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Original Article

Enhancing diagnostic accuracy in acute scrotum in the pediatric emergency department: A combined diagnostic model integrating the TWIST score and systemic inflammatory markers

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ABSTRACT

Objective: Timely and accurate differentiation of testicular torsion (TT) from epididymo-orchitis (EO) in pediatric patients presenting with acute scrotum is crucial to prevent testicular loss. The Testicular Workup for Ischemia and Suspected Torsion (TWIST) score is widely used, but lacks laboratory markers. We aimed to evaluate whether combining systemic inflammatory markers with the TWIST score improves diagnostic accuracy.

Materials and Methods: We retrospectively evaluated 99 pediatric patients diagnosed with TT (n=50) or EO (n=49). Clinical findings, TWIST scores, and inflammatory markers (NLR, SII, PLR) were recorded. Receiver operating characteristic (ROC) analysis was used to assess diagnostic performance. Multivariable logistic regression was performed to build a combined diagnostic model using TWIST score and the single most predictive inflammatory marker (NLR) to avoid potential collinearity between collinear biomarkers.

Results: A total of 99 pediatric patients were included in the study; TT was diagnosed in 50 (50.5%) and EO in 49 (49.5%) of them. Patients with TT had significantly higher TWIST scores, NLR, and SII values compared to those with EO. While individual ROC analyses demonstrated high discriminatory performance for both NLR (AUC: 0.871) and SII (AUC: 0.866), the model combining the TWIST score and NLR yielded a higher AUC (0.915) than the TWIST score alone (AUC: 0.795), suggesting improved diagnostic discrimination.

Conclusion: Integrating NLR with the clinical TWIST score may enhance diagnostic accuracy in pediatric acute scrotum, providing a simple and robust clinical decision-support tool to guide early surgical decision-making.

Keywords: Epididymitis, inflammation, spermatic cord torsion, testicular torsion, TWIST score

Introduction

Acute scrotum is usually characterized by sudden onset of scrotal redness, swelling, and pain associated with inflammatory processes (1,2). The main causes of acute scrotum include torsion of the testis and its appendages, epididymitis and orchitis, incarcerated inguinal hernia, hydrocele, trauma, testicular laceration, scrotal edema, acute varicocele, testicular tumor, Henoch-Schönlein purpura, and scrotal abscess (3). Epididymo-orchitis (EO) is inflammation of the epididymis and testicles and is the most common cause of acute scrotum in prepubertal boys and is usually treated conservatively (4). Testicular torsion (TT) occurs as a result of the spermatic cord twisting around itself and requires urgent surgical intervention. Among the two most common etiologies, delay in TT diagnosis can lead to permanent testicular damage and infertility (2,5-7).

In the literature, the Testicular Workup for Ischemia and Suspected Torsion (TWIST) scoring system has been shown to be useful in the diagnosis of testicular torsion (8). Although the TWIST score helps to practically estimate TT risk at the bedside, it has some limitations, especially in cases of intermittent torsion. The most commonly used method for diagnosing testicular torsion is Color Doppler Ultrasonography (CDUS). However, in some cases of testicular torsion, it has been shown that testicular blood flow continues (9). Additionally, among the disadvantages of CDUS are that it is not always accessible and that it depends on the radiologist's experience (10).

In recent years, studies have been conducted on systemic inflammatory markers such as the neutrophil-lymphocyte ratio (NLR), platelet-lymphocyte ratio (PLR), and systemic immune-inflammation index (SII) that evaluate laboratory tests in the diagnosis of TT (11). However, these parameters

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have not yet been integrated into a validated clinical scoring system.

The aim of this study was to evaluate a combined diagnostic model integrating clinical TWIST Score with systemic inflammatory markers for the differential diagnosis of TT and EO in the pediatric emergency department, and to develop a new clinical decision support tool that could increase diagnostic accuracy in early diagnosis.

Materials and Methods

Study design and setting

In this retrospective observational study, the medical records of patients aged 0-18 years who presented to the pediatric emergency department of Dr. Sami Ulus Maternity, Child Health and Diseases Training and Research Hospital, a tertiary pediatric referral center in Ankara, with acute scrotal pain between July 1, 2017, and July 31, 2022, were reviewed.

Patient selection

The definitive diagnosis of TT was confirmed through surgical exploration by a pediatric surgeon, whereas the diagnosis of EO was established by pediatric emergency and pediatric surgery specialists based on clinical and CDUS findings. Trauma history, previous scrotal surgery, and other causes of acute scrotum were exclusion criteria. A total of 99 patients meeting the inclusion criteria were analyzed: 50 were diagnosed with TT and 49 with EO. The flow chart of patient selection and exclusion criteria is shown in Figure 1.

Clinical and laboratory data collection

From medical records; patients' age, the time between symptom onset and hospital presentation, and physical examination findings at presentation were recorded. The TWIST Score was calculated for each patient using the scale: testicular swelling (2 points), firm testicle (2 points), absence of cremasteric reflex (1 point), nausea or vomiting (1 point), and high-riding testis (1 point). Patients with a score of ≥5 were categorised as high risk for testicular torsion.

The white blood cell count (WBC), absolute neutrophil count (ANC), absolute lymphocyte count (ALC), platelet count (PLT), NLR, PLR, and SII were recorded at presentation. SII was calculated using the formula: platelets × neutrophil/lymphocyte count.

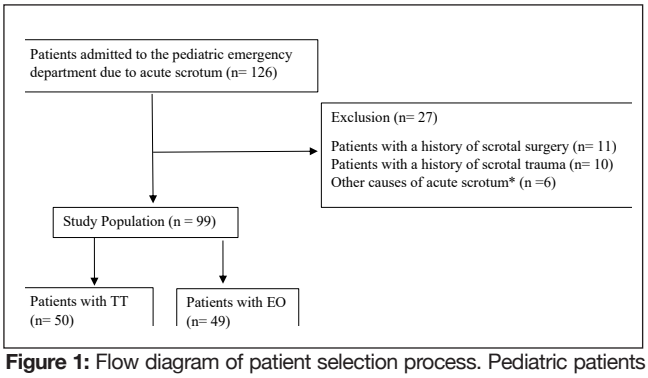


Figure 1: Flow diagram of patient selection process. Pediatric patients presenting with acute scrotal pain were evaluated between July 2017 and July 2022. A total of 99 patients (50 testicular torsion, 49 epididymo-orchitis) were included in the final analysis. ***:** Hydrocele, Inguinal Hernia, Henoch-Schönlein Purpura, Varicocele, **TT:** Testicular Torsion, **EO:** Epididymo-orchitis

Statistical Analysis

SPSS (Statistical Package for Social Sciences) for Windows 22.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. The distribution of variables was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Continuous variables were expressed as medians and interquartile ranges (IQRs) due to non-normal distribution, and categorical variables were summarized as counts and percentages (n, %). Categorical variables were analyzed using the chi-square or Fisher's exact test, while continuous variables were compared using the Mann–Whitney U or independent t-test, depending on data distribution. ROC analysis was used to evaluate the diagnostic value of TWIST Score, NLR, PLR, and SII, and to calculate the area under the curve (AUC) for each parameter. The optimal cut off values were determined using the Youden index. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for the TWIST Score, individual biomarkers and the combined model. Multivariable logistic regression analysis was performed to identify independent predictors of TT and to generate predicted probabilities for the combined model (TWIST + NLR). A p-value of less than 0.050 was considered statistically significant.

Results

A total of 99 pediatric patients were included in the study; TT was diagnosed in 50 (50.5%) and EO in 49 (49.5%) of them. The median age of patients was 144 (IQR: 111–177) months, and the median age of patients in the TT group was significantly higher than that in the EO group [162.5 months (IQR: 138–183) vs. 124.0 months (IQR: 85–150), p<0.001]. The symptom duration was significantly shorter in TT patients [6 hours (IQR: 3–8)] compared to EO patients [24

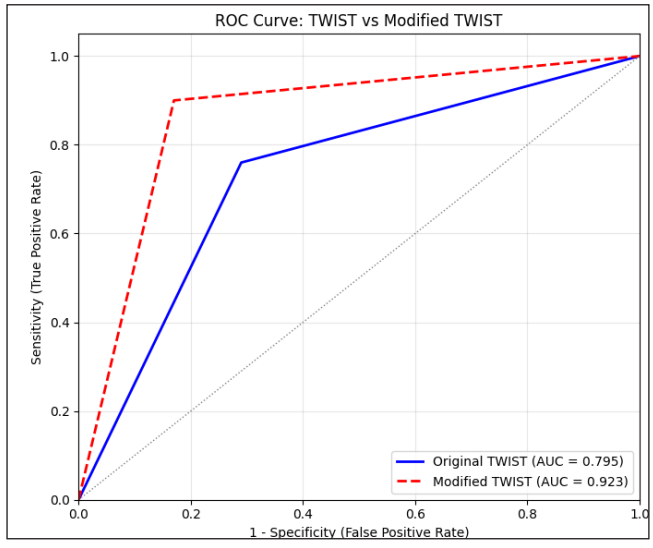


Figure 2: ROC curves illustrating and comparing the diagnostic accuracy of the original clinical TWIST score (AUC: 0.795) and the Combined Diagnostic Model integrating TWIST score with NLR (AUC: 0.915).

Table I: Demographicand clinical characteristics of the patients

	Total	Testicular Torsion	Epididymo orchitis	p
Total number of patients	99	50	49	-
Age,month*	144 (111-177)	162.5 (138-183)	124 (85-150)	<0.001
Side†				
Right	52 (52.5)	24 (48)	28 (57.1)	0.353
Left	46 (46.4)	26 (52)	20 (40.8)	
Bilateral	1 (1.01)	-	1 (2.04)	
TWIST Score*	-	4.0 (2.0-5.0)	2.0 (2.0–3.25)	<0.001
TWIST Category†				
Low Risk	40 (40.4)	3 (6)	37 (75.5)	<0.001
Middle Risk	32 (32.3)	22 (44)	10 (20.4)	
High Risk	27 (27.2)	25 (50)	2 (4.9)	
Scrotal Swelling†	77 (77.7)	42 (86)	35 (71.4)	0.103
Hard Testis†	4 (4.04)	2 (4)	2 (4.08)	0.684
Absence of cremasteric reflex†	55 (55.5)	43 (86)	12 (24.4)	<0.001
High riding testis†	34 (34.3)	32 (64)	2 (4.08)	<0.001
Nausea / vomiting†	32 (32.3)	29 (58)	3 (6.1)	<0.001
Abdominal pain†	12 (12.1)	11 (22)	1 (2.04)	0.002
Groin pain†	98 (98.9)	49 (98)	49 (100)	0.505
Scrotal Tenderness†	97 (97.9)	49 (98)	48 (97.9)	0.747
Scrotal redness†	57 (57.5)	23 (46)	34 (69.3)	0.015
Symptom duration, hour*	8 (6- 24)	6 (3-8)	24 (12-48)	<0.001

: median (IQR) (Mann–Whitney U), †: n(%) (chi-square or Fisher's exact test)

hours (IQR: 12–48)] (p<0.001). Of the 50 patients diagnosed with TT, seven had a symptom duration of 12 hours or longer, and necrotic areas were detected in four of these patients (57.1%) during surgery. In 43 TT patients (86%), the symptom duration was less than 12 hours, and necrotic areas were detected in three of them (6.9%). High-riding testis (p<0.001), absence of cremasteric reflex (p<0.001), and nausea or vomiting (p<0.001) were significantly more common in the TT group. Additionally, abdominal pain was also reported more frequently in the TT group (p=0.020). The edian TWIST Score was significantly higher in TT patients [(4.0 (IQR: 2.0–5.0)] compared to EO patients [2.0 (IQR: 2.0–3.25)] (p<0.001). The demographic and clinical characteristics of patients diagnosed with TT and EO are presented in Table I.

CDUS was performed on all patients. According to the results, TT diagnosis was initially made in 51 patients using CDUS, but EO diagnosis was confirmed in three of these patients (5.9%) as a result of surgical exploration. In contrast, normal perfusion was observed on CDUS in two patients (4.0%) who ultimately received a TT diagnosis.

When the laboratory data of patients at the time of presentation were evaluated, the median WBC (p<0.001), ANC (p<0.001), NLR (p<0.001), PLR (p=0.002), and SII (p<0.001) values were found to be significantly higher in TT patients. The laboratory data of the patients are presented in Table II.

Table II: Laboratory parameters and diagnostic performance of TWIST, inflammatory markers and combined model in diagnosing testicular torsion

Laboratory Parameter	TT Group*	EO Group*	p
WBC (×10³/μL)	12.3 (10.6–14.8)	9.2 (7.8–10.9)	<0.001
ANC (×10³/μL)	8.4 (6.7–10.2)	5.6 (4.2–7.0)	<0.001
NLR	4.2 (3.1–5.8)	2.1 (1.5–3.0)	<0.001
PLR	152 (132–179)	110 (91–127)	0.002
SII	1120 (905–1410)	650 (478–815)	<0.001

: median (IQR) (Mann–Whitney U)

ROC analysis demonstrated that NLR and SII have high diagnostic performance in identifying TT. The AUC for NLR was 0.871 (95% CI: 0.79–0.93), and the optimal cut off value was determined to be 3.16; at this value, sensitivity was 84.0% and specificity was 77.6%. The AUC for SII was 0.866 (95% CI: 0.79–0.92), with a cutoff value of 921; sensitivity was determined to be 78.0% and specificity 81.6%. PLR showed moderate performance (AUC: 0.726). In multivariable logistic regression analysis, TWIST ≥5 (OR =7.3, 95% CI: 3.1–17.4, p<0.001) and NLR >3.16 (OR=5.8, 95% CI: 1.9–11.6, p=0.002) were identified as independent predictors for TT (Table III). To avoid statistical collinearity while capturing both clinical and inflammatory risk factors, a combined diagnostic model integrating the TWIST score with NLR was evaluated. According to ROC analysis, the AUC value of the combined model (TWIST+NLR) was 0.915, demonstrating superior diagnostic performance compared to the original TWIST Score alone (AUC:0.795, sensitivity 76.0%, specificity 71.0%). Comparative ROC curves are presented in Figure 2, while detailed laboratory values and diagnostic measurements are presented in Table II-III.

Discussion

In this study, we evaluated pediatric patients presenting to the emergency department with acute scrotal pain to determine the diagnostic utility of combining clinical risk stratification with systemic inflammatory biomarkers. Differentiating testicular torsion from epididymo-orchitis remains a high-stakes clinical challenge where rapid diagnosis directly dictates organ salvage. Our findings indicate that integrating peripheral inflammatory markers—specifically the neutrophil-to-lymphocyte ratio—with the TWIST score substantially improves diagnostic performance.

Testicular torsion and EO are among the most common causes of acute scrotum, and confirming the diagnosis is important for rapid treatment planning (12). While the main treatment option for TT is surgical intervention, conservative treatments are preferred for EO (13). When torsion develops, testicular venous drainage is affected first, followed by edema, hemorrhage, and finally a decrease in arterial blood flow (14). If blood flow decreases, the testicle begins to be affected within 4–6 hours and necrosis occurs (15). The testis preservation rate is nearly 100% in cases operated on within the first 6 hours, while this rate drops to 20% in cases treated after 12 hours (16,17). In our study, consistent with

Table III: ROC analysis for diagnostic accuracy and multivariable logistic regression for independent predictors of testicular torsion

Variable	AUC	Cut-off	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Odds Ratio (95% CI)	p
TWIST Score	0.795	≥5	76.0	71.0	78.5	69.2	7.3 (3.1–17.4)	<0.001
NLR	0.871	>3.16	84.0	77.6	80.7	81.2	5.8 (1.9–11.6)	0.002

ROC: *Receiver Operating Characteristic,* ***AUC:*** *Area Under the Curve,* ***PPV:*** *Positive Predictive Value,* ***NPV:*** *Negative Predictive Value.*

the literature, necrotic areas were detected in four (57.1%) of seven TT patients with a symptom duration of 12 hours or longer. No necrosis was observed in three (6.9%) of the 43 TT patients with a symptom duration of less than 12 hours. Therefore, early diagnosis and prompt treatment in patients suspected of having TT are crucial in preventing the development of necrosis. Clinical findings are highly valuable in the diagnosis of TT in children presenting with scrotal pain. The TWIST score is the most commonly used scoring system for diagnosing TT (12,18). In a study evaluating 96 pediatric patients presenting with acute scrotal complaints, the mean TWIST score was 5.7±1.2 in the TT group and 1.46±0.67 in the non-torsion group (19). In our study, the median TWIST score was 4.0 (2.0–5.0) in TT patients and 2.0 (2.0–3.25) in EO patients. The absence of the cremasteric reflex, a component of the TWIST scoring system, is an important finding in favor of TT (20). In our study, 86% of TT patients had no cremasteric reflex, while this rate was 24.4% in EO patients. Other components of the TWIST scoring system, such as high-riding testis and nausea/vomiting, were also more common in TT patients. The TWIST score may be guiding in the differentiation between TT and EO in patients presenting with acute scrotal pain.

In the diagnosis of acute scrotum, CDUS can be used to evaluate testicular perfusion, testis size, and echogenicity. Absence of arterial perfusion may indicate TT or early-stage partial/intermittent torsion, but continued perfusion does not rule out TT. In the early stages of TT, CDUS may cause false negative results in intermittent or incomplete torsion (21). In this study, two patients with CDUS results favorable for EO were diagnosed with TT during surgery. Additionally, three patients suspected of having TT based on CDUS were diagnosed with EO after surgery. These findings highlight the drawbacks of relying solely on ultrasound findings, particularly in cases of intermittent or partial torsion or when the operator's experience is limited.

Systemic inflammation plays a prominent role in the ischemic cascade following spermatic cord torsion (22). Torsional ischemia triggers an acute systemic stress response characterized by rapid neutrophil activation and relative lymphopenia. In previous studies, when patients diagnosed with acute scrotum were compared with healthy control groups, WBC, ANC, AMC, PLR, and NLR levels were found to be higher in TT patients (23,24). It has been reported that NLR levels show a positive correlation with symptom duration and represent a critical factor affecting testicular salvage within the first 12 hours (25). Zhu et al. (26) mphasized that WBC, PLT, and NLR may be decisive in distinguishing TT from EO. It is well established that ischemia and reperfusion injury are the fundamental mechanisms in TT (27). During this process, ALC decreases while ANC increases in peripheral blood in response to systemic inflammation (28). In our study, WBC, ANC, NLR, PLR, and SII were likewise significantly elevated in TT patients. While hematologic parameters demonstrated diagnostic capacity in our cohort, incorporating the NLR alongside the TWIST score into a combined multivariable predictive model achieved superior diagnostic accuracy compared to the TWIST score alone. This combined approach may offer significant practical benefits in emergency settings. Integrating laboratory-derived inflammatory indicators with clinical examination scores may enable clinicians to make safer, faster surgical decisions, particularly in resource-limited or high-volume pediatric emergency departments.

Limitations

This study has limitations, including its retrospective single-center design and relatively small sample size. Additionally, systemic inflammatory markers can be influenced by concurrent systemic conditions or infections. Prospective, multicenter studies with larger pediatric cohorts are warranted to validate these clinical decision models.

Conclusion

In conclusion, combining the clinical TWIST score with the neutrophil-to-lymphocyte ratio may enhance diagnostic performance for distinguishing testicular torsion from epididymo-orchitis in pediatric emergency practice. This integrated strategy may provide a reliable, accessible decision-support mechanism when ultrasound is unavailable or equivocal.

Ethics committee approval

This study was conducted in accordance with the Helsinki Declaration Principles. The study was approved by Dr. Sami Ulus Maternity, Child Health and Diseases Training and Research Hospital (21.09.2022, reference number: E-22/09-434).

Contribution of the authors

Study concept and design: BA, AG, İB, OA, NT. Analysis and interpretation of data: BA, OA, BÖ, RMY, Cİ. Drafting of the manuscript: BA, AG, HGÇ, İFÖ, MMG. Critical revision of the manuscript for important intellectual content: BA, AG, NT. All authors reviewed the results and approved the final version of the article.

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Conflict of interest

The authors declare that there is no conflict of interest.

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