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Original Research Article

Validation and comparison of clinical predictive scores for testicular torsion in children with acute scrotum

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ABSTRACT

Background: Testicular torsion scoring systems, based on a combination of clinical and imaging factors, have been developed to improve the diagnostic accuracy of testicular torsion in patients presenting with acute scrotum. This study aimed to validate and compare two current testicular torsion scores the Boettcher Alert Score (BAL) and the Testicular Workup for Ischemia and Suspected Torsion (TWIST)-in a retrospective cohort of pediatric patients with acute scrotum.

Methods: We conducted a retrospective study of all pediatric patients admitted to our institution for acute scrotum between January 2010 and December 2022. Patients were categorized into the testicular torsion (TT) group and the non-testicular torsion (NTT) group. Collected data were used to calculate the scoring systems and perform statistical analyses.

Results: A total of 241 patients were included, of whom 80 (33.2%) had testicular torsion. The mean age in the TT group was 13 years. The optimal individual cut-off value for the BAL score was >1 (sensitivity 90%, specificity 80.75%), and for the TWIST score >4 (sensitivity 82.5%, specificity 80.75%). A high-risk TWIST score >5 had a specificity of 80.75% and a negative predictive value (NPV) of 90.28%, while a BAL score of 4 showed a specificity of 98.48% and NPV of 94.2%. The area under the ROC curve was slightly higher for the BAL score (0.917; 95% CI, 0.875–0.949) than for the TWIST score (0.897; 95% CI, 0.851–0.932). The difference between the two scores was not statistically significant.

Conclusion: The TWIST and BAL clinical scores have significant diagnostic value and may assist in the evaluation of testicular torsion in children. Both scores could be incorporated into a standardized approach for assessing pediatric acute scrotum, potentially reducing time to definitive diagnosis, and minimizing ischemia duration.

Keywords: Testicular torsion, Acute scrotum, Scoring systems, Diagnosis, Children

INTRODUCTION

TT is the most common pediatric urological emergency and, if not promptly treated, can result in ischemia-reperfusion injury, leading to testicular loss or infertility.[1,2] TT can occur at any age but predominantly affects neonates and adolescents aged 12–18 years, with a peak incidence around 13–14 years. Its estimated incidence in children is 3.8%.[3,4] Clinically, TT typically presents with sudden-onset, unilateral scrotal pain, often accompanied by swelling, nausea, and vomiting.[5] Diagnosis may be challenging due to symptom overlap with other causes of acute scrotum, including epididymo-orchitis, torsion of the testicular appendage, trauma, strangulated hernia, and torsion-detorsion syndrome.[6] Early intervention within six hours of symptom onset

yields testicular salvage rates of 90–100%, which decline to 20–50% between 6 and 12 hours and to 0–10% after 12–24 hours.[6] Despite its clinical significance, TT accounts for only 10–15% of pediatric acute scrotum cases, making routine surgical exploration impractical for all patients.[6-8] Therefore, rapid and accurate diagnosis is critical.[6] While clinical indicators such as short symptom duration, nausea, absent or abnormal cremasteric reflex, high testicular position, and testicular firmness can guide diagnosis, overlap with other conditions often limits diagnostic certainty.[7,9-11] Doppler ultrasound (DUS) is the primary imaging modality due to its high sensitivity and specificity.[12]

To further enhance diagnostic accuracy, scoring systems combining clinical and imaging findings have been developed. The BAL, derived from a cohort of 242 children, identifies four predictors of TT: symptom duration <24 hours, nausea or vomiting, high testicular position, and abnormal cremasteric reflex, with a score ≥2 indicating a high probability of torsion.[6,7] The TWIST score incorporates five weighted variables: swelling, firm testicle, nausea or vomiting, high testicular position, and abnormal cremasteric reflex, with scores ≥3 suggesting high probability and scores ≥5 warranting immediate surgical exploration without imaging.[10,13] This study aimed to validate and compare the predictive accuracy of these scoring systems in a large pediatric cohort presenting with acute scrotum.

METHODS

This retrospective cohort study included all male children aged 0 days to 18 years who were admitted and underwent surgery for acute scrotum at the Department of Pediatric Surgery, Clinical Center University of Sarajevo, between January 2010 and December 2022. Only patients younger than 18 years who underwent surgical intervention for acute scrotum were included. Patients with malignant testicular diseases, epididymal cysts, or incomplete/missing hospitalization records were excluded from the study. Patients were categorized into four age groups: 0–1 year, 2–5 years, 6–11 years, and 12–18 years. The duration of symptoms was defined as the time from reported symptom onset until presentation to the emergency department (ED) and was classified as <6 hours, 6–18 hours, and >18 hours. Two testicular torsion scoring systems-the BALS and the TWIST score-were assessed in all patients. The local institutional review board obtained ethical approval for this study (Ethical Committee of the Clinical Center, University of Sarajevo, protocol code: 51-30-5-6239/23, date of approval: 10 February 2023). Due to the retrospective nature of the study, informed consent was waived.

Statistical analysis

The statistical analysis employed the Wilcoxon signed-rank test, Spearman's rank correlation coefficient, and the Kappa statistic to evaluate the concordance of diagnostic scoring systems. Categorical data were analysed by using the chi-square (χ^2) test. The diagnostic performance of the BALS and TWIST scores in identifying testicular torsion was assessed over the calculation of sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). Receiver Operating Characteristic (ROC) curve analysis was conducted to evaluate the diagnostic accuracy of the BALS and TWIST scores and to determine sensitivity and specificity across individual score thresholds. A p-value of <0.05 was considered statistically significant, with the confidence level set at 95%. All statistical analyses were performed using IBM SPSS Statistics version 25.0 and MedCalc version 13.1.

RESULTS

A total of 241 male patients aged 0 to 18 years underwent surgery for acute scrotum at the Pediatric Surgery Clinic, Clinical Center University of Sarajevo, between January 2010 and December 2022. Intraoperative diagnoses revealed that 80 patients (33.2%) had TT, while 161 patients (66.8%) were diagnosed with NTT, including torsion of a Morgagni cyst, epididymitis, orchitis, and epididymo-orchitis. Statistically significant differences between TT and NTT groups were observed in symptom duration, patient age, clinical outcomes, and Doppler vascularisation (Table 1).

Table 1: Comparison between TT and NTT groups.

		Group			
		TT (n=80)	**NTT (n=161)**	**Total (n=241)**	
Time elapsed from onset of symptoms	<6 hours	29 (36.3)	20 (12.4)	49 (20.3)	χ^2=18,984 p=0.0001
	6-18 hours	10 (12.5)	23 (14.3)	33 (13.7)	
	>18 hours	41 (51.2)	118 (73.3)	159 (66.0)	
Age groups (in years)	0-1	11 (13.8)	9 (5.6)	20 (8.3)	χ^2=70.145 p=0.0001
	1-5	2 (2.5)	18 (11.2)	20 (8.3)	
	6-11	5 (6.3)	88 (54.7)	93 (38.6)	
	12-18	62 (77.5)	46 (28.6)	108 (44.8)	
Age (Median; IQR)		13 (11.5-15)	10 (7-11)	11 (7-13)	Z=-6.327 p=0.0001
Trauma	No	73 (91.3)	135 (83.9)	208 (86.3)	χ^2=2.476

Continued.

		Group			
		TT (n=80)	NTT (n=161)	Total (n=241)	
	Yes	7 (8.8)	26 (16.1)	33 (13.7)	p=0.163
Outcome	Orchidectomy	36 (45.0)	0 (0.0)	36 (14.9)	χ^2=85.173 p=0.0001
	Orchidopexy	44 (55.0)	161 (100.0)	205 (85.1)	
Doppler vascularisation	No vascularisation	57 (71.3)	26 (16.1)	83 (34.4)	χ^2=71.865 p=0.0001
	Vascularization	23 (28.7)	135 (83.9)	158 (65.6)	

Table 2: Comparison of BALS between TT and NTT groups.

		Group			
		TT (n=80)	NTT (161)	Total (n=241)	
BALS mean value (SD; IRQ)		2,64 (0.88; 2-3)	0.73 (0.9; 0-1)	1.37 (1.26; 0-2)	Z=-10.906 p=0.0001
BALS	<2 (low)	8 (10.0)	130 (80.7)	138 (57.3)	χ^2=111.523 p=0.0001
	2-3 (medium)	59 (73.8)	29 (18,0)	88 (36.5)	
	4 (high)	13 (16.3)	2 (1.2)	15 (6.2)	
Duration of symptoms less than 24 hours	No	41 (51.2)	119 (73.9)	160 (66.4)	χ^2=111.523 p=0.0001
	Yes	39 (48.8)	42 (26.1)	81 (33.6)	
Nausea/vomiting	No	54 (67.5)	126 (78.3)	180 (74.7)	χ^2=3.274 p=0.084
	Yes	26 (32.5)	35 (21.7)	61 (25.3)	
High-riding testicle	No	14 (17.5)	141 (87.6)	155 (64.3)	χ^2=114.357 p=0.0001
	Yes	66 (82.5)	20 (12.4)	86 (35.7)	
Abnormal cremasteric reflex	No	1 (1.3)	140 (87.0)	141 (58.5)	χ^2=161.712 p=0.0001
	Yes	79 (98.8)	21 (13.0)	100 (41.5)	

Table 3: Comparison of TWIST scores between TT and NTT groups.

		Group			
		TT (n=80)	NTT (n=161)	Total (n=241)	
TWIST mean value (SD; IRQ)		5.75 (1.25; 5-7)	3.00 (1.61; 2-4)	3.91 (1.98; 2-6)	Z=-10.209 p=0.0001
TWIST	≤2 (low)	1 (1.3)	82 (50.9)	83 (34.4)	χ^2=95.300 p=0.0001
	3-4 (medium)	13 (16.3)	48 (29.8)	61 (25.3)	
	≥5 (high)	66 (82.5)	31 (19.3)	97 (40.2)	
Nausea/vomiting	No	52 (65.0)	126 (78.3)	178 (73.9)	χ^2=4.205 p=0.030
	Yes	28 (35.0)	35 (21.7)	63 (26.1)	
High-riding testicle	No	14 (17.5)	140 (87.0)	154 (63.9)	χ^2=111.768 p=0.0001
	Yes	66 (82.5)	21 (13.0)	87 (36.1)	
Absent cremasteric reflex	No	1 (1.3)	140 (87.0)	141 (58.5)	χ^2=161.712 p=0.0001
	Yes	79 (98.8)	21 (13.0)	100 (41.5)	
Testicular swelling	No	4 (5.0)	15 (9.3)	19 (7.9)	χ^2=1.371 p=0.314
	Yes	76 (95.0)	146 (90.7)	222 (92.1)	
Hard testicle	No	13 (16.3)	104 (64.6)	117 (48.5)	χ^2=50.009 p=0.0001
	Yes	67 (83.8)	57 (35.4)	124 (51.5)	

Table 4: Comparison of BALS and TWIST scores using the Wilcoxon signed-rank test.

	Median (IRQ)	P value
BALS	1 (0-2)	p<0.0001
TWIST	4 (2-6)	

z=-13.193

Table 5: Correlation (Spearman) between BALS and TWIST Scores.

Coefficient value	95% CI	P value
$r_{s\,(238)}$ =0.773	0.742-0.893	<0.0001

Df (238)

Table 6: Agreement between BALS and TWIST diagnostic scores.

Kappa	0.243 (95% CI, 0.157-0.842)	p<0.0001

Table 7: Sensitivity, specificity, positive and negative predictive values of diagnostic scores in the diagnosis of testicular torsion.

	Sensitivity % (95% CI)	Specificity% (95% CI)	PPV % (95% CI)	NPV % (95% CI)
BALS (<2)	10.0 (4.43-18.76)	19.25 (13.47-26.2)	5.80 (2.54-11.11)	30.1 (21.45-39.2)
TWIST (≤2)	1.25 (0.21-6.80)	49.07 (1.12-57.05)	1.20 (0.20-6.56)	50.0 (41.95-58.05)
BALS (2-3)	73.75 (62.71-82.95)	81.99 (75.17-87.59)	67.05 (56.21-86.7)	86.27 (79.79-91.30)
TWIST (3-4)	17.5 (9.92-27.62)	19.25 (13.47-26.20)	9.72 (5.42-24.78)	31.96 (22.85-42.2)
BALS (4)	61.9 (38.45-81.84)	98.48 (94.62-99.54)	86.87 (59.51-97.95)	94.20 (88.86-97.46)
TWIST (≥5)	82,5 (72.38-90.08)	80.75 (73.80-86.53)	68.04 (57.8-77.15)	90.28 (84.22-94.58)

Table 8: Sensitivity, specificity, positive and negative predictive values of diagnostic scores by age groups of patients.

		Sensitivity% (95% CI)	Specificity% (95% CI)	PPV% (95% CI)	NPV% (95% CI)
BALS (<2)	0-1 year	44.45 (16.92-76.50)	44.44 (13.97-78.60)	50.00 (31.55-76.90)	40.00 (12.40-73.63)
	1-5 years	0.00 (0.00-80.71)	33.33 (13.42-58.99)	0.00 (0.00-26.65)	75.00 (35.05-96.07)
	6-11 years	0.00 (0.00-52.05)	12.50 (6.42-21.27)	0.00 (0.00-4.72)	68.75 (41.36-88.87)
	12-18 years	4.84 (1.07-13.51)	21.74 (10.97-36.37)	7.69 (1.70-20.89)	14.49 (7.19-25.05)
TWIST (≤2)	0-1 years	0.00 (0.00-28.67)	88.89 (51.74-98.16)	0.00 (0.00-83.45)	42.11 (20.30-66.47)
	1-5 years	0.00 (0.00-80.71)	44.44 (21.58-69.21)	0.00 (0.00-31.03)	80.00 (44.43-96.89)
	6-11 years	0.00 (0.00-52.05)	50.00 (39.15-60.85)	0.00 (0.00-8.12)	89.80 (77.76-96.56)
	12-18 years	1.61 (0.27-8.70)	41.30 (27.00-56.77)	3.57 (0.60-18.41)	23.75 (14.95-34.58)
BALS (2-3)	0-1 year	54.55 (23.50-83.08)	55.56 (21.40-86.03)	60.00 (26.37-87.60)	50.00 (18.98-81.11)
	1-5 years	100.00 (19.29-100.00)	70.59 (44.05-89.58)	28.57 (4.52-70.73)	100.00 (73.35-100.00)
	6-11 years	60.00 (15.40-93.51)	87.50 (78.73-93.58)	21.43 (4.91-50.79)	97.47 (91.13-99.62)
	12-18 years	77.42 (65.02-87.06)	80.43 (66.08-90.62)	84.21 (72.13-92.50)	72.55 (58.25-84.10)
TWIST (3-4)	0-1 year	18.18 (2.82-51.76)	77.78 (40.06-96.53)	50.00 (8.30-91.70)	43.75 (19.83-70.08)

Continued.

		Sensitivity% (95% CI)	Specificity% (95% CI)	PPV% (95% CI)	NPV% (95% CI)
	1-5 years	0.00 (0.00-80.71)	83.33 (58.56-96.23)	0.00 (0.00-69.52)	88.24 (63.52-98.20)
	6-11 years	20.00 (3.30-71.19)	63.64 (52.69-73.63)	3.03 (0.51-15.82)	93.33 (83.79-98.11)
	12-18 years	16.13 (8.03-27.67)	76.09 (61.23-87.40)	47.62 (25.75-70.19)	40.23 (29.85-51.29)
BALS (4)	0-1 year	-	-	-	-
	1-5 years	0.00 (0.00-80.71)	94.44 (72.63-99.07)	0.00 (0.00-83.45)	89.47 (66.82-98.39)
	6-11 years	40.00 (6.49-84.60)	100.00 (95.85-100.00)	100.00 (19.29-100.00)	96.65 (90.65-99.28)
	12-18 years	17.74 (9.22-29.54)	97.83 (88.43-99.64)	91.67 (61.46-98.61)	46.88 (36.61-57.34)
TWIST (≥5)	0-1 year	81.82 (48.24-97.18)	33.33 (7.88-69.93)	60.00 (32.33-83.57)	60.00 (15.40-93.51)
	1-5 years	100.00 (19.29-100.00)	72.22 (46.53-90.20)	28.57 (4.52-70.73)	100.00 (75.12-100.00)
	6-11 years	80.00 (28.81-96.70)	86.36 (77.39-92.74)	25.00 (7.42-52.37)	98.70 (92.95-99.78)
	12-18 years	82.26 (70.46-90.78)	82.61 (68.57-92.16)	86.44 (75.01-93.94)	77.55 (63.37-88.21)

Table 9: Sensitivity and specificity of BALS and TWIST scores depending on criterion value.

	Criterion	Sensitivity	Specificity
BALLS	≥0	100.00	0.00
	>0	100.00	50.93
	>1	90.00	80.75
	>2	57.50	96.27
	>3	16.25	98.76
	≥4	0.00	100.0
TWIST	≥0	100.00	0.00
	>1	100.00	9.32
	>2	98.75	50.93
	>3	92.50	62.73
	>4	82.50	80.75
	>5	70.00	91.93
	>6	31.25	98.14
	≥7	0.00	100.00

In the overall cohort, the mean BALS score was 1.37±1.26 (IQR: 0–2). TT patients had a mean BALS score of 2.64 (IQR: 2–3), whereas NTT patients had a mean score of 0.73 (IQR: 0–1). Most patients (57.3%) scored <2, corresponding to the low-risk category. Within the TT group, 73.8% had a BALS score of 2–3, while 80.7% of NTT patients scored <2 (Table 2). The mean TWIST score for the overall sample was 3.91±1.98 (IQR: 2–6). TT patients had a mean TWIST score of 5.75±1.25 (IQR: 5–7), and NTT patients had a mean score of 3.00 ± 1.61 (IQR: 2–4). The highest proportion of patients (40.2%) had a TWIST score ≥5, corresponding to the high-risk category, and all clinical symptoms included in the TWIST score, except testicular swelling, were significantly more frequent in TT patients (Table 3).

The median BALS score was 1 (IQR: 0–2), and the median TWIST score was 4 (IQR: 2–6). Wilcoxon signed-rank testing confirmed a statistically significant difference between these medians ($z=-13.193$; $p<0.0001$) (Table 4). Spearman's rank correlation showed a strong positive correlation between BALS and TWIST scores in TT patients ($r_s=0.773$; $p<0.0001$) (Table 5), and Cohen's kappa indicated moderate agreement between the two scoring systems ($\kappa=0.243$; 95% CI: 0.157–0.842; $p<0.0001$) (Table 6). At a BALS score of 4 and a TWIST score ≥5, the diagnostic performance was as follows: BALS-sensitivity 61.9%, specificity 98.48%, PPV 86.87%, NPV 94.2%; TWIST-sensitivity 82.5%, specificity 80.75%, PPV 68.04%, NPV 90.28% (Table 7). Age-stratified analyses demonstrated variable diagnostic performance: for 0–1 year, BALS sensitivity 54.55% and

specificity 55.56%, TWIST sensitivity 81.82% and specificity 33.33%; for 2–5 years, BALS and TWIST both had 100% sensitivity with specificity of 70.59% and 72.22%, respectively; for 6–11 years, BALS sensitivity 40% and specificity 100%, TWIST sensitivity 80% and specificity 86.36%; and for 12–18 years, BALS sensitivity 77.42% and specificity 80.43%, TWIST sensitivity 82.26% and specificity 82.61% (Table 8).

ROC curve analysis confirmed the clinical utility of both scoring systems. The BALS score demonstrated a slightly higher area under the curve (AUC=0.917; 95% CI: 0.875–0.949) than TWIST (AUC=0.897; 95% CI: 0.851–0.932), though the difference was not statistically significant (z=0.837; p=0.403). The optimal cut-off values were >1 for BALS (sensitivity 90.0%, specificity 80.75%) and >4 for TWIST (sensitivity 82.5%, specificity 80.75%) (Table 9, Figure 1).

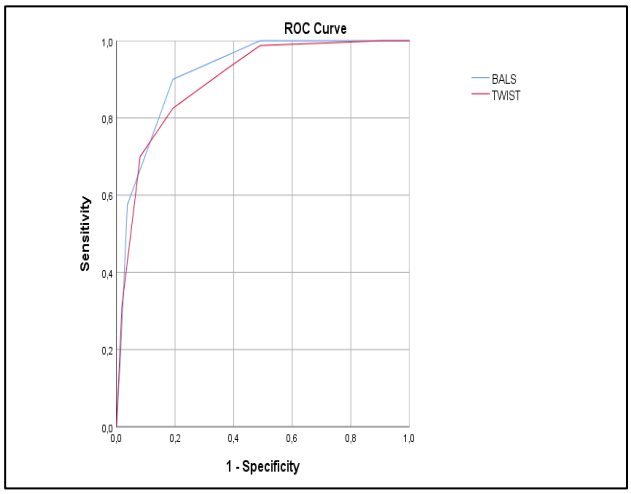

Figure 1: ROC curve for BALS and TWIST scores.

DISCUSSION

Acute scrotum is a common medical emergency encountered in surgical departments and emergency care, with TT representing the leading cause in the pediatric population. Diagnosing TT is both challenging and time-sensitive. Many cases present ambiguously, often prompting additional diagnostic tests and procedures, which may delay urgent surgical intervention.[14] Studies have reported delays of 48 to 119 minutes due to color Doppler ultrasonography, highlighting the need for efficient, clinically-based decision-making. Clinical scoring systems such as BALS and TWIST may help identify high-risk patients, potentially reducing reliance on imaging and laboratory tests.[9,15-18]

In this study, 241 patients aged 0–18 years who underwent surgery for acute scrotum were evaluated using the BALS and TWIST scores. Based on intraoperative diagnoses, 80 patients (33.2%) were classified as TT and 161 patients (66.8%) as NTT. The most represented age group was 12–18 years (44.8%), consistent with previous reports indicating a peak incidence during early adolescence.[3,19,20] The lowest patient numbers were observed in the 0–1 year and 1–5-year groups (8.3% each), although a secondary neonatal peak is recognized in the literature.[3,21]

Symptom duration prior to surgical evaluation was often prolonged. Among TT patients, 51.2% presented more than 18 hours after symptom onset, while 73.3% of NTT patients sought care after this interval. Delayed presentation may reflect parental unawareness, delayed primary care evaluation, or referral delays. Literature suggests that the risk of orchiectomy increases with time, with critical testicular salvage occurring within 4–8 hours of symptom onset.[22]

Trauma accounted for a minority of cases, consistent with prior studies estimating 5–8% of TT cases as trauma-related.[23,24] In this cohort, trauma history was noted in 8.8% of TT patients and 16.1% of NTT patients. Overreliance on imaging, particularly ultrasound, poses challenges in resource-limited settings, and some institutions prefer immediate surgical exploration guided by clinical assessment.[14]

Clinical scoring systems provide objective support for diagnosis. In our study, TT patients had significantly higher TWIST scores compared to NTT patients, aligning with prior reports by Frohlich et al, Pan et al and Manohar et al.[4,25,26] Similarly, BALS scores reflected high-risk status in the majority of TT patients, with 73.8% scoring, consistent with original studies by Boettcher et al and Klinke et al.[2,3,6,27] The TWIST score also demonstrated high diagnostic value: 82.5% of TT patients had scores ≥5, compared to 19.3% of NTT patients, corroborating findings by Pan et al and other investigators.[25] Although predictive values in this study were slightly lower than those reported in original studies Barbosa et al sensitivity, specificity, PPV, and NPV remained within acceptable ranges, supporting TWIST as an effective clinical tool.[9]

Analysis of optimal cut-off values revealed that a BALS score >1 achieved 90.0% sensitivity and 80.75% specificity, while a TWIST score >4 achieved 82.5% sensitivity and 80.75% specificity. Both scoring systems demonstrated high diagnostic utility, with areas under the ROC curve exceeding 0.5, consistent with prior reports. Sheth et al reported an AUC of 0.95, Frohlich et al reported 0.82, and Barbosa et al demonstrated AUCs of 0.983 and 0.996 in prospective and retrospective analyses, respectively.[4,9,13]

Overall, these findings reinforce the clinical relevance of BALS and TWIST scoring systems in the evaluation of pediatric acute scrotum. They support rapid risk stratification, help guide surgical decision-making, and may reduce unnecessary imaging, ultimately improving patient outcomes.

CONCLUSION

The clinical scoring systems, TWIST and BALS, demonstrate substantial diagnostic value and can assist in the evaluation of testicular torsion in children. Their high accuracy across different pediatric age groups supports their use in emergency settings. However, these scores should not be used as the sole criterion for surgical decision-making. By standardizing clinical and physical findings, TWIST and BALS provide a structured and reliable diagnostic framework, potentially enabling the exclusion of testicular torsion even at the primary healthcare level.

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