05	62%	100%	100%	70%
No flow on CDU	7	1	<0.05	88%	86%	88%	86%
Degree >360°	5	4	NS	—	—	—	—
Grade III (no bleeding)	6	0	<0.05	75%	100%	100%	78%

Testicular flow on CDU

Absence of flow on CDU had a sensitivity and specificity of 88% and 86%, respectively (Table 2). In one patient the testicle could be salvaged in spite of the absence of flow on CDU (false positive), whereas another had a normal blood flow, but testicular atrophy was present 3 months after orchidopexy (false negative). Detection of normal blood flow by preoperative CDU carries a probability of 86% (NPV of absence of flow) that the testicle is not damaged. If testicular blood flow is absent, in 88% of cases the twisted testicle cannot be salvaged.

Degree of torsion

The median degree of torsion was not statistically significantly different between the two groups (540°, $p > 0.05$), nor was there a difference comparing cases with torsion ≤360° to those with torsion >361° (Table 2).

Intraoperative testicular bleeding test

Grade I and III on bleeding test proved fully accurate predictors. All the patients with grade III bleeding required orchidectomy and presented necrotic tissue on pathology. All grade I cases were salvaged and did not develop atrophy during follow up. Of the five cases with grade II bleeding, all underwent orchidopexy but in two the testicle atrophied during follow up. Absence of bleeding had 75% sensitivity and 100% specificity (Table 2).

Overall

We could differentiate three groups of patients. In five (33%), the history was longer than 10 h, CDU did not show any blood flow and the bleeding test was grade III. All of these required orchidectomy and the testicle was necrotic on pathology. At the opposite end of the spectrum, in four cases (27%) history was shorter than 10 h, CDU did show blood flow and the bleeding test was grade I. All of these underwent orchidopexy and none developed testicular atrophy during follow up. In between, six patients (40%) presented no agreement among the three variables. In one, in spite of a history shorter than 10 h, there was no flow on CDU and no bleeding (grade III); hence the testicle was removed and proved necrotic. The five remaining patients underwent orchidopexy and in two the testicle atrophied during follow up.

Discussion

The acute scrotum in children is often a diagnostic puzzle with the need to differentiate, promptly and accurately, cases of TT from those of a number of other non-surgical conditions [1]. Radiological studies, such as CDU and scintigraphy [3,4], have been suggested to be of use in order to spare unnecessary surgery, but no agreement has been reached about the ideal work up of these patients, and some authors still advise surgical exploration in every case [5].

Clinical problems and medico-legal issues are not limited to the preoperative diagnosis of TT. In many cases, during exploration, the clinician faces the dilemma of whether to remove a testicle whose viability seems questionable and, in the absence of objective criteria, can only rely upon their own empirical experience. We decided therefore to evaluate some parameters commonly used in the assessment of patients with an acute scrotum to ascertain if they could be used as predictors of testicular salvageability.

Duration of symptoms before surgery is a well known predictor of outcome in TT [6]. Jefferson et al. reported that in their experience no testicle with a history >12 h could be salvaged [7], and Barada et al. warned that patients younger than 18 years old are at increased risk of delayed presentation [8]. Testicular infarction begins after 2 h of ischemia, becomes irreversible after 6 h and complete infarction is established after 24 h. Although our experience is consistent with such a natural history, we also observed testicular necrosis (or atrophy after orchidopexy) in patients undergoing early surgery (history <10 h). Similarly, Sessions et al. reported that 27% of their patients undergoing orchidopexy within 4 h of onset of symptoms developed testicular atrophy during follow up [6]. On the other hand, we acknowledge that the fact that in none of our cases with a history longer than 10 h could the testicle be salvaged may be due to the limited number of studied cases, a type II error. Others have reported testicles salvaged more than 24 h after onset of symptoms [9].

Three variables could account for the different effects of torsion on testicular outcome, the degree of torsion, the thickness of the cord and the degree of bell-clapper deformity (attachment of the mesorchium on the testicle) [10]. The latter determines whether torsion will occur, the possible degree of twisting and the likelihood of spontaneous detorsion. Cord thickness can explain why, for the same degree of twisting, blood flow is completely impaired in some testicles but preserved in others. The thicker the cord the greater the length over which twisting occurs.

Hence, thicker cords lead to formation of longer helices with a minor degree of blood flow impairment than thinner cords do for the same degree of twisting. Finally, the degree of torsion does not seem a critical factor in clinical practice as most of the torsions are in the range 360°–540°. We did not observe any statistically significant difference in the degree of torsion between patients undergoing orchidopexy and those requiring orchidectomy.

These anatomical observations can also explain the cases with preserved flow on CDU in spite of the presence of torsion [10]. Initial studies interpreted these cases as false positives [11], but this may not be correct. Of note, our cases with torsion and preserved flow had also a short history. Blood flow impairment proceeds in a step-wise fashion: obstruction of venous drainage with vascular engorgement of the testicle occurs first and arterial inflow is impaired only secondarily.

In contrast to these cases with torsion and preserved flow there are those with no flow on CDU but with a viable testicle. Technical reasons can account for these cases. It is essential to set the scanner for detection of slow flowing blood. The gain should be increased, the pulse repetition frequency decreased and a small color sample window used. In spite of these technical aspects, flow detection remains critically dependent on testicular size and can be difficult in pre-pubertal boys with a testicular volume of 1–2 cm^3. Ingram and Hollman noted that no flow is detectable in 38% of normal children younger than 13 years [12]. Use of contrast agents seems promising in this respect, although they would not be practical in the setting of an urgent evaluation [13].

In the current study, we evaluated only the presence/absence of flow as a predictor. Other features, such as the appearance of the testicle on grey-scale ultrasound scan, can drive the decision making [14,15]. Marked testicular enlargement and hypoechogenity are signs of ischemia, and a heterogeneous testicular structure of ongoing necrosis [14,15].

During surgical exploration, we perform a deep incision of the tunica albuginea after detorsion in order to evaluate active testicular bleeding. Only fresh bleeding should be considered. A 10-min wait is mandatory, especially in pubertal patients, who may need a long time to start bleeding due to parenchymal edema and hemorrhagic areas. In keeping with a previous report [16], this test seems to be an effective means to assess objectively testicular viability during surgery. The efficacy has been confirmed by the pathology finding of ischemic necrosis in all the removed testes with a bleeding test grade III. Similarly, all the testicles with grade I bleeding could be salvaged and did well. We could identify a grey area in those patients with a bleeding test grade II. Of five such patients, all had a history shorter than 10 h, blood flow on CDU was present in three, all underwent orchidopexy, but the testicle atrophied in two (one with flow and the other without flow on CDU).

In conclusion, as for the diagnosis of TT, there is no one history, physical, laboratory or radiological finding that might predict testicular salvageability. This can only be determined at surgical exploration and was, in our experience, independent of the degree of torsion. When the history is longer than 10 h, there is no flow on CDU and there is no bleeding from the testicle 10 min after incision of the tunica vaginalis, than orchiectomy is the appropriate option. Orchidopexy is appropriate when all these variables are negative. There is a group of patients in whom there is no agreement among these variables. For these, the indication for either orchidectomy or ochidopexy remains unclear, and parents should be informed of the risk of testicular atrophy after orchidopexy.

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Effect of Pediatric Testicular Torsion on Testicular Function in the Short Term

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ABSTRACT

Purpose: To evaluate short-term testicular outcome after torsion in children.
Methods: Fifty-four children and adolescents were evaluated after 6 months of the operation for testicular torsion. Testicular volume was measured and circulating Inhibin B, FSH, LH and testosterone levels were checked.
Results: Delay from the onset of symptoms to surgery was **shorter** in the orchidopexy group ($n = 47$), than in the orchiectomy group ($n = 7$, $p = 0.001$). In the orchidopexy group, the median volume of the affected testis was 83% (IQR 43–104) of the contralateral testis ($p = 0.002$). The plasma hormone levels in orchidopexy and orchiectomy groups were: 148 ng/l (IQR 108–208) *vs.* 129 ng/l (IQR, 123–138, $p = 0.269$) for Inhibin B; 4.5 IU/L (IQR2.6–6.9) *vs.* 11.7 IU/L (IQR 4.3–12.8, $p = 0.037$) for FSH; 2.9 IU/L (IQR 1.3–3.7) *vs.* 4.8 (IQR 3.0–5.6, $p = 0.066$) for LH; and 13.6 nM (IQR 6.5–18.0) *vs.* 14.5 nM (IQR 6.7–15.9, $p = 0.834$) for testosterone. The association between FSH, LH as well as testosterone levels was most clear with the volume of the contralateral testis (Rho = 0.574, $p < 0.001$, Rho = 0.621, $p = 0.001$ and Rho 0.718, $p < 0.001$ respectively).
Conclusions: Testicular function is mainly dependent on the volume of contralateral testicle after testicular torsion. However, testis preserving surgery tends to maintain better function than orchiectomy.
Type of study: Retrospective review.
Level of evidence: III

Testicular torsion can lead to testicular damage and even to complete necrosis of the testis. Fortunately, testicular torsion is a rare event with an annual incidence of 4.5/ 100,000 in males aged 1–25 years [1,2]. The effect of unilateral torsion on total testicular function is apparently rather small, but, in some cases, the function may be compromised [3–5]. The suggested reasons have been ischemia–reperfusion injury and testicular dysplasia as well as loss of testicular cells [4,6–8].

Some studies have suggested that preserving surgery of the affected testis may be even more harmful to the contralateral testis than orchiectomy [7]. Consequently, the threshold to do orchiectomy may wary between the different centers. In our previous pilot study with children and adolescents, there was a tendency towards better testicular function, if the twisted testis was preserved [8]. Accordingly we have selected the line to avoid orchiectomy unless the twisted testis is clearly necrotic.

In this study, we expanded our original pilot study, in an attempt to evaluate whether an active approach to preserve the twisted testis appears justified [8]. Testicular function was evaluated with hormonal measurements primarily reflecting the function of seminiferous epithelium (FSH and Inhibin B) or testosterone production (LH and testosterone), and testicular size was measured with ultrasound.

1. Material and methods

Fifty-four patients operated between 2000 and 2018 for testicular torsion and followed in the division of pediatric urology were evaluated after the institutional Ethics Committee had approved the study based on a retrospective chart review. Testicular volume and serum Inhibin B, FSH, LH and testosterone levels were measured six months (range 5–18) after the surgery. Five patients who fulfilled the criteria were included from our previous study [8]. After that, 49 consecutive patients were included. **However, 14 patients were excluded because of insufficient follow-up investigations (testicular volume measurements and InhibinB as well as FSH values missing or too short follow-up time, $n = 11$) or because the patient had moved to other district ($n = 3$).**

The age of the patient, the duration of symptoms and the type of the operation were recorded. **Twisted testicle was removed if the black color did not change after untwisting and no fresh bleeding appeared after small incision to testicle**. Testicular volume was

Declarations of interest: none.

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measured in 47 patients with ultrasound and in four patients with a ruler applying ellipsoid formula ($a \times b \times c \times 0.52$). Serum Inhibin B, FSH, LH and testosterone values were measured in 50, 51, 46 and 50 patients respectively. Normal laboratory values for FSH and LH were for age group 2–5 years, 0.2–1.4 IU/l and 0–0.5 IU/l; age group 6–10 years, 0.2–1.4 IU/l and 0–0.5 IU/l; and age group 11–20 years, 0.2–8 IU/l and 0.5–5.3 IU/l respectively. For testosterone, normal values were 0.1–1.1 nmol/l for pre pubertal, 0.4–2 nmol/l in Tanner stage 2–3 and 10–23 nmol/l for adult males.

1.1. Statistical analysis

The association between testicular volume and the delay of surgery from the onset of symptoms as well as association with hormonal values was evaluated with Spearman rank correlation. The differences of volumes between twisted and contralateral testis were evaluated with Wilcoxon signed rank test. Categorical values were compared with Fisher's exact test. Continuous variables are expressed as medians and interquartile ranges (IQR) or ranges. For the analyses Statview® 5.0.1, SAS Institute Inc. was used. P-value <0.05 was considered significant.

2. Results

2.1. Testicular volume

Testicular torsion occurred on the left side in 28 of 54 cases (52%) and it was operated at the median age of 14 years (IQR 12.8–14.5, range 1.8–16.3, p = 0.817 between orchidopexy ($n = 46$) and orchiectomy ($n = 7$) groups). Delay from the onset of symptoms to surgery was 6 h (IQR 4–13) in the orchidopexy group, and 48 h (IQR 30–72) in the orchiectomy group (p = 0.001). In the orchidopexy group, the median volume of the twisted testis was 83% (IQR 43–104) of the contralateral testis at follow-up (p = 0.002), and the time in the delay of the operation and the degree of relative volume reduction were associated (Rho −0.676, p < 0.001, Fig. 1)). In five cases, the preserved twisted testis became atrophic (volume less than 20% of the contralateral testes). In those cases, the delay of surgery was in median 72 h (range 20–168).

2.2. Hormonal values

Serum FSH values were lower in patients after testis preserving surgery than after orchiectomy (Table 1). In LH values, there was a similar but nonsignificant tendency. Age-specific FSH values were altogether abnormal in 4/7 patients in the orchiectomy group and in 5/45 patients in the orchidopexy group (p = 0.013).

Serum FSH, LH and testosterone levels associated with total testicular volume (p = 0.026, 0.001 and < 0.001 respectively) and especially with the volume of the contralateral testis (p < 0.001 for all) in the patients who had undergone testicular preserving surgery (Table 2)**. Testosterone and LH levels associated also with the volume of the twisted testis (p = 0.009 and 0.001 respectively)**. In the patients with testicular sparing surgery, the degree of relative shrinking in affected testis was not associated with serum Inhibin B, FSH, LH or testosterone values (p > 0.2 for all). The result suggests that Sertoli cell function is mainly dependent on the volume of contralateral testis, but apparently, the twisted testis has some influence on testosterone production.

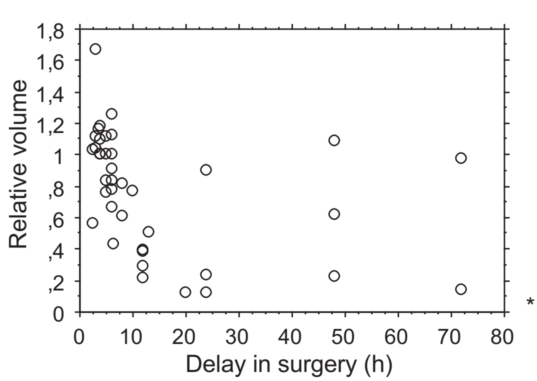

Fig. 1. Time from the onset of symptoms to surgery and the volume of twisted testicle in relation to contralateral testicle after half a year. * The relative volume of twisted testis was 0.02 in one patient with 168 h delay in surgery.

Table 1
Serum hormone levels half a year after testicular torsion.

	Orchidopexy ($n = 47$)		Orchiectomy ($n = 7$)		p-value
	n	value	n	value	
Inhibin B (ng/L)	44	148 (IQR 108–208)	6	129 (IQR 123–138)	0.269
FSH (IU/L)	44	4.5 (IQR 2.6–6.9)	7	11.7 (IQR 4.3–12.8)	0.037
LH (IU/L)	41	2.9 (IQR 1.3–3.7)	5	4.8 (IQR 3.0–5.6)	0.066
Testosterone (nmol/l)	44	13.6 (IQR 6.5–18.0)	6	14.5 (IQR 6.7–15.9)	0.834

3. Discussion

In this study, testicular size and function were investigated about six months after surgery for testicular torsion. The time from the onset of symptoms to surgery was longer in the patients who underwent orchiectomy compared with the patients having testicular sparing surgery. In addition, the time between the onset of symptoms and surgery and the relative atrophy rate of the twisted testis to the contralateral testis were associated in the testicular-preserving surgery group. Sertoli cell function according to serum FSH levels was mainly associated with the volume of contralateral testis. However, the function was somewhat better in the patients with testicular-preserving surgery. Also, testosterone production associated strongly with the volume of contralateral testis. However, there was also a significant association between the relative volume of the twisted testis and Leydig cell function. We could not find any evidence for harmful effect as a result of damaged testis left in place after detorsion and orchidopexy.

In our study, the rate of severe testicular damage was 12/54 (22%) when calculating together orchiectomy cases and cases with later atrophy of the affected testis. In previous studies, testicular torsion leads usually to orchiectomy or testicular atrophy in 30–67% of cases [1,9–11]. In a recent study, all the twisted testicles were spared and 11 out of 30 testicles underwent at least 80% volume loss during the median follow-up of 111 days [10]. Duration of symptoms before the surgery has been one of the most important factors dictating the fate of the testis in our and in previous studies [10,12]. Symptom history longer than 6 h prior to surgery can lead to some degree of volume reduction, but after 24 h, the twisted testis rarely survives [10,12]. Although a delay in the treatment from the onset of symptoms usually leads to loss of the

Table 2
Spearman correlation between testicular volumes and serum hormonal levels in patients with testicular preserving surgery half year after testicular torsion.

	Volume of contralateral testis		**Volume of twisted testis**		**Total testicular volume**	
	Rho	p-value	Rho	p-value	Rho	p-value
Inhibin B	0.207	0.185	0.244	0.118	0.291	0.063
FSH	0.574	<0.001	0.329	0.293	0.348	0.026
LH	0.621	<0.001	0.427	0.009	0.532	0.001
Testosterone	0.718	<0.001	0.502	0.001	0.658	<0.001

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testicle, it does not mean that the patients with long-lasting symptoms are not in the need of urgent treatment. In our study, one testis maintained normal volume despite of symptoms lasting for 96 h. Apparently, in clinical situations, testicular twisting does not necessarily lead to immediate loss of circulation, **and at least the cases with sudden progression of symptoms must be considered for urgent treatment.**

In this study, 9/52 patients (17%) had abnormal FSH values and the risk was increased in those who had undergone orchiectomy. FSH and Inhibin B measurements have turned out to be useful in the determination of the fertility potential [13–17]. In this study, FSH, LH and testosterone values associated best with the volume of the contralateral testis. Some association existed also between the volume of affected testis and LH as well as testosterone values. Similarly in the study evaluating hormonal profiles in monorchid boys, the Sertoli cell function was worse in the patients than in the controls with two testicles [18]. However, in that study there was no apparent difference in the function of Leydig cells. In experimental models, the twisted testis has been observed to lose germ cell population more often than Sertoli and Leydig cells [19]. In our study, atrophied testis was not causing negative impact on testicular function according to reproductive hormonal values. In previous studies with semen analyses, the results have been contradictory showing decreased or normal sperm counts after unilateral torsion [4,20]. In the study of Romeo et al., serum Inhibin B levels were reduced in the patients who had testicular torsion on average 5 years earlier compared to controls [21]. In that study, no difference was observed between those who had undergone testis preserving surgery or orchiectomy. However, in the Chinese study, all 86 patients had normal FSH levels at follow-up both in orchiectomy and orchidopexy groups [22]. In the study by *Anderson* et al. the, the sperm quality of 16 patients was better in orchiopexy than in orchiectomy group [23]. However, in the study by Arap, the sperm count **and presence of antisperm antibodies** of 24 patients were similar in both groups but the motility was better in in the orchiectomy group [20].

Our study has limitations. There was some variation in the follow-up times although they were scheduled to be 6 months afterwards. In some cases, not all the scheduled investigations were realized. However, the follow-up appointment was at least five months after surgery, and in our clinical experience, it is a sufficient time for the development of testicular atrophy. There was variation in patients' ages, and unfortunately, the pubertal status was not recorded. However, we used age-specific reference values and the volumes of the twisted testes were compared with the contralateral ones in the same patients. The orchiectomy rate in our study was small for comparisons, but, on the other hand, orchiopexy results were in the favor for testicular salvage.

4. Conclusions

In this study, we found out that the larger the total testicular volume, the better the testicular function appeared to be after testicular torsion. Sertoli cell function appeared mainly dependent on the volume of the contralateral testis, and it seems that, in doubtful cases, it may be better to preserve the affected testis than to remove it.

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Tunica vaginalis flap for salvaging testicular torsion: A matched cohort analysis

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Summary

Introduction
In testicular torsion, ischemia time from pain onset impacts testicular salvage. A tunica albuginea fasciotomy to relieve compartment pressure followed by a tunica vaginalis flap (TVF) may enhance salvage.

Objective
To define the optimal window of ischemia time during which TVF may be most beneficial to avoid orchiectomy.

Study design
A retrospective cohort study of males presenting with testicular torsion at a single tertiary-care institution from January, 2003 to March, 2017. Ischemia time was defined as duration of pain from onset to surgery. Because TVF would be an option to orchiectomy, and it was found that ischemia time was longer in testicles that underwent orchiectomy, matching was performed. Cases of torsion treated with TVF were matched 1:1 with cases treated with orchiectomy on age at surgery, and ischemia time. Outcomes included postoperative viability, defined as palpable testicular tissue with normal consistency, and atrophy, defined as palpable decrease in size relative to contralateral testicle. Sensitivity analyses were performed restricting to the subgroups with postoperative ultrasound, >6 months' follow-up, and additionally matching for degrees of twist.

Results
A total of 182 patients met eligibility criteria, of whom 49, 36, and 97 underwent orchiectomy, TVF, and septopexy alone, respectively. Median follow-up was 2.7 months; 26% of patients had postoperative ultrasound (61% of TVF group). In the orchiectomy, TVF, and septopexy groups, respectively, median ischemia times were 51, 11, and 8 h, postoperative viability rates were 0, 86, and 95%, and postoperative atrophy rates were 0, 68, and 24%. After matching, 32 patients with TVF were matched to 32 patients who underwent orchiectomy. In the TVF group, postoperative viability occurred in 95% (19/20) vs 67% (8/12) of patients with ischemia times ≤24 and >24 h, respectively. Atrophy occurred in 67% (12/18) vs 83% (10/12) of these same respective patients. Sensitivity analysis by ultrasound and longer follow-up found similar viability results, although atrophy rates were higher. Additional matching for degrees of twist showed lower viability and higher atrophy rates for increasing ischemia times.

Discussion
Patients who presented with testicular torsion with ischemia times ≤24 h and who were being considered for orchiectomy may have benefitted most from TVF, albeit at high risk of atrophy. However, for ischemia times >24 h, TVF may still have preserved testicular viability in two-thirds of cases. A limitation was short follow-up.

Conclusion
A TVF was a valid alternative to orchiectomy for torsed testicles, albeit with high testicular atrophy rates.

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Introduction

Testicular torsion is a potentially devastating acute surgical emergency. With an annual incidence of 1 per 4000 males aged <25 years, torsion occurs when the testicular vessels twist [1]. Subsequent ischemia to the testicle makes torsion highly time-sensitive [1]. Rates of salvage decline rapidly the longer the duration of ischemia time from onset of pain, with orchiectomy rates inversely rising and nearing 80–90% when ischemia times exceed 24 h [2].

Various techniques have been developed for enhancing salvage rates at the time of surgery, including: clinical pathways to expedite the process from emergency room admission to operating room [3]; manual detorsion while awaiting surgery [4]; and assessing for bleeding after a deep incision into the testicle [5] to assess possible viability. One innovation has been the conceptualization of torsion as a form of compartment syndrome, with fasciotomy through the tunica albuginea relieving the intracompartmental pressure [6]. An adjacent tunica vaginalis flap (TVF) could be mobilized and used to cover the defect in the tunica albuginea rather than primarily closing the tunica albuginea, which recreates compartment syndrome [6]. While the success rate of TVF repair has been previously explored [7], defining the window of ischemia time for optimal utilization of this method has not yet been performed. In addition, a thorough time-stratified assessment of viability versus atrophy of the affected testicle is lacking.

The current study therefore sought to further characterize these gaps in knowledge of the utility of TVF repair for testicular torsion. It also shared a current clinical algorithm developed since the TVF repair was first described [6]. It was hypothesized that: of torsed testicles being considered for orchiectomy and not septopexy alone TVF repair may be optimally suited for ischemia times ≤24 h.

Materials and methods

Study design and setting

This was a retrospective cohort study of an Institutional Review Board-approved prospective patient registry of patients who presented with testicular torsion at a single tertiary referral center. Patients could have arrived by car, ambulance, or helicopter.

The institutional clinical pathway for acute scrotal pain in the Emergency department includes initial rapid assessment by the Emergency department team. Scrotal ultrasound is utilized depending on the clinical suspicion of the Emergency department team. Once Urology is consulted after diagnosis of acute torsion, time to the operating room is routinely within the hour.

Participants

All children aged ≤21 years who underwent surgery for testicular torsion between January, 2003 and March, 2017 were reviewed. Children were excluded from analysis if they had bilateral torsion, extravaginal torsion, intermittent torsion, torsion in an undescended testicle, were aged <5 years (due to potential heterogeneity in presentation compared to older children), or had no follow-up visit to document postoperative findings. Children who had an estimated ischemia time of >96 h were further excluded because of the very low chance of viability.

Exposures

The primary exposure of interest was use of TVF. Three tunica vaginalis grafts were included, since the concept is the same. The surgery chosen – orchiectomy, TVF, or septopexy alone without TVF – was at the discretion of the

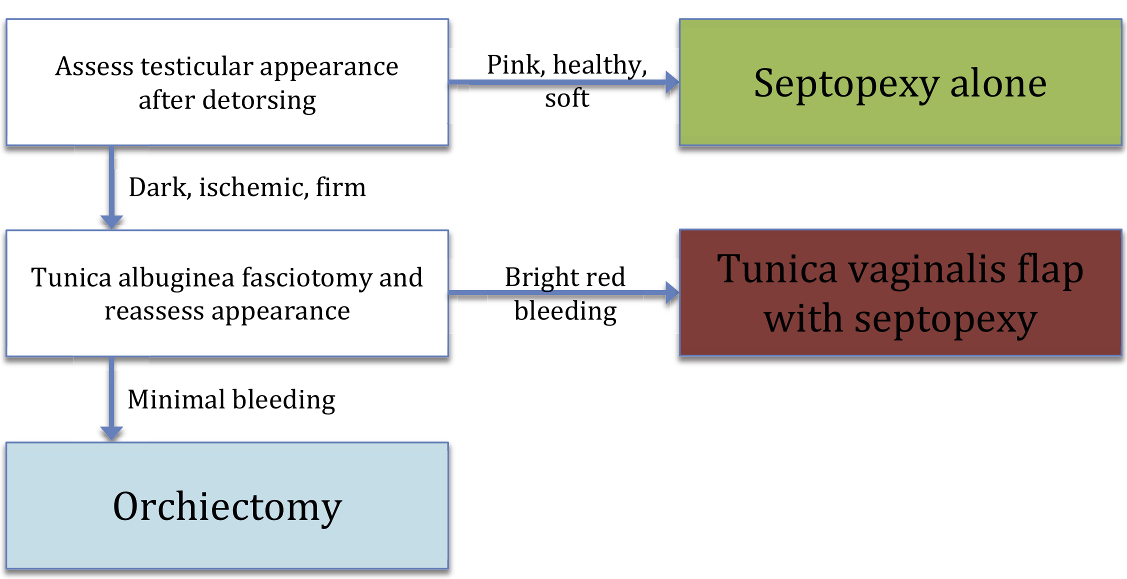

Figure 1 Intraoperative algorithm for acute testicular torsion.

operating surgeon. This decision was not based solely on estimated hours of ischemia, but rather on the appearance of the testicle once delivered onto the operative field, its subsequent appearance after reducing the torsion, and its subsequent appearance after a fasciotomy was made in the tunica albuginea. The intra-operative clinical algorithm is shown in Fig. 1. For patients who underwent TVF, the technique has been previously described [6]. Drains were placed as needed. The general follow-up protocol included a postoperative visit within the first 2–6 weeks after surgery, repeated every 2–3 months if needed. Scrotal ultrasound was obtained on a case-by-case basis.

Outcomes

The primary outcome was testicular viability from the latest follow-up visit. For patients who underwent a scrotal ultrasound, viability was defined as having normal blood flow to the affected testicle, regardless of testicular size. For patients who did not undergo a scrotal ultrasound, viability was defined by the examining surgeon as palpable testicular tissue, regardless of size, of normal consistency and firmness in the affected testicle that would be thought to survive.

A secondary outcome was testicular atrophy from the latest follow-up visit. Atrophy was defined as smaller size of the affected testicle relative to the contralateral healthy testicle on scrotal ultrasound or on palpation. Because documentation was lacking on % size decrease on palpation, this outcome was dichotomized into any atrophy versus none. If no specific indication of the presence or absence of atrophy was noted for a patient on follow-up, it was kept as a missing value.

Covariates

Other characteristics that were collected included age at surgery (continuous), laterality, estimated ischemia time in hours from pain onset to surgery (<6, 6–12, 12–24, 24–48, 48–96), and degrees of twist found intra-operatively (<360, 360–720, >720, unknown).

Statistical analysis

Univariate analyses using Fisher's exact and Kruskal–Wallis tests for categorical and continuous variables, respectively, were used to compare the orchiectomy, TVF, and detorsion alone groups. Because TVF would be considered if orchiectomy were considered (Fig. 1) and ischemia times were significantly longer in testicles that underwent orchiectomy than TVF, a matched analysis of TVF and orchiectomy patients was performed to explore viability and atrophy rates after TVF, given the same clinical characteristics that otherwise would have led to orchiectomy.

Each patient who underwent TVF was matched 1:1 with a patient who underwent orchiectomy. The study exactly matched on estimated ischemia time within each pair and then balanced the age at surgery by minimizing the Mahalanobis distance [8] between TVF and orchiectomy patients, using a caliper of 0.1 standard deviations. Matching was performed with replacement of patients who underwent orchiectomy, to ensure best matches and maximize analysis of TVF cases. All matches were performed first without viewing outcomes [9]. Balance after matching was assessed using standardized mean differences (SMD), which ignored sample sizes, with values <0.1 deemed as excellent [10].

Three sensitivity analyses were performed. The first restricted the matched cohort analysis to those patients who only completed a postoperative scrotal ultrasound. A second sensitivity analysis was performed where degrees of twist was included in the matching algorithm; the primary analysis had excluded degrees of twist because of missing data for this covariate. A third restricted the matched cohort to those with only >6 months of follow-up.

Given that data were sparse regarding viability and atrophy rates following TVF, no power calculations were performed; this was considered an exploratory and hypothesis-generating study. As such, no formal statistical tests were performed comparing TVF to orchiectomy outcomes in the matched analysis. All analyses were performed with Stata (v14, StataCorp, College Station, TX) with a two-tailed alpha of 0.05.

Results

During the study time frame, 368 patients underwent surgery for testicular torsion. After applying exclusion criteria, 182 remained and constituted the study cohort (Fig. 2). Intra-operative assessment of degrees of twist was missing in 43 patients (24%); postoperative atrophy was missing in 46 patients (25%).

Of the 182 patients: 49, 36, and 97 underwent orchiectomy, TVF, and septopexy alone, respectively (Table 1). Median age at surgery was 14 years (range 5–18). Median overall follow-up was 2.7 months; in the TVF group, median follow-up was 4.5 months (interquartile range 2.1–12.5). In the orchiectomy, TVF, and septopexy alone groups, respectively, median ischemia times were 51, 11, and 7 h; postoperative viability rates were 0, 86, and 95%; and postoperative atrophy rates were 0, 68, and 24%. Patients who only had septopexy had more right-sided torsions than the other groups. Of patients who had degrees of twist documented, orchiectomy patients had significantly higher degrees of twist compared to TVF and septopexy alone patients (median 540 vs 360 vs 315, respectively). Postoperative ultrasound was performed on 47 patients (26%); among TVF patients, 22 (61%) received a postoperative ultrasound. When stratified by estimated ischemia time, relative rates of orchiectomy increased with increasing ischemia time (Fig. 3). After successfully matching 32 patients with TVF to 32 patients with orchiectomy, excellent balance in age at surgery and ischemia time was achieved between the orchiectomy and TVF groups (Supplemental Table 1). In the TVF group, atrophy data were missing in two of the 32 (6%) patients.

Within the matched cohort, clinical viability was 95% (19 of 20) using TVF until ischemia time was >24 h (Table 2), at which point viability rates appeared to decrease. For ischemia times of 24–48 and 48–96 h, respectively, 63% (five of eight) and 75% (three of four) of patients who underwent TVF were clinically viable; there was a cumulative

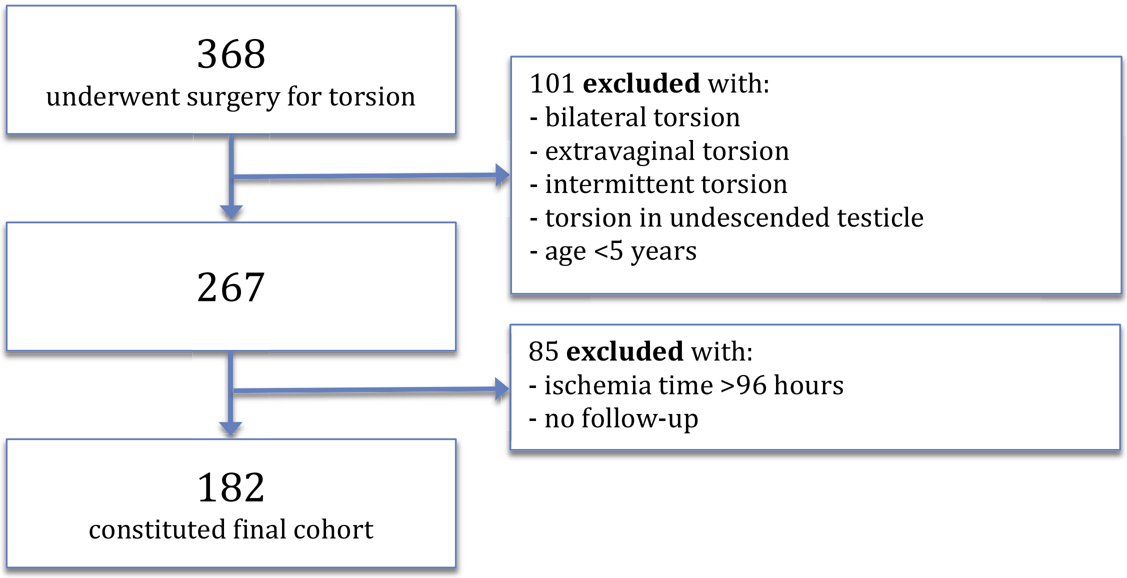

Figure 2 Study flowchart.

Table 1 Cohort characteristics by surgery type.

Variable	Detorsion	TVF	Orchiectomy	*P*-value
Number (%)	97 (53)	36 (20)	49 (27)	
Ischemia time, hours, median (IQR)	7 (5–11)	11 (6–26)	51 (29–72)	<0.001
Ischemia time, hours, *n* (%)				<0.001
<6	28 (29)	4 (11)	2 (4)	
6–12	48 (50)	15 (42)	4 (8)	
12–24	9 (9)	5 (14)	4 (8)	
24–48	8 (8)	8 (22)	6 (12)	
48–96	4 (4)	4 (11)	33 (67)	
Age, years, median (IQR)	15 (13–16)	14 (13–15)	14 (13–14)	0.03
Left laterality, *n* (%)	47 (49)	26 (72)	32 (67)	0.03
Degrees of twist, median (IQR)[a]	315 (180–540)	360 (180–720)	540 (360–720)	<0.001
Ultrasound, *n* (%)	21 (22)	22 (61)	4 (8)	<0.001
Viability, *n* (%)	90 (95)	31 (86)	–	0.14
Atrophy, *n* (%)	19 (24)	23 (68)	–	<0.001
Follow-up, months, median (IQR)	2.2 (1.4–3.8)	4.5 (2.1–12.5)	2.6 (1.2–5.2)	0.006

P-values from Kruskal–Wallis and Fisher's exact tests for continuous and categorical variables, respectively.
IQR, interquartile range; TVF, tunica vaginalis flap.
[a] Data on degrees of twist available for 38, 27, and 74 patients in orchiectomy, TVF, and detorsion groups, respectively.

viability rate of 67% (8 of 12) for ischemia time >24 h. Clinical atrophy was common. For ischemia times ≤24 h, the atrophy rate was 67% (12 of 18). For ischemia times >24 h, the atrophy rate was 83% (10 of 12).

The viability results were similar on sensitivity analysis when restricted to radiographic follow-up; atrophy rates were worse (Supplemental Table 2). For ischemia times ≤24 h, the viability and atrophy rates were 91% (10 of 11) and 91% (10 of 11), respectively. For ischemia times >24 h, the viability and atrophy rates were 63% (five of eight) and 100% (eight of eight), respectively. Despite smaller sample size, the second sensitivity analysis that additionally matched on degrees of twist showed similar results – for the same degrees of twist, increasing ischemia time was associated with lower viability and higher atrophy rates (Supplemental Table 3). Upon restriction to testicles with >6-months follow-up, viability rates were 90% (9 of 10) for ischemia times ≤24 h, compared to 60% (three of five) for ischemia >24 h (Supplemental Table 4). Atrophy rates were, respectively, 80% (8 of 10) and 100% (five of five).

Discussion

The current findings from the overall cohort confirm that with increasing ischemia time from onset of pain, rates of orchiectomy rise while rates of septopexy alone fall. Repair with TVF offers a method through which to salvage certain

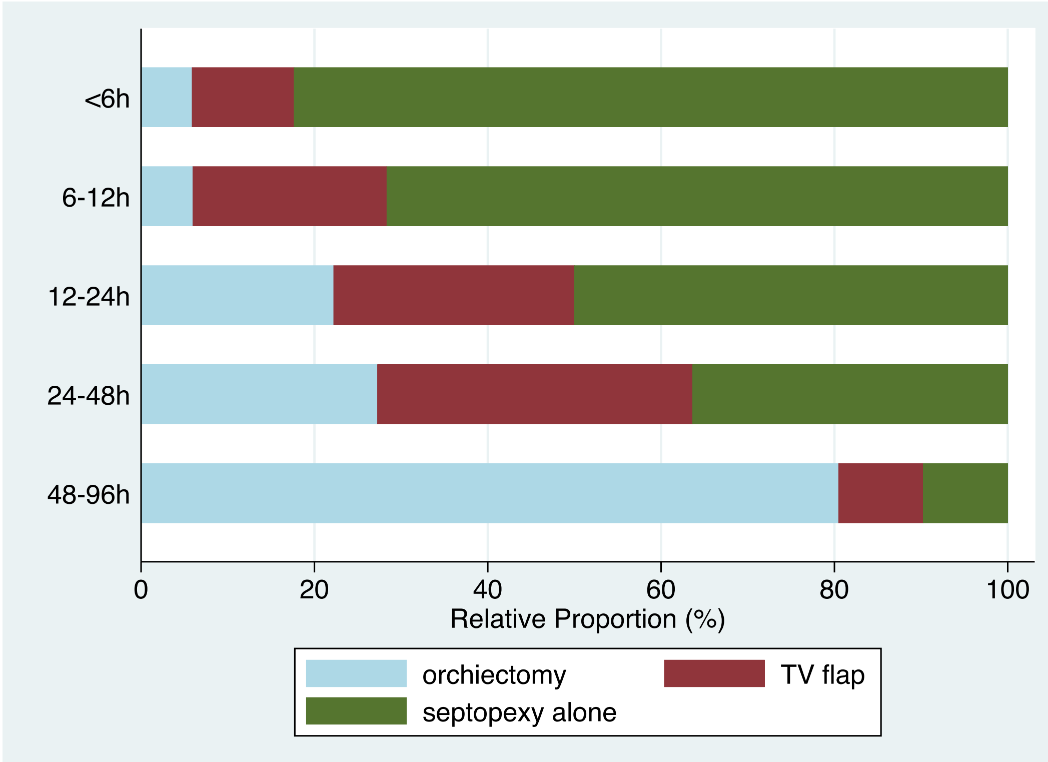

Figure 3 Relative rates of surgical type by ischemia time (in hours).

Table 2 Outcomes in matched cohort of TVF and orchiectomy patients.

Outcome	Ischemia time, hours	TVF, *n* (%)
Overall viability ($n = 32$)	<6	0 (0)
	6–12	14/15 (93)
	12–24	5/5 (100)
	24–48	5/8 (63)
	48–96	3/4 (75)
Overall atrophy ($n = 32$)	<6	0 (0)
	6–12	10/14 (71)
	12–24	2/4 (50)
	24–48	6/8 (75)
	48–96	4/4 (100)

TVF, tunica vaginalis flap.

testicles that otherwise would be removed. In the current matched cohort study, the use of TVF in testicles otherwise being considered for orchiectomy appeared to confer higher viability and lower atrophy if ischemia times were ≤24 h vs >24 h. For ischemia times >24 h, testicles treated with TVF were viable in nearly two thirds of cases, albeit at higher risk of atrophy. The current results suggest a clinical niche for application of TVF in testicular torsion, but warrant tempering patient/parent expectations of full recovery.

The immediate benefit of TVF at time of initial detorsion is obvious: the testicle is preserved and not removed. It is important to note that TVF should not be considered when detorsion alone with septopexy is possible, which suggests less severe testicular injury, but rather when orchiectomy is the alternative (Fig. 1). Thus, TVF outcomes should not be compared directly to detorsion alone outcomes. Early series of the TVF technique have indicated promising results. The original description, in 2008, of TVF in three patients found symmetric clinical and radiographic salvage in two of three patients, with a third showing signs of radiographic atrophy but preserved blood flow [6]. Since this study others have shared their experience with TVF. In Toronto, 59 patients presented with acute torsion requiring surgical exploration over 10 years; of these, 11 underwent detorsion with TVF with a mean ischemia time of 31 h [7]. The authors obtained scrotal ultrasound on follow-up for all 11 TVF patients, with 54% (6 of 11) meeting stringent criteria for salvage (normal blood flow with <50% relative atrophy) that otherwise would have been removed. Given differences in the definition of salvage by Figueroa et al., their salvage rate of 54% is comparable with the current viability rate of 63% for >24 h on strictly radiographic assessment. Overall, both the findings by Figueroa et al. and the current results consisted of low numbers. Larger-sized studies with radiographic follow-up are warranted to be able to draw more definite conclusions about the benefits of TVF.

Less is known about the potential harms of TVF utilization in testicular torsion. Although the aims of the current study were not to examine the specific effects of TVF on fertility, it is necessary to discuss briefly. One study of men who had undergone orchiectomy for torsion noted abnormal semen analyses, though no different from other mono-orchid men [11]. Another study of boys who underwent septopexy versus orchiectomy for torsion noted lower serum inhibin B levels when compared to age-matched healthy controls, but normal levels of serum testosterone, follicle-stimulating hormone, and luteinizing hormone [12]. Concern for infertility may arise due to violation of the blood-testis barrier with the incision through tunica albuginea. However, levels of direct anti-sperm antibody in patients with septopexy or orchiectomy for torsion were not significantly different from those of normal controls [13]. Additionally, a study of prepubertal open testis biopsies showed no subsequent evidence of direct anti-sperm antibodies [14]. Of note, no studies have explicitly included patients with TVF repair; this remains a knowledge gap to be addressed by future studies.

The risk of subsequent testicular atrophy for preserved testicles can be substantial. The current study found that for testicles that had been twisted for >24 h, the rate of clinical atrophy was 83% with the TVF technique. Even for ischemia times ≤24 h, atrophy occurred in 67% of TVF testicles. However, two points must be clarified regarding atrophy: first, presence of atrophy does not equal loss of complete testicular function, which would result from orchiectomy; second, atrophy likely results not from interventions at time of initial scrotal exploration, but rather from the cumulative ischemic injury to the testicle. Evidence of the latter is that atrophy may result from simple detorsion alone. An older study of 64 boys who underwent detorsion alone for testicular torsion during 1979–1991, with follow-up in 25 boys, found a 100% atrophy rate for testicles twisted beyond 24 h [15]. Another study of over 500 torsed testicles that underwent detorsion alone showed an atrophy rate of 80% for ischemia times >24 h [2]. In the current overall cohort, detorsion alone for torsions with >24 h of ischemia time yielded an atrophy rate of 60% (6 of 10) (data not shown). As stated previously, the decision to perform detorsion alone (versus TVF or orchiectomy) is not solely dependent on the ischemia time, but rather a stepwise algorithm of clinical appearance, as shown in Fig. 1. For some testicles twisted >24 h, intra-operative recovery after simple detorsion might be substantial enough to require no more than straightforward septopexy. However, for other testicles twisted >24 h orchiectomy may be the gold standard. It is in this latter group, not the former, that TVF for decompression of testicular compartment syndrome is advocated for consideration.

The current study had several limitations. First, follow-up protocols were not standardized with a scrotal ultrasound. Thus, 61% of TVF patients had radiographic documentation of viability and atrophy, which was based on surgeon preference and may have introduced selection bias. However, the results for viability were similar when restricted only to the subgroup that had radiographic follow-up (95 vs 91% for ischemia times ≤24 h, and 67 vs 63% for >24 h, respectively). Second, as with all observational studies, the study faced potential unobserved confounding, misclassification of ischemia time or outcomes, and other sources of selection bias. However, it tried to address these shortcomings by applying stringent exclusion criteria, separating the outcomes of viability from atrophy, and using a matching methodology to pair TVF and orchiectomized testicles with similar ischemia times. Additionally, the possibility of conducting a randomized trial regarding testicular torsion is likely very low, leaving observational studies as the best possible type of study. Third, the study was derived from a single institution and hence limited in generalizability. It is unclear whether national practice patterns reflect the utilization of TVF as much as at the current institution. However, with at least one other major tertiary referral center publishing their early experience with TVF [7], it is hoped that others will follow suit. Lastly, the follow-up period was short and fertility effects of TVF repair were unknown. Longer-term reassessment of testicular viability and atrophy is currently ongoing. It is hoped that multi-institutional prospective cohorts can be formed and followed with formal semen analyses collected once puberty is completed.

In conclusion, the TVF technique allows select torsed testicles otherwise destined for orchiectomy to be preserved, albeit at risk of subsequent atrophy. The optimal clinical setting for TVF may be those rare testicles with ischemia times ≤24 h where orchiectomy is being considered. However, for ischemia times >24 h where orchiectomy rates are higher, TVF still may be a valid option. This study offered a clinical algorithm for utilization of TVF, and encourages others to follow and modify as needed. Though a promising technique for one of the true pediatric urological emergencies, TVF requires further long-term large-scale study into its benefits and potential harms.

Ethical approval

This protocol was reviewed and approved by the Institutional Review Board.

Conflicts of interest

The authors declare no conflicts of interest.

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Data statement

All research data used in this study are confidential and unable to be shared.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jpurol.2018.01.010.

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Review article

A systematic review and meta-analysis revealing realistic outcomes following paediatric torsion of testes

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Summary

Introduction
Reported testicular loss rates following paediatric testicular torsion often reflect the surgical decision-making process, rather than long-term survival of the testes.

Objectives
We aim to perform systematic analysis and meta-analysis to investigate testicular salvage rates and to assess predictors of long-term viability.

Study design
Systematic review according to PRISMA guidelines was performed to investigate immediate and long-term (>12 months) testicular loss rates following torsion in the paediatric population. Literature search and study inclusion were performed by two investigators. A study quality score was derived and attributed to each study. Predictors of testicular loss were described. Proportions meta-analysis was performed with random effects modelling, and testing for heterogeneity.

Results
Twelve studies were includedm, 6 reporting early orchidectomy rates, and 6 reporting long-term outcomes. Study quality was generally low.

Discussion
The mean early testicular loss rate was 39%, whereas meta-analysis revealed late loss to approach 50%. Predictors of outcomes include prehospital symptom duration, location of presentation, transfer to a tertiary centre, social affluence and use of ultrasound prior to diagnosis or transfer.

Conclusions
This study has shown a considerable late testicular loss rate, which must be relayed to families even after testicular salvage. Delay in time to presentation is consistently found to predict poor outcomes.

Background

Testicular torsion is a urological emergency with time-critical need for surgery, with most reports suggesting 6 h as the cut-off for testicular viability [1]. Many authors report intra-operative testicular salvageability after periods of prehospital delays in excess of 18 h [2] but do not report on the long-term outcomes of these testes. Longer term follow-up shows near 100% atrophy for testes presenting in over 24 h [3,4].

We aim to perform systematic analysis and then meta-analysis to investigate testicular salvage rates following adolescent torsion and to assess predictors of viability, with defined primary outcomes of initial orchidectomy and atrophy of testes at 12 months and secondary outcomes as predictors of testicular loss in children presenting with testicular torsion.

Methods

Search strategy

The two investigators, C.M. and R.K., interrogated the databases: PubMed (Medline), Trip database and the Cochrane Library using the search terms: torsion AND (testicle OR testis OR testes OR testicular OR scrotum) AND (child OR infant OR paediatric OR paediatric OR adolescent OR young) to identify all articles pertaining to torsion in the paediatric population. Once identified from the database searches, these articles were further screened to identify those describing outcomes following testicular torsion.

Inclusion and exclusion criteria

We searched for studies reporting populations of children presenting with testicular torsion

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which reported rates of testicular loss, both early (immediate orchidectomy) and late (>12 months) atrophy. Case series, observation cohort studies and randomised control trials were included, if available.

All studies pertaining to children and adolescents (aged 1–19 years) were included. Studies that described a population of age predominantly under 19 years but also some adults were included if the median age of the cohort was below 16 years. Studies from the last 30 years (i.e. 1st generation) were included as older studies many not represent current presentation patterns or hospital service logistics.

Non-English articles; review articles, case reports and education articles; articles pertaining to intra-abdominal testes, undescended testes, polyorchidism and testicular trauma; articles with a title including the words misdiagnosis, mimicking or masquerading and articles investigating the efficacy of diagnostic predictors of testicular torsion in the setting of acute scrotum were excluded.

Study appraisal and synthesis

The systematic review was carried out according to the preferred reporting items PRISMA guidelines for systematic and meta-analysis. Two authors (C.M. and R.K.) assessed titles and abstracts for inclusion and came to agreement on included studies with discussion. A study quality scale was derived with study methodology, participant numbers and objectivity of follow-up at 12 months, with scoring points as shown in Table 1; a cumulative score <6 was considered low; 6–7, moderate and >8, high. Scores were attributed by both the authors, and agreement reached in all.

Data analysis

Meta-analysis of proportions was carried out using MedCalc Statistical Software, version 17.9.7 (MedCalc Software bvba, Ostend, Belgium; http://www.medcalc.org; 2017), with a random effects model using a Freeman Turkey transformation. Random effects modelling was chosen apriori due to anticipated heterogeneity. Heterogeneity was reported with I^2 statistics, with 0–40% not important, 30–60% moderate, 50–90% substantial and 75–100% considerable.

Results

Study selection

Search results are shown as in Fig. 1. Twelve studies met inclusion criteria for systematic review for outcomes following testicular torsion. Six with defined long-term follow-up were included for meta-analysis. Agreement of inclusion was 100% between authors.

Included studies

Twelve studies describing testicular outcomes following torsion were included. Four studies described outcomes from surgery for acute scrotum, but data for testicular torsion could be extracted and were therefore included [2,5–7]. For inclusion into meta-analysis, follow-up for >12 months was desired in all patients, but this would limit to a single study [1]; therefore, all studies with evidence of any postdischarge follow-up were included [1,3,5,6,8,9].

Excluded studies

Of 57 screened abstracts and titles, review of the full article led to 45 exclusions. Most commonly, this was due to the focus of the article being on diagnosis of testicular torsion or including adult and child populations (Fig. 1).

Study characteristics

The systematic review results included nine retrospective case series, two national registry data set enquiries from the United States and one case-control study. The quality of the studies was generally poor with quality scores as follows: 8 studies were of low quality, 3 of moderate quality and 1 of high quality.

Seven studies described the technique by which the surgeon made the decision to remove the testis in theatre, and five did not [3,7,10–12]. Four studies described assessing bleed time [5,6,8,13], and three described using visual assessment of intra-operative testicular viability [1,2,9].

Table 2 shows the characteristics of the 12 studies, including methodology, numbers of participants with torsion of testes, protocol and time of longer term follow-up, attributed quality and the main findings of predictors of outcomes.

Risk of bias

All studies but one suffered from follow-up bias; in six, no long-term follow-up was reported; in five, follow-up was reported with no case-control. Two studies reported data from clinical coding and insurance databases of the United States [10,11]. Reporting this data has a risk of poor accuracy due to coding errors and does not allow investigation

Table 1 Quality assessment for included studies.

Study design		Number of participants		Objectivity of follow-up at 12 months	
Retrospective	1	0–15	1		0
Prospective	2	15–30	2	Nil	2
Cohort with controls	3	30–45	3	Clinical	4
RCT	4	45+	4	US or testicular function studies	

RCT, randomised controlled trial; US, ultrasound of testes.

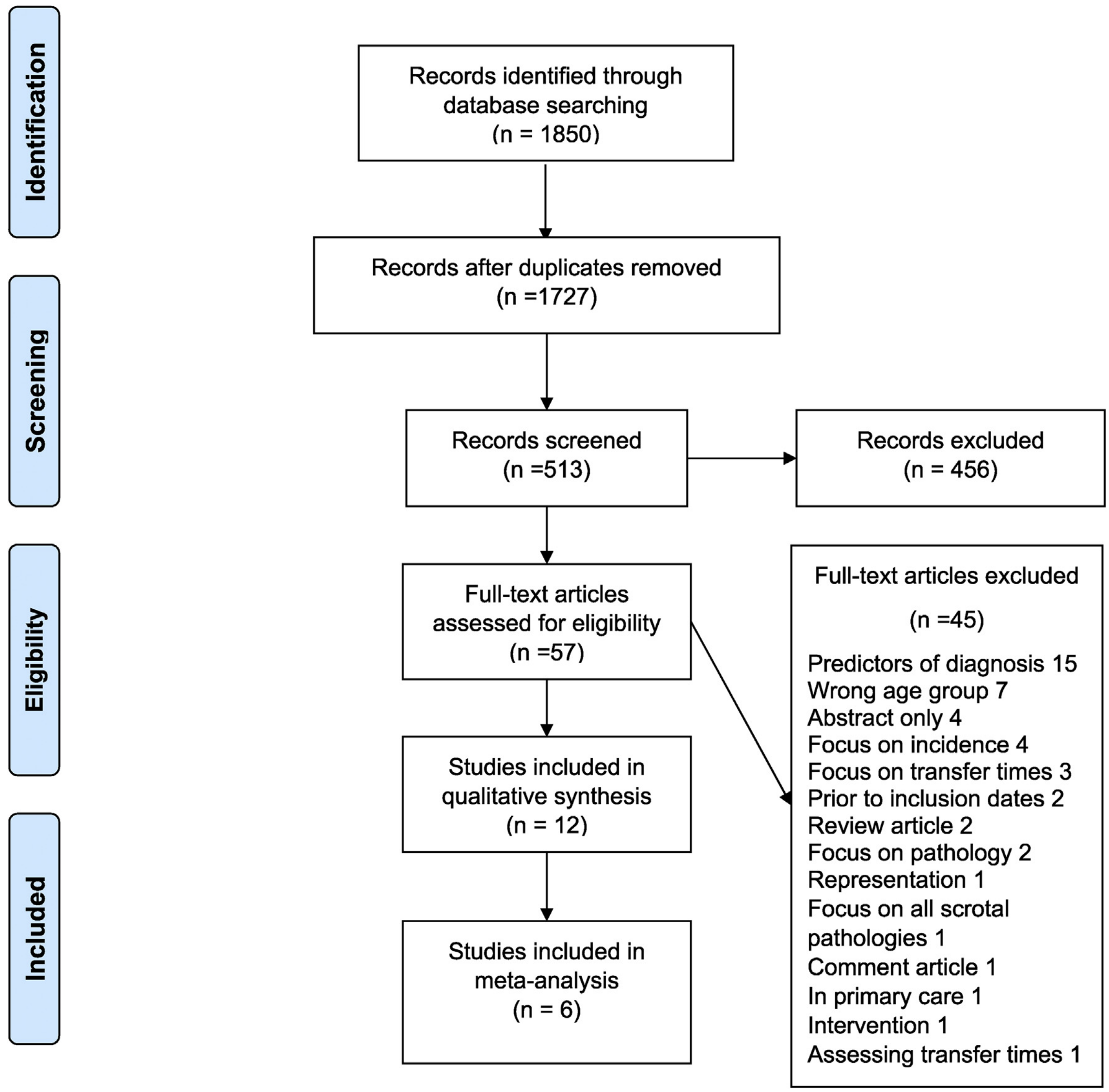

Fig. 1 Study selection using preferred reporting items for systematic review and meta-analysis PRISMA 2009 format.

of clinically relevant parameters. Neither article interrogating coding databases were able to describe time from the onset of symptoms to presentation as prehospital information was not available.

Synthesis of results of outcomes following testicular torsion

Rates of orchidectomy at surgery for testicular torsion range from 20 to 60% [3,7], with a mean of 39%. Rates of testicular loss at longer term follow-up range from 30 to 67% [3,6], suggesting a considerable late testicular atrophy rate.

Longer term testicular function in those who have undergone torsion compared with controls who had not experienced torsion were reported by one article [5]. They compared follicle stimulating hormone (FSH), luteinizing hormone (LH) and testosterone levels, at a median follow-up of 7 years, to controls and found no difference in those with either orchidectomy or orchidopexy. They found no reported sexual dysfunction, and those who wanted children had been able to have children. They found compensatory hypertrophy of the majority of non-torsed testes.

Predictors of testicular loss

Time to presentation

All studies that were able to gather data on duration of prehospital symptoms found this to be a significant predictor of testicular loss, both early and late. Pogorelic et al. [6] found mean symptom duration to be 6 h (range 1–72) in testicular salvage and 46 h (range 12–120) in testicular loss. Saxena et al. [1] divided groups into those presenting <6 h and >6 h from the onset of symptoms and found orchidectomy rates to be 9 vs 56%, respectively. Cimador found that all young people presenting with more than 10 h of symptoms developed testicular loss [8]. Lian classified outcomes into groups presenting within 24 h and those presenting after and found a testicular atrophy rate of 38% and 91%, respectively.

Table 2 Description of study characteristics and predictors of testicular loss.

Study	Methodology	Number of patients with torsion	Long-term follow-up, median (range)	Attributed quality	Predictors of testicular loss (and important negative findings)
Castaneda-Sanchez et al. 2017 [12]	Retrospective case review	165	Nil	Low	**Time to wait for surgery**, 334 ± 250 min vs 216 ± 110 min, loss vs salvage **Ethnicity**: orchidectomy rates 27% Caucasian, 47% Hispanic, 38% Afro-American and 67% Asian No difference in outcomes: age, time from triage to provider, driving distance, degree of torsion and ambient temperature
Preece et al. 2017 [9]	Retrospective case review	125	Clinical ad hoc (not reported)	Low	**Duration of symptoms, US** performed before transfer No association with transfer, public vs private insurance, age and demographics
Pogorelic et al. 2016 [6]	Retrospective case review	142	Clinical ad hoc (not reported)	Low	**Time from the onset to presentation**: median 46 h vs 6 h, loss vs salvage
Lian 2016 et al. [3]	Retrospective case review	85	>6 months clinical 12.5 months (6–88 mo)	Moderate	**Pain duration** <24 h vs > 24 h 38% vs 91% atrophy Heterogenous texture of testes on US
Sood et al. 2016 [10]	US coding database review	16185	Nil	Low	Medicaid and self-pay, comorbidity and urban location
Dias 2016 [13]	Retrospective case review	142	Nil	Low	Presentation delay and **degree of torsion** Not associated with age
Johnston et al. 2015 [7]	Retrospective case review	35	Nil	Low	Prehospital delay 72 h vs 2 h 27, loss vs salvage
Moslemi and Kamalimotlagh 2014 [2]	Retrospective case review	68	Nil	Low	Nil described
Saxena et al. 2012 [1]	Retrospective case review	94	Clinical ad hoc 2.5 yrs (18 mo-5 yrs)	Moderate	**Time to presentation:** < 6 vs > 6 h 9% vs 56% testicular loss
Yang et al. 2011 [5]	Case–control	118	Testicular function and USS testes 7 yrs (3 mo–16.5 yrs)	High	**Time to presentation**: median 90 versus 12 h (lost vs salvage) **Degree of torsion**: median 360° vs 540° (loss vs salvage)
Zhao 2011 [11]	US coding review	2443	Nil	Low	Medicaid insurance, non-ER presentation, treatment at a children's hospital, black child
Cimador 2007 [8]	Retrospective case review	15	Routine CDU at 3,6 and 12 months postoperatively 2.6 yrs (0.8–4.1 yrs)	Moderate	**Time to presentation** >10 h all lost, absence of flow on CDU, grade 3 and 2 intra-operative bleed time No association with degree of torsion

US, ultrasound; ER, emergency room; CDU, colour Doppler ultrasound; yrs, years; mo, months.

Time from presentation to hospital or triage to surgery was found not to be associated with outcomes by Dias et al. [13] but was found to be significant by Castañeda-Sánchez et al. [12]. Wait time to surgery for those losing their testes was 334 min versus 216 min for testicular salvage although this may represent an elective delay to surgery in those with a clearly lost testis.

Degree of torsion

The degree of torsion has previously been found to be associated with testicular loss [5]. There was disagreement within the systematic review, with Dias et al. [13] finding a clear correlation of testicular loss with the degree of torsion, with all young people with greater than 5 radians having 100% testicular loss. Castañeda-Sánchez et al. and Cimador et al. [8,12] found no difference by the degrees of torsion.

Transfer

Due to decreasing willingness for 'paediatric' operations taking place at non-tertiary centres, there has been an increase in the number of adolescents transferred to paediatric surgical centres for scrotal exploration. There is concern that this delay due to transfer times may lead to higher rates of testicular loss. This is supported to some extent by this review: In those presenting within 24 h of testicular pain, transfer was associated with greater loss (30.4 vs 15.2%) [9].

Use of ultrasound

Ultrasound finding of heterogeneous texture of testes has been found to predict testicular loss [5], although this may be a confounding association as heterogenous ultrasound findings may prompt surgeons to remove the testes and therefore increase orchidectomy rates. This review suggests that the use of ultrasound delays time to theatre and therefore decreases testicular salvage rates [7,9].

Age

Within the population described in this systematic analysis, age did not seem associated with outcomes [12,13]. Only Johnston et al. found an association of participants aged above 14 years with worse outcomes, but they found significant correlation with increased time to presentation and therefore attributed the poor outcomes to delay to presentation [7].

Racial and other social demographics

Three articles found ethnicity and social demographics to be associated with outcomes in America. Orchidectomy rates were found to be 27%, 47%, 38% and 67% in Caucasian, Hispanic, Afro-American and Asian children, respectively [12], although database review by Sood et al. did not support these findings [10]. They found worse outcomes in children from America insured with Medicaid or self-pay, with comorbidities and from an urban location. Zhao et al. reflected both these with worse outcomes if presenting with Medicaid insurance and children from Black families [11].

Meta-analysis

Studies that described outcomes with evidence of longer term follow-up were included in a proportional meta-analysis. Table 3 shows the proportion of children and young people with testicular loss after testicular torsion. Funnel plot of the data (Fig. 2) and I^2 statistics suggest considerable heterogeneity, but there was no evidence of publication bias (see Fig. 3).

Discussion

In this synthesis of articles describing outcomes for testicular torsion, a mean orchidectomy rate of 39%, with a late testicular loss rate of 49%, was determined. If only moderate- or high-quality articles are taken into account, so defined by evidence of routine and objective follow-up after torsion of testes, the rates of testicular loss in the paediatric and adolescent population approach 60% overall.

Predictors of outcomes include prehospital symptom duration, location of presentation (with non-emergency room presentation having higher loss rates [11]), transfer to a tertiary centre, degree of torsion, ethnicity, social affluence and use of ultrasound before diagnosis or transfer.

All articles that were able to collect clinically relevant variables predicting testicular loss find delay to presentation to be significantly associated with testicular loss. The findings of higher testicular loss associated with speciality paediatric hospitals [11] most likely reflect delay to surgery due to transfer rather than poorer surgical care in a tertiary unit. Unfortunately, due to the heterogeneity of the time points assessed in each article, a single clear cut-off time which predicts testicular loss cannot be derived. Almost 100% loss was found after 24- and 10-h delay from the onset of symptoms to presentation to hospital [3,8], and 56% loss was found at 6 h [1]. Therefore, it would be reasonable to council families that there is concern for testicular survival

Table 3 Showing proportion of testicular loss at longer term follow-up, with random effects model weighting.

Study	Sample size	Proportion %	95% CI	Weight %
Preece 2017	125	37.6	29.098 to 46.704	17.87
Pogorelic 2016	142	29.6	22.220–37.809	18.03
Lian 2016	85	61.2	49.988–71.562	17.24
Saxena 2012	94	48.9	38.478–59.463	17.42
Yang 2011	118	66.9	57.692–75.332	17.78
Cimador 2007	15	53.3	26.586–78.733	11.65
Total (random effects)	579	49.2	36.107–62.281	100

Test for heterogeneity I^2 89.9% (95% CI, 80.6–94.7), $p < 0.0001$.
CI, confidence interval.

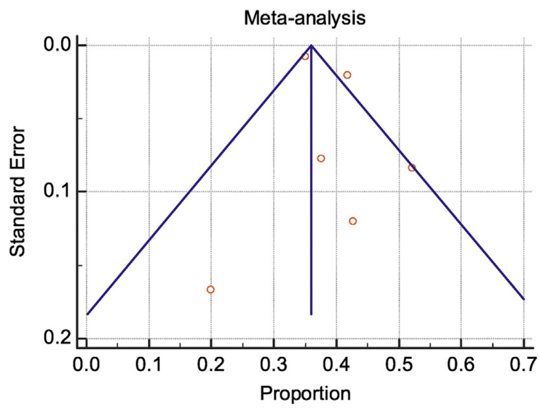

Fig. 2 Funnel plot of 6 studies included in meta-analysis of testicular loss with longer term follow-up.

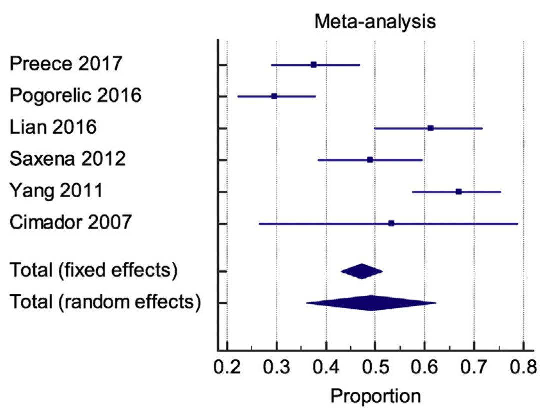

Fig. 3 Forest plot of pooled outcomes from 6 studies reporting outcomes at longer term follow-up after testicular torsion.

after 6 h and significant possibility of testicular loss after 10 h.

At scrotal exploration, the surgeon decides whether to fix the testes or to remove it. There are described aids to this decision-making, which include prior ultrasound findings or bleed time [8], but ultimately reported orchidectomy rates represent surgeon attitudes and optimism. With longer term follow-up, the optimists reporting low orchidectomy rates may find considerable atrophy rates. Average time to atrophy is 12.5 months [3]; therefore, articles reporting outcomes under 12 months are likely to underestimate their testicular loss rates. Only one article described hormonal outcomes after torsion [5] and found no difference in those undergoing torsion to controls, which contradicts previous evidence which suggests that Leydig function is affected by torsion of the testis [14,15]. No recent articles assessed spermatic outcomes after torsion. Previous studies have shown abnormal spermiograms after torsion in postpubertal young men, with considerably worse outcomes in those with prolonged presentation (>12 h) opposed to urgent presentation to hospital. Follow-up of those who undergo prepubertal torsion has shown relatively normal spermiograms and long-term paternity rates, despite marked unilateral testicular atrophy [16]. The authors would recommend follow-up with ultrasound documentation of testicular volumes for at least 18 months in all young men after torsion. Recommendations regarding semen quality assessment based on this review could not be made, but the previous evidence would suggest that this should be considered in postpubertal young men.

The quality of articles in this analysis was generally poor, with only one article reporting longer term case–controlled outcomes. Heterogeneity was high, and as such, applying the findings, the reader must consider specific population needs and demographics, such as nationality and healthcare system logistics.

Conclusions

Studies looking at outcomes from testicular torsion and predictors of testicular loss suffer from retrospective methodology. Despite this, conclusions can be drawn. In discussing outcomes of surgery after testicular torsion in children and adolescents, surgeons must make families aware of the late atrophy risk, especially when delay to presentation has been in excess of 10 h. All studies the methodology of which allowed them to gather data on prehospital duration of symptoms and delays found this to be significantly associated with testicular loss. Therefore, to improve testicular salvage rates, young men with testicular pain need to present to hospitals earlier.

Author statements

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Ethical approval

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Competing interests

None declared.

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Sutured point-fixation versus Jaboulay fixation for salvaged testicular torsion in children

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ABSTRACT

Background: Surgical techniques for fixation of the testis are varied and subject to ongoing debate. Non-sutured techniques may avoid the theoretical morbidities of sutured fixation of the testis yet are criticized for insufficient prophylaxis against future torsion. This study aims to compare outcomes between sutured (point-fixation) versus Jaboulay fixation.
Methods: Emergency scrotal explorations performed at a tertiary hospital in the state of South Australia between February 2002 and December 2017 were analyzed to identify cases of testicular torsion. Primary outcome measures included future testicular torsions and return to theater episodes following initial testicular fixation. Secondary outcome measures included re-presentations and post-operative complications.
Results: A total of 482 scrotal compartments were explored in 244 boys with acute testicular torsion. Testis fixation was performed using sutured point-fixation in 58.4% and Jaboulay tunica plication in 41.6%. No future testicular torsion occurred regardless of fixation technique. There were no significant differences in returns to theater (0.4% versus 1.2%, $p = 0.12$), re-presentations (6.9% versus 6.0%, $p = 0.83$), and post-operative complications (1.7% versus 1.8%, $p = 1.0$) in testes that previously underwent sutured or Jaboulay fixation, respectively.
Conclusion: Jaboulay testicular fixation techniques are comparable with sutured point-fixation techniques in effectiveness and morbidity.
Type of Study: Treatment Study.
Level of Evidence: Level III.

Testicular torsion, also known as spermatic cord torsion, is a surgical emergency. In salvaged testes, surgical fixation is universally recommended as treatment and prophylaxis against future testicular torsion. Wide variation in practice exists for the operative technique used to achieve fixation of the testis [1].

Sutured fixation has been described with both absorbable and non-absorbable sutures. There are concerns regarding complications that could potentially arise from fixation sutures [2]. This has led to the development of non-sutured fixation methods, such as the Jaboulay procedure [3,4]. The Jaboulay procedure involves anterior longitudinal incision of tunica vaginalis and subsequent eversion and loose plication of the parietal layer of the tunica vaginalis leaves, which does not involve placement of suture material through the tunica albuginea (Fig. 1). Apposition of the tunica albuginea against the scrotal wall induces consistent adhesion formation [5]. By avoiding a trans-parenchymal suture, this procedure theoretically avoids the risk of morbidities associated with sutured fixation.

There is insufficient empirical data to inform decision-making regarding the optimal method of fixation and whether non-sutured fixation provides adequate prophylaxis against future torsion. The aim of this study is to evaluate the comparative effectiveness and morbidities of sutured versus Jaboulay fixation of the testis in testicular torsion.

1. Materials and methods

1.1. Study setting

The study was undertaken at a tertiary hospital in the state of South Australia following ethics review board approval. Our tertiary pediatric

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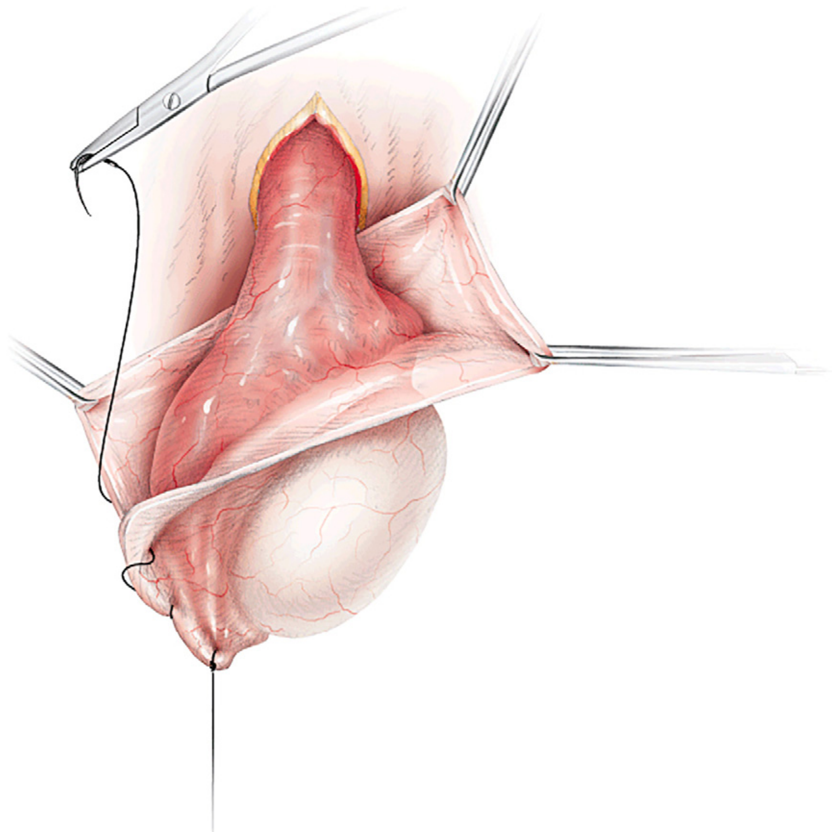

Fig. 1. Example of a typical Jaboulay fixation of testis performed in our hospital, with a single interrupted or figure-of-eight absorbable suture used to achieve loose everted posterior plication of the tunica vaginalis (reproduced from Rioja et al. [3] with permissions from BJU International, John Wiley & Sons).

surgery service provides care for a local population of approximately 1.6 million people.

1.2. Data collection

We retrospectively reviewed all pediatric patients admitted between February 2002 and December 2017 with a Commonwealth Medicare Benefits Schedule code 37604 for the "exploration of scrotal contents" for the indication of acute scrotum. Acute scrotum was defined as acute testicular pain or swelling. Exclusion criteria were scrotal pathologies other than testicular torsion (n = 978), elective scrotal explorations (n = 42), patient's age less than 1 year (n = 20), incomplete documentation (n = 12), non-viable testes which underwent orchiectomy (n = 80) and viable testes which underwent dartos pouch fixation (n = 3). The final study population included boys more than 1 year of age, with testicular torsion identified intra-operatively which subsequently underwent either sutured or Jaboulay fixation. All testes from the contralateral scrotal compartment in this cohort, if explored, were included into the analysis.

Operative records were retrieved from the operating room management information system database. Scrotal-related Emergency Department re-presentations and subsequent return to theater episodes were obtained from the electronic medical records. Operative records and follow up data were obtained from electronic medical records that cover all public hospitals and their respective Emergency Departments within South Australia. For each patient, data retrieved included age of patient, clinical information (presenting symptoms and indications for surgical exploration), intra-operative findings and technical details of the surgery (duration of surgery, testicular fixation technique and suture characteristics).

1.3. Definition of fixation of testis techniques

Sutured fixation of the testis was regarded as placement of sutures to fix the tunica albuginea to the dartos, scrotal septum or scrotal wall. This may be performed with any number of sutures either absorbable or non-absorbable. In this study, any fixation of testis involving placement of suture material through the tunica albuginea was regarded as a sutured fixation technique, regardless of whether a Jaboulay placement was performed in combination. Typical suture material used for Jaboulay was 4/0 polyglactin and either 4/0 or 5/0 polyglactin, polydioxanone or polypropylene for point fixation.

1.4. Outcome assessment

Outcomes were compared between sutured versus non-sutured fixation techniques. Primary outcome measures included 1) future testicular torsion and 2) return to theater episodes following first testicular fixation. Future testicular torsion events were defined as the incidence of testicular torsion in a previously explored hemiscrotum. Return to theater episodes included boys who underwent a second scrotal exploration. Return to theater diagnoses were determined from the second operation notes.

Secondary outcome measures were 1) re-presentations to the Emergency Department and 2) post-operative complications. Acute scrotum related re-presentations included any return to the Emergency Department for either testicular pain or swelling that occurred any time after the first scrotal exploration. Emergency Department physician's discharge diagnoses and/or findings on scrotal ultrasound (if performed), were used in combination to identify the reasons for Emergency Department re-presentations and the incidence of post-operative complications. The study period extended to April 2018 for all outcome variables.

Table 1
Demographic information and clinical characteristics of 244 boys who underwent emergency scrotum exploration for acute testicular torsion, within the 15-year study period.

	Overall (n = 244)	Sutured fixation (n = 97)	Jaboulay fixation (n = 67)	Orchiectomy (n = 80)
Mean age (years) ± SD	12.7 ± 3.5	13.3 ± 2.8	13.2 ± 2.6	11.6 ± 4.4
Mean follow-up (years) ± SD	6.3 ± 4.7	6.2 ± 4.6	5.3 ± 4.7	7.4 ± 4.8
Mean operative time (minutes) ± SD	65.7 ± 17.1	63.4 ± 16.7	65.7 ± 16.4	68.4 ± 17.8
Side of pathology				
Left	127 (52.0%)	45 (46.4%)	34 (50.7%)	48 (60.0%)
Right	114 (46.7%)	50 (51.5%)	32 (47.8%)	32 (40.0%)
Bilateral	3 (1.2%)	2 (2.1%)	1 (1.5%)	0 (0.0%)
Number of sides explored				
Bilateral exploration (%)	238 (97.5%)	94 (96.9%)	65 (97.0%)	79 (98.8%)
Unilateral exploration (%)	6 (2.5%)	3 (3.1%)	2 (3.0%)	1 (1.3%)

Table 2
Testicular fixation techniques used in the study cohort (n = 399 viable testes after exclusion of 80 non-viable testes and 3 testes fixed by dartos pouch replacement). *There is no significant difference (p = 0.68, chi-square test).

	Overall (n = 399)	Viable, de-torted testes (n = 167)	Viable, non-torted testes (n = 232)
Sutured fixation*	233 (58.4%)	99 (59.3%)	134 (57.8%)
Jaboulay fixation*	166 (41.6%)	68 (40.7%)	98 (42.2%)

1.5. Statistical analysis

Statistical analysis was performed with the Statistical Package for the Social Sciences for Windows, Version 21.0. A p value <0.05 indicated statistical significance. Data was expressed as mean ± standard deviation for continuous variables and as a number and percentage for categorical variables. Categorical data between the groups was compared using the $\chi 2$ test or Fisher's exact test, while continuously distributed data was compared using either a Mann–Whitney U test or an analysis of variance.

2. Results

2.1. Operative characteristics of the study population

The study cohort comprised 244 boys (mean age 12.7 ± 3.5 years) with an intra-operative finding of testicular torsion (Table 1). The incidence of bilateral testicular torsion was 1.2% (3/244). A total of 247 torted testes (viable or non-viable) were recorded. Both scrotal compartments were explored in 97.5% (238/244), accounting for a total of 482 testes. Mean duration of follow-up was 6.3 ± 4.7 years.

Eighty non-viable testes were excised (80/482), such that the salvage rate was 67.6% (167/247). Testicular fixation techniques used in the remaining testes are described in Table 2. Sutured fixation was performed in 58.0% (233/402). A Jaboulay procedure was used in 41.3% (166/402) and placement in dartos pouch in 0.07% (3/402). The 3 testes which were placed in the dartos pouch were excluded from the analysis. The study cohort selection strategy is summarized in Fig. 2.

2.2. Characteristics of sutured fixation techniques

Selection of suture material was identifiable in 93.6% (216/233), described in Table 3. Absorbable sutures were used in 84.9% (185/216), with polyglactin (Vicryl®, Somerville, NJ, USA) being the most frequently used. The number of fixation points applied were explicitly described in 58.8% (137/233), of which a three-point fixation was applied in 65.7% (90/137).

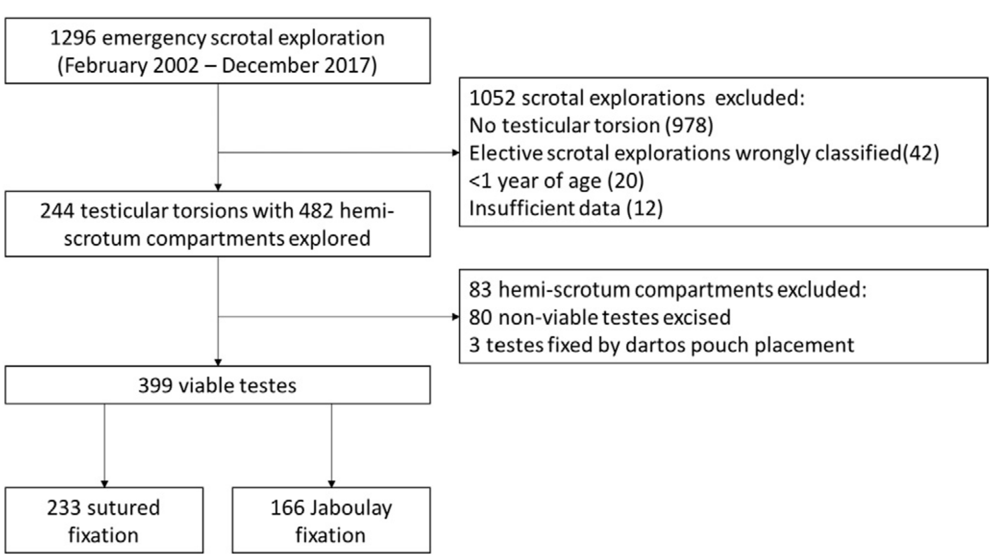

Fig. 2. Study cohort selection process, incorporating inclusion and exclusion criteria.

Table 3
Characteristics of sutured fixation techniques (n = 233 testes).

Suture material	
Absorbable sutures*	185 (84.9%)
Non-absorbable sutures*	33 (15.1%)
Not described	15 (6.4%)
Number of fixation points applied	
1 – Point fixation**	9 (6.6%)
2 – Point fixation**	33 (24.1%)
3 – Point fixation**	90 (65.7%)
4 – Point fixation**	5 (3.6%)
Not described	92 (39.3%)

* Denominator was 216, after excluding the cases where the choice of suture material was not described.
** Denominator was 137, after excluding cases where the number of fixation points applied was not described.

2.3. Acute scrotum re-presentations and post-operative complications

Re-presentations to an Emergency Department with acute unilateral scrotal symptoms occurred in 6.5% of the previously explored scrotal compartments (26/399) (Table 4). Overall reasons for re-presentation to an Emergency Department includes non-specific testicular pain (2.5%), post-operative complications (1.8%) (post-operative infection (0.3%), post-operative hematoma (1.0%) and post-operative wound breakdown (0.5%)), epididymo-orchitis (1.3%), new traumatic injury (0.8%) and incidental scrotal findings (0.3%). There were no differences in Emergency Department re-presentations (6.9% versus 6.0%, $p = 0.83$) and post-operative complications (1.7% versus 1.8%, $p = 1.0$) in testes that previously underwent sutured or Jaboulay fixation respectively.

2.4. Return to theater events

Among the 26 patients who re-presented to the Emergency Department, 3 returned to the operating theater (3/402). The first patient returned to the operating theater with a necrotic testis 32 days after a trial of viability for a previous testicular torsion. The second patient returned to the operating theater 1 day post-scrotal exploration for evacuation of a haematocele. The third patient had no acute scrotal pathology identified on the second exploration. There was no significant difference in return to theater events (1.2% versus 0.4%, $p = 0.57$) between sutured versus Jaboulay fixation groups respectively.

Importantly, regardless of whether a sutured or Jaboulay fixation method was used during the original scrotal exploration, there was zero incidence of future testicular torsion.

3. Discussion

Like many surgical operations, variations in operative technique abound for emergency scrotal exploration. Strong anecdotal opinions are proffered regarding the preferred strategy to surgically fixate the testis to prevent future torsion. We have identified that both sutured and Jaboulay techniques are similarly effective in achieving this goal, with zero future torsion events occurring during our 15-year study period. Morbidity of sutured and Jaboulay techniques were also comparable, with no significant differences in Emergency Department re-presentations and return to theater episodes.

In our study cohort, torted testes were more likely to undergo sutured fixation rather than Jaboulay fixation. If a sutured fixation was applied, the use of absorbable sutures and 3 point-fixation sites were preferred. The observed variation in surgical technique is not unique to our hospital (Table 3) [1]. In a postal questionnaire study involving 97 pediatric surgeons, 85% of respondents indicated that they would perform a sutured fixation for suspected testicular torsion [6]. Preferred sutured techniques among these respondents were sutured fixation alone (63%), a combination of Jaboulay and sutured fixation (17%), and combined sutured fixation with dartos pouch placement (20%).

Jaboulay fixation techniques are criticized for potential inadequate security against future torsion. Surgical fixation relies on adhesion formation between the exposed tunica albuginea and dartos. This mechanism has been verified in rat model studies, demonstrating formation of circumferential adhesions following eversion of tunica vaginalis, which in turn, provide excellent fixation of the testis [5]. Adhesion formation is not instantaneous, meaning that adhesion maturation necessitates a period of days to weeks, during which there exists a vulnerability to future torsion. Our finding of a zero future torsion incidence with Jaboulay fixation is consistent with similarly reassuring data from a 14-year longitudinal study involving 88 non-sutured fixations performed during emergency scrotal exploration [7]. Interestingly, previous cases of recurrent testicular torsion after sutured fixation have been reported in the literature [8,9]. An important technical aspect of Jaboulay fixation is to ensure that the posterior plication of tunica leaves is sufficiently loose to avoid iatrogenic arterial or venous insufficiency of the cord by impingement caused by tight plication.

Concerns are raised for morbidities related to sutured techniques that, by definition, require the surgical breach of the tunica albuginea for point fixation. These potential morbidities include testicular infarction from hemorrhage-related compartment syndrome [10], intraparenchymal abscess formation [11], and impaired fertility [2]. We did not encounter these complications in our study; instead, we report comparable morbidity between sutured and Jaboulay techniques.

A limitation of this study is the retrospective study design. This limited our ability to assess the impact on various confounding variables on clinical outcome. These variables would include severity of torsion on presentation, time since torsion onset, seniority of the operating surgeon, and reliance on the accuracy of historical medical documentation. For example, Emergency Department re-presentation diagnoses were based on emergency physicians' clinical assessments. We believe the lack of standardization of operative technique, including selection of suture material, enhances the generalizability of our results as it reflects the reality of everyday clinical practice with variations in subtle aspects of operative technique such as choice of suture material. Strengths of our study are the long follow up duration and confidence that our study captured a complete state-wide population.

Table 4
Re-presentations and returns to theater for sutured and Jaboulay testicular fixation technique groups. ED = Emergency Department.

	Overall (n = 399 testes)	Sutured fixation (n = 233 testes)	Jaboulay fixation (n = 166 testes)	p-value
Overall ED re-presentations (%)	26 (6.5%)	16 (6.9%)	10 (6.0%)	0.8383
Non-specific symptoms	10 (2.5%)	7 (3.0%)	3 (1.8%)	0.532
Epididymo-orchitis	5 (1.3%)	3 (1.3%)	2 (1.2%)	1
Post-operative complications	7 (1.8%)	4 (1.7%)+	3 (1.8%)*	1
Incidental findings	1 (0.3%)	1 (0.4%)++	0 (0.0%)	1
Traumatic injury	3 (0.8%)	1 (0.4%)	2 (1.2%)	0.573
Future torsion events (%)	0	0 (0.0%)	0 (0.0%)	1
Return to theater (%)		1 (0.4%)	2 (1.2%)	0.573

* Wound infection (1), Scrotal hematoma (2).
+ Scrotal hematoma (2), Wound breakdown (2).
++ Varicocele (1).

Lastly, it must be acknowledged that very high abnormal tunica investment of the cord may result in narrow tunica leaves that are insufficient in substance and laxity to be reflected posteriorly and plicated. In this circumstance, the Jaboulay fixation technique is simply not achievable and sutured point-fixation is the necessary and appropriate alternative.

4. Conclusion

Our findings confirm considerable variation in surgical practice for operative technique of testicular fixation in emergency scrotal exploration for torsion. We identified equal effectiveness between sutured and Jaboulay fixation techniques for security of prophylaxis against future testicular torsion. These techniques are also comparable for rates of return to operating theater, Emergency Department re-presentations and post-operative complications.

With comparable key outcomes, the technical simplicity of Jaboulay techniques leads us to recommend this method for testis fixation.

Study supervision

Associate Professor Day Way Goh.

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Declarations of interest

None.

Support

None.

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Late hormonal function after testicular torsion

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Abstract
Introduction: Testicular torsion may be an important cause of male infertility. We aimed to investigate the late hormonal function in patients with testicular ischemia/reperfusion injury of the testis after orchidectomy or detorsion.
Methods: Twenty patients (mean age, 13.6 years) were prospectively evaluated at a mean of 5 years after testicular torsion. The serum follicle-stimulating hormone, luteinizing hormone (before and after gonadotropin-releasing hormone stimulation), testosterone, and inhibin B were measured. Fifteen age-matched adolescents without evidence of endocrine disease were used as controls for inhibin B values. Data are quoted as mean ± SEM.
Results: Twelve patients were treated with detorsion and orchidopexy, and 8 underwent orchidectomy. Serum follicle-stimulating hormone, luteinizing hormone, and testosterone were all within the reference range. Inhibin B levels were significantly reduced in the 2 groups compared with the controls (34.5 ± 5.2 vs 63.9 ± 12.8 pg/mL, $P = .02$), but were not significantly different between the orchidectomy group and the group that underwent detorsion (41.3 ± 9.7 vs 30.4 ± 5.9 pg/mL, $P = .41$).
Conclusion: Hormonal testicular function can be compromised after testicular torsion, although the type of surgery (orchidectomy or orchidopexy) does not seem to change the effect of this ischemia/reperfusion injury.

Testicular torsion is a urologic emergency that may be an important cause of male infertility [1], with seminal analysis being normal in less than 50% of cases in the long term [2]. It is possible that temporary reduction of blood flow could affect the contralateral testis, and a variety of different mechanisms have been described [2]. Previous studies have focused on the exocrine function after detorsion and/or orchidectomy, as this has been reported to be more vulnerable than endocrine function [3-5].

Recently, new hormones associated with testis function have been described such as inhibin B; and this is considered a reliable marker of Sertoli cell function and spermatogenesis in both adults and adolescents [6,7]. Such hormonal profiling

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has not been described previously in the follow-up of boys who have sustained an episode of testicular torsion.

Our aim was to investigate this late hormonal function in adolescents with a history of torsion whether treated by orchidectomy or detorsion and orchidopexy.

1. Methods

Patients with a history of surgically treated testicular torsion were identified from hospital records. They were divided into 2 groups according to the type of treatment: group 1 (orchidectomy) and group 2 (detorsion and orchidopexy). All had testicular ultrasonography, semen analysis, and a hormonal profile. Testicular size was calculated using the ellipsoid formula (0.52 × length × width × depth). A seminal sample (obtained in the hospital by masturbation after at least 3 days of abstinence) was requested from patients aged at least 18 years. Samples were evaluated for ejaculated volume, sperm concentration, morphology, motility, and fertility index. The hormonal profile was evaluated using blood obtained between 8:00 and 9:00 AM. Serum follicle-stimulating hormone (FSH), luteinizing hormone (LH) (both before and after gonadotropin-releasing hormone stimulation), and testosterone were measured by standard radioimmunoassay.

Serum inhibin B was measured using an enzyme-linked immunosorbent assay kit (DSL-1084100; Diagnostic System Laboratories Inc, Webster, TX). This is a quantitative measurement of dimeric inhibin B in human serum. The inhibin B enzyme-linked immunosorbent assay is an enzymatically amplified 2-site, 2-step sandwich-type immunoassay. In the assay, standards, controls, and unknown serum samples were incubated in microtitration wells coated with anti-inhibin β_B subunit antibody.

Fifteen age-matched adolescents with similar pubertal development and without any endocrine disease were used as controls for inhibin B values.

Results are reported as mean (SEM). Groups were analyzed and compared using an unpaired *t* test. A Spearman coefficient was used to express correlation. $P < .05$ was considered statistically significant.

Table 1 Mean (SEM) of FSH, LH, testosterone, and inhibin B serum levels from patients with orchidectomy (n = 8) and patients with detorsion (n = 12)

	Group 1 Orchidectomy (n = 8)	Group 2 Detorsion (n = 12)	*P*
FSH (basal) (mIU/mL)	6.2 ± 1.2	2.9 ± 0.6	.04
FSH (peak) (mIU/mL)	11.4 ± 3.2	7.8 ± 1.4	.5
LH (basal) (mIU/mL)	5.6 ± 1.4	2.2 ± 0.56	.06
LH (peak) (mIU/mL)	27.1 ± 9.2	17.3 ± 3.8	.43
Testosterone (ng/dL)	505 ± 129	417 ± 107	.43
Inhibin B (pg/mL)	41.3 ± 9.7	30.4 ± 5.9	.41

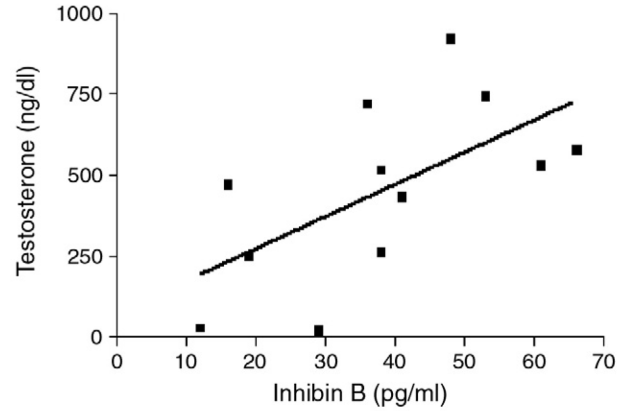

Fig. 1 Basal testosterone and serum inhibin B after testicular torsion (n = 20). There is significant positive correlation ($r = 0.66$, $P = .02$).

2. Results

Twenty male subjects (mean age at time of study, 13.6 years) were evaluated prospectively at a mean of 5 years after an episode of testicular torsion. Eight had been treated with orchidectomy for necrosis (group 1). Twelve were considered viable at the time of surgery and subjected to orchidopexy after detorsion (group 2). Our usual practice is not to fix the contralateral testis in either situation. Subsequently, testicular atrophy was noted in 6 patients (50%), with the atrophic remnant removed in 2.

The serum basal FSH, LH, testosterone, and the gonadotropin-releasing hormone stimulation values were normal in all subjects (Table 1). However, inhibin B levels were significantly reduced in the 2 groups compared with the controls (34.5 ± 5.2 vs 63.9 ± 12.8 pg/mL, $P = .02$), whereas inhibin B values were not significantly different between group 1 and group 2 (41.3 ± 9.7 vs 30.4 ± 5.9 pg/mL, $P = .41$) (Table 1). There was a significant correlation between inhibin B and both testosterone levels ($r = 0.66$, $P = .02$) (Fig. 1) and testis volume ($r = 0.57$, $P = .03$) in both groups (Fig. 2).

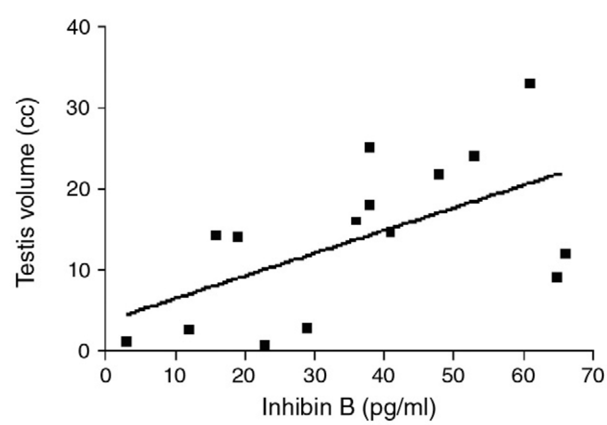

Fig. 2 Testis volume (bilateral or single) and serum inhibin B after testicular torsion (n = 20). There is significant positive correlation ($r = 0.57$, $P = .03$).

Seminal analysis showed a significantly reduced fertility index (according to World Health Organization criteria) in both groups. In particular, after detorsion, only 1 patient out of 4 had a fertility index of 60 (>50 is considered normal), the other 3 being frankly abnormal. Similar results were identified in those who had undergone orchidectomy (all 3 patients had a negative fertility index).

3. Discussion

The initial degree of testicular ischemia largely depends on its duration. Surgical detorsion allows reperfusion but may be in itself responsible for an ischemia/reperfusion type of injury that could further damage the testis [8,9]. After detorsion, if there is bleeding from incision of the albuginea, then typically, the testis is fixed to the scrotum; and only if it appears frankly necrotic will it be removed. Salvage rates have been reported in 30% to 50% of cases [2,10].

Longer-term effects may be observed in adulthood in terms of reduced fertility and impairment of spermatogenesis and seem to indicate that other mechanisms may be involved in testicular damage. For instance, preexisting congenital dysplasia in the contralateral testis may explain some disturbances of spermatogenesis [2]. Other postulated mechanisms include an autoimmune response, triggered by blood-testis barrier breakdown, secondary to ischemic damage leading to exposition of antigenic material and formation of antibodies against testicular elements [11]. Finally, one theory suggests that there is a reflex vasoconstriction in contralateral testicular vessels mediated by sympathetic nerves. This reflex vasoconstriction causes bilateral testicular hypoxia and subsequent damage [12].

The present study confirms previous data showing subfertility after unilateral testicular torsion [2,3], possibly owing to germinal epithelium being more prone to damage after ischemia/reperfusion injury. The endocrine profile seems to be more resistant to ischemia, and previous results have been contradictory. Generally, serum levels of LH, prolactin, testosterone, and FSH have been reported to be within the reference range [3,5]. Recently inhibin B has been described as a marker of Sertoli cell function, with high sensitivity in predicting the quality of spermatogenesis in adults [13]. In prepubertal boys, inhibin B levels seem to predict the testosterone response to human chorionic gonadotropin, giving reliable information about the function of the testes [7]. Inhibin B secretion depends on the interaction between Sertoli cells and germ cells. In particular, it is known that spermatids influence inhibin production and that these cells are sensitive to hyperthermia. Reduced inhibin B serum levels have been described in adolescents with known causes of subfertility such as varicocele. In this group, reduction of inhibin B has been ascribed to an early arrest of spermatogenesis or a depletion of germ cells and associated with a reduced testicular volume on the affected side [14]. Reduced levels of inhibin B have been recently described in adolescent patients after testicular torsion, particularly after orchidectomy [15].

Our study has shown that both exocrine and endocrine functions can be compromised in the late follow-up after torsion. We could not demonstrate any significant variation between the group treated with detorsion and fixation and the group treated with orchidectomy in terms of fertility index or inhibin values. We confirmed the role of inhibin B as a marker of Sertoli cell and germinal function because it is significantly reduced and correlates with testosterone production and testis volume. We observed no difference in terms of fertility index between the 2 treatment groups.

Testicular torsion is responsible for late impairment of both exocrine and endocrine functions. Inhibin B is a reliable marker of testis function and can be correlated with testis volume and testosterone production. Although the best treatment option remains controversial, late follow-up seems to be indicated to define its natural history.

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A comparison of clinical outcomes of acute testicular torsion between prepubertal and postpubertal males

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Summary

Short introduction/background
Surgical intervention for acute testicular torsion can require either orchiopexy or orchiectomy. The decision of which surgery to perform is dependant on the amount of time that the testicle experienced ischemia and the viability of the testicle after reperfusion.

Objective
It is hypothesized that (1) there is a difference in orchiectomy and orchiopexy rates between prepubertal and postpubertal males with acute testicular torsion and (2) presenting symptoms may vary between the two age groups as prepubertal males may present with atypical symptoms, which could result in delayed presentation and diagnosis.

Study design
A retrospective chart review was conducted on pediatric patients who were diagnosed with acute testicular torsion between June 2010 and August 2017. Demographic and clinical characteristics were extracted: age, ethnicity, referral pattern, primary insurance status, symptoms at presentation, prior history of ipsilateral testicular pain or intermittent torsion, recent trauma to genitalia, duration of symptoms (hours), gradual vs. acute onset of symptoms, time/weekday/season at presentation, and time interval from arrival at the study institution to surgical intervention (minutes). Patients were categorized into two groups: prepubertal group (age 1–12 years) and postpubertal group (age 13–18 years). Statistical analyses were performed using R, version 3.3.1.

Results
Ninety-one patients were included in the study. The overall orchiectomy rate was 30.8%. More prepubertal males underwent orchiectomy than postpubertal males (42.4% vs. 24.1%, respectively). Prepubertal males were more likely to present with abdominal pain than postpubertal males (27.3% vs. 10.3%, respectively). Those who underwent orchiectomy were more likely to present with longer duration of symptoms, testicular swelling, and abdominal pain than those who underwent orchiopexy. The risk of orchiectomy decreased by 14% per 1-year increase in age (odds ratio [OR]: 0.86, 95% confidence interval [CI]: 0.94–1.00, $p = .009$). A steady decline in the proportion of patients undergoing orchiectomy was seen from 1 to 12 years of age.

Discussion
This study found that prepubertal males are at higher risk for orchiectomy than postpubertal males. The risk of orchiectomy decreases by 14–16% per 1-year increase in age. Prepubertal males are more likely to present with atypical symptoms and delayed presentation and diagnosis, leading to delayed surgical intervention. It is important for providers to perform a genital examination in prepubertal males who present with abdominal pain to rule out acute testicular torsion. Patients presenting with longer duration of symptoms, testicular swelling, and abdominal pain are at higher risk for orchiectomy. No correlation was found between orchiectomy rate and ethnicity, referral status, primary insurance status, and time/weekday/season at presentation.

Conclusion
Among patients presenting to a tertiary pediatric hospital with acute testicular torsion, prepubertal males (younger than 12 years) are at higher risk for orchiectomy than postpubertal males. Prepubertal males are more likely to present with atypical symptoms which results in delayed presentation and diagnosis, leading to delayed in surgical intervention.

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Table Clinical variables for pediatric males with acute testis torsion by age.

Variable	All (n=91)	Age: 0-12 (n=33)	Age: 13-18 (n=58)	*p*
Testicular pain				
Yes	83 (91.2%)	26 (78.8%)	57 (98.3%)	0.003
No	8 (8.8%)	7 (21.2%)	1 (1.7%)	
Testicular swelling				
Yes	51 (56.0%)	17 (51.5%)	34 (58.6%)	0.520
No	40 (44.0%)	16 (48.5%)	24 (41.4%)	
Abdominal pain				
Yes	15 (16.5%)	9 (27.3%)	6 (10.3%)	0.045
No	76 (83.5%)	24 (72.7%)	52 (89.7%)	
Outcome				
Orchiopexy	63 (69.2%)	19 (57.6%)	44 (75.9%)	0.098
Orchiectomy	28 (30.8%)	14 (42.4%)	14 (24.1%)	
Time from arrival to surgery (min)				
Median [IQR]*	168 [119.5-250]	195 [138-285]	146 [112.2-198.8]	0.016

*IQR = interquatile range

Introduction

Acute testicular torsion is an emergency that occurs as a result of ischemia to the testicle due to twisting of the spermatic cord. It has an annual incidence of 1 per 4000 males younger than 25 years [1,2]. Surgical intervention for acute testicular torsion can result in either testicular salvage with detorsion and orchiopexy or testicular loss with orchiectomy. Orchiectomy rates reported in the literature range from 32 to 44% [1—4]. Generally, it is accepted that detorsion within 6—8 hours of symptom onset results in high rates of testicular salvage. Therefore, testicular salvage is dependent on three key components: timely presentation, prompt diagnosis, and expeditious surgical intervention.

Signs and symptoms of acute testicular torsion include acute scrotal pain, nausea, emesis, testicular tenderness, abnormal testicular lie within the scrotum, absent cremasteric reflex, and scrotal swelling. However, not all patients with acute testicular torsion present with this set of typical symptoms. Unfortunately, presenting symptoms can be vague, particularly in younger populations. Therefore, younger age may be associated with delayed presentation and delayed diagnosis, which could result in higher orchiectomy rates in younger patients.

It is hypothesized that (1) there is a difference in orchiectomy and orchiopexy rates between prepubertal and postpubertal males with acute testicular torsion and (2) age and presenting symptoms have an effect on orchiectomy vs. orchiopexy rates between the two age groups as prepubertal males may present with atypical symptoms, which could result in delayed presentation and diagnosis, leading to a higher orchiectomy rate in this age group.

Materials and methods

After obtaining the institutional review board approval (CHW IRB #111167), a retrospective chart review was performed to identify all pediatric male patients diagnosed with acute testicular torsion from June 2010 to August 2017. The electronic medical record was queried using International Classification of Diseases (ICD-9) codes 608.2, 608.20, and 608.22 and ICD-10 codes N44.00 and N44.02. Common Procedural Technology (CPT) codes were then assessed for scrotal exploration, orchiopexy, or testicular torsion reduction (54600, 54620, and 54640) and orchiectomy (54520). Exclusion criteria included (1) patients older than 18 years; (2) males without a diagnosis of acute testicular torsion; (3) patients with neonatal testicular torsion (ICD-9 code 608.21 and ICD-10 code 44.01); (4) patients diagnosed with torsion of testis appendix (ICD-9 code 608.23 and ICD-10 code 44.03); and (5) patients with missing data (including lack of genitourinary examination on initial evaluation).

Demographic and clinical characteristics were extracted on patients who met study criteria to include age, ethnicity (white, black, Hispanic, Asian), referral pattern, primary insurance status (private, government, self-pay), symptoms at presentation (testicular pain, testicular swelling, nausea, emesis, isolated abdominal or hip pain, gait abnormality), prior history of ipsilateral testicular pain or intermittent torsion, recent trauma to genitalia, duration of symptoms (hours), gradual vs. acute onset of symptoms, time/weekday/season at presentation, and time interval from arrival at our institution to surgical intervention (minutes).

Descriptive statistics were calculated for all variables. Continuous variables were summarized via median and interquartile range. Categorical variables were summarized via frequency and percentage. Patient age was analyzed as a continuous variable and a categorical variable. Patients were categorized into two groups: prepubertal group (1—12 years of age) and postpubertal group (13—18 years of age). The age cutoff of 13 years was selected a-priori to correspond with the typical age of puberty onset based on existing data. Baseline variables and outcomes were compared between age groups using a Wilcoxon rank-sum test for each continuous variable and a Fisher exact test for each categorical variable. Univariate comparisons by orchiopexy vs. orchiectomy status were performed using the same methods.

A LOESS (locally estimated scatterplot smoothing) method of non-parametric regression was used to estimate the proportion with orchiectomy across ages. Univariate

Table 1 Clinical variables for pediatric males with acute testis torsion by age and by outcome.

Variable	All (n = 91)	Age 0–12 years (n = 33)	Age 13–18 years (n = 58)	p-value	Orchiopexy (n = 63)	Orchiectomy (n = 28)	p-value
Duration d symptoms (hours)							
Median [IQR][a]	10 [4–24]	12 [4–48]	95 [4–24]	0.551	5 [3–12]	45 [16.5–78]	<0.001
Onset of symptoms							
Acute	54 (59.3%)	18 (54.5%)	36 (62.1%)	0.512	45 (71.4%)	9 (32.1%)	<0.001
Gradual	37 (40.7%)	15 (45.5%)	22 (37.9%)		18 (28.6%)	19 (67.9%)	
Testicular pain							
Yes	83 (91.2%)	26 (78.8%)	57 (98.3%)	0.003	60 (95.2%)	23 (82.1%)	0.101
No	8 (8.8%)	7 (21.2%)	1 (1.7%)		3 (4.8%)	5 (17.9%)	
Testicular swelling							
Yes	51 (56.0%)	17 (51.5%)	34 (58.6%)	0.520	29 (46.0%)	22 (78.6%)	0.006
No	40 (44.0%)	16 (48.5%)	24 (41.4%)		34 (54.0%)	6 (21.4%)	
Abdominal pain							
Yes	15 (16.5%)	9 (27.3%)	6 (10.3%)	0.045	7 (11.1%)	8 (28.6%)	0.063
No	76 (83.5%)	24 (72.7%)	52 (89.7%)		56 (88.%)	20 (714%)	
Nausea							
Yes	50 (54.9%)	17 (51.5%)	33 (56.9%)	0.665	33 (524%)	17 (60.7%)	0.501
No	41 (45.1%)	16 (48.5%)	25 (43.1%)		30 (47.6%)	11 (39.3%)	
Emesis							
Yes	36 (39 6%)	16 (48.5%)	20 (34.5%)	0.265	22 (34.9%)	14 (50.0%)	0.245
No	55 (60 4%)	17 (51.5%)	38 (65.5%)		41 (65.1%)	14 (50.0%)	
Recent history of trauma to genitalia							
Yes	11 (12.1%)	7 (21.2%)	4 (6.9%)	0.090	6 (9.5%)	5 (17.9%)	0.303
No	80 (87.9%)	26 (78.8%)	54 (93.1%)		57 (90.5%)	23 (82.1%)	
Prior history of ipsilateral testicular pain							
Yes	21 (23.1%)	4 (12.1%)	17 (29.3%)	0.074	18 (28.6%)	3 (10.7%)	0.104
No	70 (76.9%)	29 (87.9%)	41 (70 7%)		45 (71.4%)	25 (89.3%)	
Prior diagnosis of ipsilateral intermittent torsion							
Yes	1 (1.1%)	0 (0.0%)	1 (1.7%)	>0.999	1 (100.0%)	0 (0.0%)	>0.999
No	90 (98.9%)	33 (100.0%)	57 (98.3%)		62 (68.9%)	28 (31.1%)	
Abnormal gait							
Yes	3 (3.3%)	1 (3.0%)	2 (3 4%)	>0.999	1 (1.6%)	2 (7.1%)	0.223
No	88 (96.7%)	32 (97.0%)	56 (96.6%)		62 (98.4%)	26 (92.9%)	
Hip pain							
Yes	3 (3.3%)	1 (3.0%)	2 (3 4%)	>0.999	2 (3.2%)	1 (3.6%)	>0.999
No	88 (96.7%)	32 (97.0%)	56.(96.6%)		61 (96.9%)	27 (96.4%)	
Outcome							
Orchiopexy	63 (692%)	19 (57.6%)	44 (75.9%)	0.098			
Orchiectomy	28 (30.8%)	14 (42.4%)	14 (24.1%)				
Time from arrival to surgery (min)							
Median [IQR][a]	168 [119.5–250]	195 [138–285]	146 [112.2–198.8]	0.016	148 [119–213.5]	194.5 [133.8–291.2]	0.045

[a] IQR = interquartile range.

logistic regression was performed to assess the association between age (as a continuous variable) and testicular pain, testicular swelling, nausea, emesis, and abdominal pain (as categorical variables). Multiple logistic regression was also performed for the primary outcome, orchiectomy, including age (continuous), referral status, onset type (gradual vs. acute), trauma, swelling, and duration of symptoms, and time interval between arrival to surgical intervention as predictors.

All statistical analyses were performed using R, version 3.3.1, (R Foundation for Statistical Computing, http://www.R-project.org). All p-values were 2-sided, and $p < .05$ was considered statistically significant.

Results

Between June 2010 and August of 2017, a total of 100 pediatric male patients underwent scrotal exploration for the diagnosis of acute testicular torsion at the study institution. Seven patients were excluded based on neonatal torsion diagnosis. Two patients were excluded because of missing data. A total of ninety-one patients were included in the final analysis. Of these, 33 patients (36.3%) were in the prepubertal group and 58 patients (63.7%) were in the postpubertal group. The median age in the prepubertal group was 9 years (interquartile range [IQR]: 5–12 years), while the median age in the postpubertal group was 14 years (IQR: 13—16 years). Of the 91 patients, 63 (69.2%) underwent orchiopexy and 28 (30.8%) underwent orchiectomy. Within the orchiopexy group, 19 patients (30.2%) were prepubertal and 44 patients (69.8%) were postpubertal. Within the orchiectomy group, 14 patients (50%) were prepubertal and 14 patients (50%) were postpubertal. When comparing orchiectomy and orchiopexy rates between the two age groups, a higher percentage of postpubertal males underwent orchiopexy than prepubertal males (75.9% vs. 57.6%, respectively) and a higher percentage of prepubertal males underwent orchiectomy than postpubertal males (42.4% vs. 24.1%, respectively) (Table 1).

When assessing for symptoms at the time of presentation, 83 patients (91.2%) presented with testicular pain. When comparing the two cohorts, prepubertal males were less likely to present with testicular pain than postpubertal males (78.8% vs. 98.3%, respectively; $p = .003$). Prepubertal males were more likely to present with abdominal pain than postpubertal males (27.3% vs. 10.3%, respectively; $p = .045$). Postpubertal males were also more likely to present with prior history of ipsilateral testicular pain than prepubertal males (29.3% vs. 12.1%, respectively; $p = .074$). Prepubertal males presented with longer duration of symptoms than postpubertal males (median times of 12 h vs. 9.5 h, respectively; $p = .551$). Moreover, interval time between arrival to the study institution and surgical intervention was statistically significant between prepubertal and postpubertal males with a median time of 195 min (IQR: 138—285 min) vs. 146 min (IQR: 112.2—198.8 min), respectively ($p = .016$) (Table 1). No statistically significant difference was found between the age groups and ethnicity, referral status, primary insurance status, time/weekday/season at presentation (Appendix A and B).

The median age among those who underwent orchiopexy was 13 years (IQR: 12—15 years) vs. 12.5 years (IQR: 6.5—15 years) in the orchiectomy group. Those who underwent orchiopexy were more likely to present with acute onset of symptoms than those who underwent orchiectomy (71.4% vs. 32.1%, $p < .001$). As expected, those who underwent orchiectomy were more likely to present with longer duration of symptoms than those who underwent orchiopexy with a median duration of symptoms of 5 h (IQR: 3—12 h) for the orchiopexy group vs. 45 h (IQR: 16.25—78 h) ($p < .001$). Those who underwent orchiectomy were more likely to present with testicular swelling than those who underwent orchiopexy (78.6% vs. 46%, $p = .006$). Interval time between arrival to the study institution and surgical intervention was statistically significant between the orchiopexy cohort and orchiectomy cohort with a median time of 148 min (IQR: 119—213.5 min) vs. 194.5 (IQR: 133.8—291.2 min), respectively ($p = .045$). Moreover, patients who underwent orchiectomy were more likely to have presented with abdominal pain than those who underwent orchiopexy (28.6% vs 11.1%, respectively; $p = .063$) (Table 1). No statistically significant difference was found between the age groups and ethnicity, referral status, primary insurance status, and time/weekday/season at presentation (Appendix A and B).

Using univariate regression analysis, the association between age and testicular pain, testicular swelling, nausea, emesis, and abdominal pain was assessed. Testicular pain as a presenting symptom was more likely with increasing age (odds ratio [OR]: 1.44, 95% confidence interval [CI]: 1.2—1.81, $p < .001$), while abdominal pain was less likely with increasing age (OR: 0.87, 95% CI: 0.77—0.99, $p = .36$). There was no statistically significant association between age and testicular swelling, nausea, and emesis (Table 2).

Using univariate logistic regression analysis, the risk of orchiectomy was calculated to decrease by 14% per 1-year increase in age (OR: 0.86, 95% CI: 0.94—1.00, $p = .009$). Using LOESS smoothing (non-parametric regression) methods, the proportion of patients with orchiectomy across ages was estimated (Fig. 1). A steady decline in the proportion of patients undergoing orchiectomy was seen from ages 1—12 years.

Multiple logistic regression was also performed for the primary outcome of orchiectomy and age, referral status, onset of symptom (gradual vs. acute), history of recent trauma to genitalia, scrotal swelling, time interval from arrival to surgical intervention, and duration of symptoms as predictors. A significant association was found between age and risk of orchiectomy with a 16% reduction in the risk of orchiectomy per 1-year increase in age (adjusted odds ratio [aOR]: 0.84, 95% CI: 0.73—0.96, $p = .015$). An association was appreciated between onset of symptoms and orchiectomy risk, but this finding was only nearing statistical significance (aOR: 3.05, 95% CI: 0.92—10.45, $p = .069$). There was no statistical significant association between risk of orchiectomy and referral pattern, history of recent trauma to genitalia, scrotal swelling, time interval from arrival to surgical intervention, and duration of symptoms (Table 3).

A second multivariate logistic regression analysis was performed using four variables as a sensitivity analysis to address concerns about overfitting the data. The variables used in this second model included age, onset of symptoms (gradual vs. acute), duration of symptoms, and time interval between arrival to surgical intervention. In this second model, there was a significant association found between age and risk of orchiectomy with a 15% reduction in the risk of orchiectomy per 1-year increase in age (aOR: 0.85, 95% CI: 0.74—0.97, $p = .017$). In addition, an association was appreciated between onset

Table 2 Univariate logistic regression assessing the association between age, presenting symptoms, and orchiectomy[a].

Variable	OR	95% confidence interval	p-value
Testicular pain	1.44	1.20—181	<0.001
Testicular swelling	1.03	0.92—114	0638
Nausea	1.00	0.90—111	0.953
Emesis	0.94	0.84—104	0.240
Abdominal pain	0.87	0.77—099	0.036

[a] An odds ratio (OR) > 1 means a greater odds of the symptom associated with increasing age. The odds ratio corresponds to an increase of 1 year in age. Symptoms with less than 5 total events were excluded from this analysis.

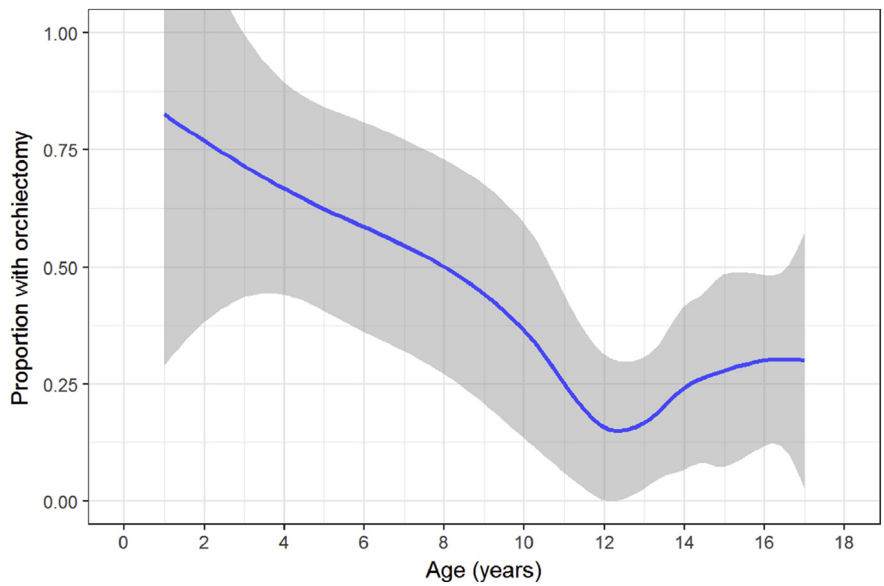

Fig. 1 LOESS plot of proportion of orchiectomy across ages in patient with acute testicular torsion demonstrating a steady decrease in the proportion of patient undergoing orchiectomy from ages 1–12 years.

of symptoms and orchiectomy risk (aOR: 3.25, 95% CI: 1.00–11.10, $p = .05$) (Appendix). There was no statistically significant association between risk of orchiectomy and duration of symptoms, and time interval between arrival to surgical intervention. The results from the second multivariate model are consistent with the previous model.

Discussion

Acute testicular torsion has an annual incidence of 1 per 4000 in patients younger than 25 years [1,2]. Its incidence is bimodal, with one peak in the neonatal period and another one around 13 years of age [5]. Delay in presentation, prompt diagnosis, and expeditious surgical intervention can lead to increased risk of orchiectomy or testis atrophy. Generally, it is accepted that detorsion within 6–8 h of symptom onset results in high probability of testicular salvage. Given this time constraint, it is important to understand features of the patient's presenting symptoms, pubertal status, and physical examination findings that will expedite the diagnosis and intervention. This will facilitate better counseling of patients and parents at the time of surgical intervention.

Many studies have aimed to identify factors that predict the risk of orchiectomy after acute testicular torsion. More specifically, the relationship between age and risk of testicular loss has previously been described in the literature. However, results have been mixed. Cost et al. [1] and Zhao et al. [2] showed declining orchiectomy rates as a function of age. However, Mansbach et al. [3] showed increased orchiectomy rates as a function of age. The current authors take it a step further and look at differences in presenting symptoms in the two age groups to shed light on potential underlying reasons in the difference of orchiectomy rate.

For the present study, the cutoff of 13 was chosen as the average age of onset of puberty and to categorize patients into the prepubertal and postpubertal cohorts. The first sign of pubertal development in males is increase in testicular volume above 4 mL (Tanner stage II) which occurs between 10 and 15 years of age [6].

Comparable with prior studies, 30.8% of the study male patients with acute testicular torsion underwent orchiectomy. A higher percentage of prepubertal males underwent orchiectomy than postpubertal males (42.4% vs. 24.1%, respectively). In addition, there was a steady decrease in the proportion of patients from ages 1–12 years who underwent orchiectomy. This study found that the risk of orchiectomy decreases by 14–16% per 1-year increase in age. Thus, more postpubertal males underwent orchiopexy than prepubertal males. These findings are comparable with other studies that have found orchiectomy rates to decrease as a function of age. Cost et al. [1] reported that orchiectomy rates declined as a function of age with almost 50% of male patients aged from 1 to 9 years undergoing orchiectomy compared with 27.7% of males aged 10–17 years. Zhao et al. [2] showed similar results, with 52% of patients in the youngest age quartile (<10 years of age) requiring orchiectomy and an OR of 1.58. In contrast, Mansbach et al. [3] found that orchiectomy rates increased as a function of age, with a 19% orchiectomy rate in the 1–9 years age group and 33% among the 10–17 years age group. According to their study, the risk of orchiectomy per 1-year increase in age was 8% (OR: 1.08, 95% CI: 1.03–1.13, $p = .003$). Castañeda-Sánchez et al. [7] also did not find a difference in age in their single-institution study between those who underwent orchiectomy vs. orchiopexy. However, the authors only included male ages 10–18 years in their study.

These differences in orchiectomy rates as a function of age may be related to younger patients presenting with different symptoms or combination of symptoms

Table 3 Multivariate logistic regression assessing predictors of orchiectomy in males aged 1—18 years with acute testicular torsion[a].

Variable	OR	95% confidence interval	P-value
Age (years)	0.84	0.73—0.96	0.015
Referral (collapsed)			
Yes vs. No	1.06	0.33—3.34	0.922
Onset			
Gradual vs Acute	3.05	0.92—10.45	0.069
Trauma			
Yes vs. No	0.86	0.13—4.67	0.869
Testicular swelling			
Yes vs. No	2.38	0.68—9.09	0.182
Duration of symptoms (hours)	1.3	0.97—1.93	0.121
Arrival to surgery time interval (hours)	1.16	0.98—1.42	0.111

[a] Multiple logistic regression was used for this analysis. Estimates are adjusted for all other variables in die table. An adjusted odds ratio (aOR) greater than 1 means a greater odds of orchiectomy compared with the reference category (or associated with a 1-unit increase for continuous predictors) after controlling for all other variables in the model.

compared with older patients. Prepubertal males were more likely to present with isolated abdominal pain, while postpubertal males were more likely to present with testicular pain. Thus, testicular pain as a presenting symptom was more likely with increasing age, while isolated abdominal pain was more likely with decreasing age. Six of the 8 males aged 5—8 years underwent orchiectomy; 3 of these presented to a primary care provider (PCP) office or urgent care with abdominal pain before presenting to the study institution.

The study findings also showed that prepubertal males presented with longer duration of symptoms than postpubertal males (median of 12 h vs. 9.5 h, respectively) and that the interval time between arrival to the study institution and surgical intervention was longer for prepubertal males than for postpubertal males (median of 195 min vs. 146 min, respectively), resulting in an interval time difference of 49 min between the two age groups. Unfortunately, being a retrospective study, the reason(s) for this time interval difference such as delayed or no initial scrotal examination could not be determined, which in return resulted in delayed diagnosis and, thus, surgical intervention. Moreover, longer duration of symptoms in younger males also suggests that delayed presentation is most likely the most important factor contributing to delay in diagnosis, surgical intervention, and, thus, orchiectomy rate.

No correlation between orchiectomy rate and insurance status (private vs. government/self-pay) was found. These results are consistent with those found by Mansbach et al. [3] who did not find a difference between Medicaid vs. self-pay vs. private insurance and rate of orchiectomy.

When looking at ethnicity as a risk factor for orchiectomy, this study found that ethnicity (white vs. non-white) was not associated with higher rate of orchiectomy. Mansbach et al. [3] found no difference between white, black, and other ethnic groups. On the contrary, Cost et al. [1] found higher rate of orchiectomy in black vs. white patients at the time of surgery (37.6% vs 28.1%, OR: 1.55, 95% CI: 1.29—1.84). Bayne et al. [8] found difference in orchiectomy rates among different ethnic groups with 67% of the Asian males undergoing orchiectomy, 38% for African-American males, 47% for Hispanics, and 27% for Caucasians. Zhao et al. [2] also found and elevated OR for orchiectomy in black male patients of 1.33.

The role of seasonal variation in testicular torsion and surgical outcomes has been reported discussed in the past. Cost et al. [1] found no difference in the number of testicular torsion cases and seasons. This study supports this finding. In addition, no difference in orchiectomy rates was found between those who presented during the day vs. night time and among the different weekdays at the time of presentation.

This study comes with limitations to include those associated with being a retrospective study. In addition, it represents a single pediatric tertiary institution experience and encompasses outcomes from six pediatric urologists. With this, the authors acknowledge that this impacts the generalizability to other practices or institutions. Moreover, with such surgeon diversity, it is understood that the threshold for orchiectomy versus orchiopexy may differ among surgeons. Moreover, the sample size is smaller than that of previous studies which often use a nationalized database, thus resulting in an underpowered study. Finally, ideal classification of patients to the prepubertal or postpubertal groups should be based on Tanner staging. However, given the retrospective nature of the study and lack of consistent Tanner staging documentation in the medical record, age of 13 years was chosen as the next best variable surrogate. This in return can result in misinterpretation of the conclusions, which are more related to age and differences in presenting symptoms, as opposed to absolute pubertal status.

Conclusion

The present study supports the hypothesis that among patients presenting to a tertiary pediatric hospital with acute testicular torsion, prepubertal males (younger than 12 years) are at higher risk for orchiectomy than postpubertal males (older than 13 years). The risk of orchiectomy decreases by 14—16% per 1-year increase in age. Prepubertal males are more likely to present with atypical symptoms which results in delayed presentation and diagnosis, leading to delayed in surgical intervention. It is important for providers to perform a genital examination in prepubertal males who present with abdominal pain to rule out acute testicular torsion. Patients presenting with longer duration of symptoms, testicular swelling, and abdominal pain are at higher risk for orchiectomy. No correlation was found between orchiectomy rate and ethnicity, referral status, primary insurance status, and time/weekday/season at presentation.

Author statements

Ethical approval

This work was approved by the Institutional Review Board at Children's Hospital of Wisconsin (CHW IRB #111167).

Funding

None declared.

Competing interest

None declared.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpurol.2019.07.020.

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Señores
JUZGADO PRIMERO CIVIL DEL CIRCUITO DE ORALIDAD DE CALI
E. S. D.

Referencia: **PROCESO VERBAL DE RESPONSABILIDAD CIVIL EXTRACONTRACTUAL**
DEMANDANTE. MARCELA MOSQUERA MOLANO Y OTROS
DEMANDADA. VANESSA PÉREZ SARDY Y OTROS
RADICACIÓN. 760013103001-2022-00195-00

ASUNTO: DICTAMEN PERICIAL DE CIRUJANO PEDIATRA.

Reciban un cordial saludo.

ANDRES FELIPE MARIN GIRALDO, mayor de edad, identificado con la cédula de ciudadanía número 75.101.120, residente y domiciliado en Santiago de Cali - Valle del Cauca, con dirección electrónica de notificación afelipemg@hotmail.com y teléfonos 318 820 0576 y (2) 372 4418, por solicitud de la Dra. **VANESSA PÉREZ SARDY** y de la apoderada judicial que le representa, bajo la gravedad de juramento presento la siguiente prueba pericial como **MÉDICO ESPECIALISTA EN CIRUGÍA GENERAL Y CIRUGÍA PEDIÁTRICA** haciendo uso de los recursos, métodos e investigaciones propias de mi ejercicio profesional.

Para dar cumplimiento al artículo 226 del Código General del Proceso, presento al juzgado la siguiente información:

- Expreso que cuento con los conocimientos necesarios, soy imparcial y no tengo impedimento alguno en la peritación que elaboro.
- Declaro que para los interesados que requieren el peritaje no he rendido dictamen pericial en el pasado.
- Anexo los certificados de formación académica que me acreditan como idónea para la presente evaluación pericial.
- Me permito enunciar o enlistar los procesos judiciales en donde he participado como perito.
- Declaro que los exámenes, métodos, experimentos e investigaciones efectuados son los mismos respecto de aquellos que utilizo en el ejercicio regular de mi profesión, indicando que una cosa es la prestación de los servicios de salud y otra, muy diferente, la elaboración de dictámenes periciales.

- Manifiesto que el dictamen fue elaborado con la historia clínica suministrada por la parte interesada correspondiente al paciente SAMUEL VELASCO MOSQUERA

INFORMACIÓN DEL PERITO

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ACTUACIÓN EN CALIDAD DE PERITO

PERITAJE EN MEDIO DE CONTROL DE REPARACIÓN DIRECTA POR COMPLICACIÓN CLINICA EN ABDOMEN AGUDO.

JUZGADO SEXTO ADMINSITRATIVO ORAL DE CALI.
Radicado. 2018 00 307.
Demandante. LUISA MARIA ROSERO TROCHEZ Y OTROS.
Demandado. HOSPITAL BENJAMIN BARNEY GASCA E.S.E Y OTROS.

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- Médico de urgencias, Hospital Departamental Santa Sofía de Manizales – Caldas, 2008 – 2010.
- Médico de Urgencias, Hospital Infantil de la Cruz Roja de Manizales – Caldas, 2008 - 2009.
- Médico de Unidad de Cuidados Intensivos, Hospital Departamental Santa Sofía de Manizales – Caldas, 2010.
- Cirujano General, Fundación Valle del Lili, 2014 – 2019.
- Cirujano grupo de cirugía de cabeza y cuello, Fundación Valle del Lili, 2016 – 2019.
- Docente hora catedra, Cirugía General, Universidad ICESI, 2014 – 2018.
- Cirujano Pediatra, Clinica Imbanaco, 2021 a la fecha.

PUBLICACIONES

- Estrategias de educación en un programa de formación en cirugía pediátrica, como respuesta a la pandemia por COVID-19. Rev Colomb Cir. 2020;35:553 https://doi.org/10.30944/20117582.780

- Novel Coronavirus Infection in an Infant with Intussusception- case report. Global Pediatric Health Volume 8: 1–3. The Author(s) 2021 Article reuse guidelines: sagepub.com/journals-permissions. DOI:10.1177/2333794X211012978.

JURAMENTO

A la fecha, no me encuentro incurso en las causales del art. 50 Código General del Proceso.

> *"Artículo 50. Exclusión de la lista El Consejo Superior de la Judicatura excluirá de las listas de auxiliares de la justicia:*
>
> *1. A quienes por sentencia ejecutoriada hayan sido condenados por la comisión de delitos contra la administración de justicia o la Administración Pública o sancionados por la Sala Jurisdiccional Disciplinaria del Consejo Superior de la Judicatura o sus Seccionales.*
> *2. A quienes se les haya suspendido o cancelado la matrícula o licencia.*
> *3. A quienes hayan entrado a ejercer un cargo oficial.*
> *4. A quienes hayan fallecido o se incapaciten física o mentalmente.*
> *5. A quienes se ausenten definitivamente del respectivo distrito judicial.*
> *6. A las personas jurídicas que se disuelvan."*

CUESTIONARIO – DICTAMEN PERICIAL.

1. ¿Qué es la torsión testicular?

La torsión testicular es una de las causas del síndrome de escroto agudo. Este síndrome se caracteriza por dolor testicular, y dependiendo de la causa se acompaña de otros síntomas y signos. Fisiopatológicamente la torsión testicular se caracteriza por el giro del testículo sobre su pedículo vascular (arteria y vena), puede ser una, dos o tres vueltas sobre el eje del pedículo. Esto compromete la irrigación vascular del testículo y dependiendo del tiempo de evolución ocasiona isquemia (disminución del flujo) y necrosis (muerte) del testículo. Ocurre más frecuentemente en la edad postpuberal seguido de los pacientes prepuberales (Con referencia a la pubertad 10-14 años). La incidencia anual está calculada en 3.8 casos por cada 100.000 hombres menores de 18 años (0.004% de esta población), lo cual lo hace un problema infrecuente.

2. ¿Diga cuáles son los signos propios de un cuadro inicial de una torsión testicular?

El síntoma principal de la torsión testicular es el dolor severo escrotal ipsilateral al testículo comprometido. El dolor usualmente se acompaña de náuseas y vómito, el dolor característicamente es implacable y obliga al niño a notificar a su cuidador o acompañante. La alteración de la percepción de los síntomas, como la severidad del dolor, puede ocurrir en niños muy estoicos, con condiciones neurológicas que alteren la percepción de los síntomas o con poca confianza con su cuidador; y esta condición puede demorar el momento del diagnóstico. Con pocas horas de evolución el escroto puede tener grados variables de eritema, masa e induración. Con varias horas de evolución la sensibilidad escrotal puede ser tanta que puede limitar la evaluación clínica por parte del médico. Algunos niños pueden consultar por dolor abdominal asociado a náuseas y vómito.

COMPONENTES DE LA HISTORIA CLÍNICA QUE SUGIERE TORSIÓN TESTICULAR:

- Dolor escrotal unilateral severo desde el inicio.
- Dolor implacable.
- Asociación del dolor con náuseas y vómito.
- Cambios en la posición normal del testículo.

HALLAZGOS AL EXAMEN FÍSICO QUE SUGIEREN TORSIÓN TESTICULAR:

- Sensibilidad testicular unilateral.
- Elevación del testículo.
- Orientación transversa del testículo.
- Palpación anterior del epidídimo.
- Ausencia de reflejo cremastérico.

3. ¿Presentaba el paciente según la valoración clínica que hace la Doctora Vanessa Pérez síntomas claros de torsión testicular para el 12 de septiembre de 2021?

Considero que de acuerdo con la valoración domiciliaria realizada el 12 de septiembre, y teniendo en cuenta además los signos y síntomas más frecuentes de torsión testicular, que fueron mencionados en el punto anterior, el cuadro clínico del paciente no era concluyente de una torsión testicular, y podría sugerir otras causas de escroto agudo (Diagnósticos diferenciales de torsión testicular)

La valoración domiciliaria de la Dra. Vanessa Pérez fue realizada el día 12 de septiembre de 2021 a las 20:29, y refiere en la historia clínica aportada como prueba (de EMI) “Dolor testicular izquierdo de inicio hoy, asociado a edema sin otro síntoma”. Al examen físico se encontró dolor en testículo izquierdo, leve edema y sin eritema; sin signos de estrangulación.

De acuerdo con el registro de llamada telefónica de solicitud de servicio a EMI el dolor había empezado el día anterior en la noche, es decir, tenía más de 24 horas de evolución. El síntoma principal fue el dolor testicular, sin embargo, no refiere una intensidad severa como es la característica de la torsión testicular, ya que permitió su estancia en casa durante estas 24 horas sin consultar al médico; además la ausencia de otros síntomas gastrointestinales como náuseas y vómito, y de hallazgos al examen físico de signos de necrosis (Coloración equimótica del escroto, signos inflamatorios del escroto, elevación del testículo, ausencia de reflejo cremastérico) Obliga a descartar múltiples causas de escroto agudo, donde la torsión testicular probablemente no es la primera posibilidad.

La probabilidad clínica de torsión testicular es alta cuando a un dolor insoportable de inició súbito y pocas horas de evolución se asocian síntomas autonómicos como náuseas y vómito. En este caso, estos síntomas gastrointestinales se presentan como consecuencia de la severidad del dolor, y, además, reflejan el carácter visceral del mismo.

4. ¿Cuáles son los diagnósticos diferenciales de escroto agudo?

a. Torsión de apéndices testiculares: los apéndices testiculares son unos remanentes embrionarios (Del desarrollo) de pequeño tamaño que están localizados en los testículos de manera variable. Estas estructuras pueden sufrir torsión, isquemia y necrosis y esto puede ocasionar dolor escrotal. El dolor usualmente no es muy severo, y no hay elevación del testículo ni otros signos de torsión testicular.
b. Tumores: los tumores del testículo pueden presentarse en niños. La edad más frecuente de presentación es entre 10-14 años. Se caracteriza por una masa progresiva indolora. A veces, puede ocasionar dolor de intensidad variable, característicamente poso intenso y difícil de localizar, de varias horas o días de evolución. Además, los tumores testiculares por sí mismos, pueden generar cuadros de torsión testicular al ocasionar la rotación del testículo sobre su pedículo vascular.
c. Hernias o hidroceles: se presenta en niños de todas las edades. Más frecuentemente derechos, pero puede ser bilateral. El síntoma más común es la presencia de una masa intermitente (que aparece y desaparece) en la región inguinal y/o escrotal. La mayoría de las veces no dolorosa, pero en casos de encarcelación puede haber dolor persistente asociado a una masa que ya no desaparece.
d. Epididimitis/ orquitis: es un proceso inflamatorio infeccioso limitado al epidídimo que puede extenderse al testículo. En la edad prepuberal es casi tan prevalente con la torsión testicular. Es más frecuente en menores de 5 años y mayores de 10 años; la sintomatología es similar a la torsión testicular, con dolor testicular, que frecuentemente es de menor intensidad al descrito en la torsión, y con ausencia de los síntomas de necrosis testicular ya mencionados.
e. Trauma: en caso de dolor testicular agudo siempre debe descartarse el antecedente de trauma como el causante de esta patología.
f. Varicocele: es la dilatación varicosa del plexo pampiriforme. Que son venas que rodean al testículo, al dilatarse generan aumento de tamaño testicular (edema) y en grados avanzados puede causar dolor, el cual generalmente es de poca intensidad y constante. Aumenta al ponerse de pie y cede al acostarse. Es más frecuente al lado izquierdo por cuestiones meramente anatómicas (desembocadura en ángulo recto de la vena espermática a la vena renal de este lado).

5. ¿Cuál es el valor predictivo de signos como las náuseas o el vómito para determinar la existencia de padecimientos como la torsión testicular?

   Las náuseas y el vómito son síntomas gastrointestinales frecuentes, que pueden estar relacionados con diferentes patologías. En el caso del dolor testicular agudo, cuando estos síntomas están asociados, son síntomas autonómicos que están en relación con el carácter visceral de la dolencia y con la severidad del dolor. Debido a que, como se mencionó en el punto anterior, existen varios diagnósticos diferenciales del síndrome de escroto agudo, se han diseñado varias escalas para tratar de predecir la probabilidad de torsión testicular.

La más socorrida de las escalas fue diseñada por Barbosa et al. Y se llama la escala TWIST (TWIST SCORE):
Dolor testicular: 2 puntos
Testículo duro: 2 puntos
Reflejo cremastérico ausente: 1 punto
Náuseas y vómito: 1 punto
Testículo alto: 1 punto.

Como es bien conocido, el diagnóstico en medicina se determina con la probabilidad. Esta escala fue analizada en dos cohortes (seguimiento de dos grupos de pacientes) para evaluar la correlación que tenía esta escala con el desenlace de torsión testicular. Se encontró que puntajes de 5 tuvo un valor predictivo positivo de 100% (Esto quiere decir que en el estudio todos los pacientes con torsión testicular tuvieron un puntaje mínimo de 5). El puntaje menor o igual a 2 se correlacionó con un valor predictivo negativo de 100% (Ninguno de los pacientes con puntaje de dos o menos tuvo torsión testicular).

Otra escala validada a nivel internacional es la escala TT de Asia:
Edad menor de 1 o mayor de 10 años: 1 punto.
Náuseas o vómito: 2 punto
Dolor testicular: 2 puntos
Testículo duro: 1 punto
Ausencia de reflejo cremastérico: 1 punto
Posición anormal del testículo: 2 puntos

Interpretación escala TT: Puntaje de 1 descartar torsión testicular y puntaje mayor o igual a 6 se asocia a alta probabilidad de torsión testicular.

Estas escalas, que son las más usadas a nivel mundial, demuestran la importancia que se da en el síndrome de escroto agudo a las náuseas y el vómito como síntomas asociados para discriminar los pacientes con alta sospecha de torsión testicular.
En otro estudio se evalúo el ODDS RATIO (OR) o razón de probabilidad de cada síntoma. Se encontró que las náuseas y el vómito tuvieron un OR de 14.17 con un intervalo de confianza de 6.11 – 32.87. Esto en términos populares quiere decir que el dolor testicular se correlaciona con una probabilidad 14 veces mayor de torsión testicular cuando está asociado a náuseas y/o vómito como síntomas concomitantes, que cuando estos síntomas no están presentes.
Como mencioné anteriormente, el diagnóstico médico se rige por la probabilidad clínica, y es posible que un paciente, o un grupo de pacientes se salgan de estos parámetros y presenten una torsión testicular a pesar de no cumplir con los criterios anotados en las escalas mencionadas. Sin embargo, dado que esto sugiere una probabilidad clínica baja, no es errado en este escenario considerar otros diagnósticos diferenciales como primera posibilidad diagnóstica.

6. ¿Es posible un cuadro clínico de torsión testicular con evolución de síntomas de más de doce horas y sin la presencia de necrosis en la zona afectada?

   Existen varios factores de los cuales depende la necrosis de un testículo que ha sufrido una torsión testicular, de los cuales sin duda el más importante es el tiempo de evolución.

   El salvamento testicular en la torsión es posible aproximadamente en el 58% de los pacientes. Grupo en el que se caracterizan síntomas de menos de 24 horas de evolución hasta el momento de la cirugía (con un promedio de 18 horas) y además el grado de torsión, menos de dos vueltas sobre el cordón espermático. Revisiones sistemáticas con metaanálisis (Estudios clínicos con gran poder de conclusión que agrupan otros estudios y que tienen gran relevancia científica y estadística) han demostrado actualmente que la probabilidad de necrosis del testículo (pérdida del órgano con necesidad de extirparlo) con 24 horas de evolución de los síntomas es del 100%.

   Sin embargo, el 73% de los pacientes a quienes es posible salvar el testículo presentan en el seguimiento atrofia testicular.
   Otro estudio demostró que los predictores de orquiectomía fueron pacientes menores de 14 años, ausencia de síntomas gastrointestinales, tiempo desde el inicio de los síntomas hasta la exploración quirúrgica mayor de 24 horas.

   Considerando que el momento en que el paciente fue valorado por la Dra. Vanessa Pérez Sardy, y de acuerdo con la evidencia suministrada, en la cual se demuestra que los síntomas llevaban al menos 24 horas de evolución, lo más probables es que ya hubiera algún grado de isquemia irreversible, y cambios testiculares que hubiesen conllevado a la orquiectomía como opción terapéutica.

   Las consecuencias de la torsión testicular no se miden solamente en necrosis y necesidad de orquiectomía (resección testicular) sino en viabilidad del testículo. Se ha encontrado que solo el 30% de los testículos rescatados (estos se refieren a los pacientes con torsión testicular en quienes ha sido posible la detorsión y fijación del testículo contralateral) son viables en el seguimiento posterior a 3 meses. La falta de viabilidad está en relación con la atrofia testicular (disminución de tamaño) y esto afecta la función testicular tanto hormonal como reproductiva. El factor que está relacionado con la atrofia testicular es la duración de los síntomas por más de 24 horas de evolución. Otros factores fueron el grado de torsión y la demora en consultar de más de 6 horas. (situaciones todas encontradas en el caso del paciente que estamos tratando: tiempo de evolución de los síntomas en el momento de la consulta de más de 24 horas, retardo en asistir al hospital de más de 6 horas y torsión severa al encontrarse en la cirugía una torsión de tres vueltas del testículo sobre el cordón espermático).

7. ¿Es indicado frente a una impresión diagnóstica de epididimitis poner al paciente analgesia como el diclofenaco? Explique su respuesta.

Ante la sospecha clínica de epididimitis está completamente indicado el uso de analgésicos antiinflamatorios como el diclofenaco, y además hace parte del tratamiento, Sobre todo en el manejo domiciliario para control de los síntomas del paciente. El uso de analgésicos no enmascara el dolor en caso de causas graves.

8. ¿Cuáles son las consecuencias para un paciente que ha sufrido una torsión testicular en cuanto a su calidad de vida y tasa de fertilidad?

   Las consecuencias de la torsión testicular se piensan que están relacionadas con la severidad de la torsión y con la necesidad de orquiectomía.
   En cuento a la orquiectomía (Extirpación quirúrgica del testículo) hay dos cuestiones fundamentales, una que depende la función del testículo y otra de tipo estético por la pérdida del órgano.
   Estudios realizados han determinado que la tasa de paternidad y la calidad de vida relacionada con la salud no muestra diferencias entre los pacientes que requirieron orquiectomía y aquellos en quienes pudo salvarse el testículo. Tampoco hubo diferencias en cuento a la función eréctil en la edad adulta en estos grupos. Estos aspectos tienen que ver fundamentalmente con la capacidad del testículo residual (el que queda) en los pacientes a quienes se hizo orquiectomía en asumir las funciones hormonales completamente, y, además, como se ha mencionado con antelación en la atrofia testicular futura que sufren los testículos que se han torcido, aunque hayan podido salvarse. Desde el punto de vista estético hay disponibilidad de prótesis testiculares que pueden colocarse en los pacientes a quienes se ha realizado orquiectomía.

LITERATURA CIENTIFICA

El cuestionario antes atendido, tiene su sustento científico en la siguiente bibliografía:

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Finalmente, me permito certificar que la información anteriormente plasmada obedece al estudio de la historia clínica que realicé personalmente y de cara a documentos científicos, de tal manera he actuado leal y fielmente a mi labor, con objetividad e imparcialidad, teniendo en consideración tanto lo que pueda favorecer como lo que sea susceptible de causar perjuicio a cualquiera de las partes.

Para lo cual aporto, literatura científica en la que apoyo mi concepto científico y mi hoja de vida con los documentos que prueban mi idoneidad científica.

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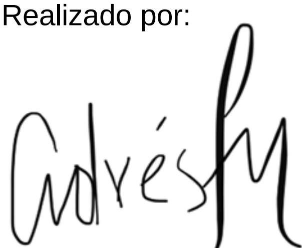

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