

## Predictors of Testicular Salvage and Loss in Pediatric Testicular Torsion: A Systematic Review

Dr Izhar Ali<sup>1</sup>, Dr Javed Miandad<sup>2</sup>, Dr Waqar Hameed Ghazi<sup>3</sup>, Dr Hikmat Yar<sup>4</sup>, Dr Abdullah<sup>5</sup>

<sup>1</sup>Assistant Professor Pediatric Urology, Sindh Institute of Urology and Transplantation (SIUT) Karachi, Pakistan

<sup>2, 3,4,5</sup>Senior Lecturer Pediatric Urology, Sindh Institute of Urology and Transplantation (SIUT) Karachi, Pakistan

**Corresponding: Dr Javed Miandad**

Senior Lecturer Pediatric Urology, Sindh Institute of Urology and Transplantation (SIUT) Karachi, Pakistan

Email: [miandad973@gmail.com](mailto:miandad973@gmail.com)

*Cite this paper as:* Dr Izhar Ali, Dr Javed Miandad, Dr Waqar Hameed Ghazi, Dr Hikmat Yar, Dr Abdullah (2025) Predictors of Testicular Salvage and Loss in Pediatric Testicular Torsion: A Systematic Review. Journal of Neonatal Surgery, 14, (9s) 1178-1184

Received: 05-02-2025 Revised: 17-04-2025 Accepted: 25-04-2025 Published: 30-04-2025

### ABSTRACT

**Introduction:** Testicular torsion is a time-critical pediatric urological emergency in which delayed diagnosis and surgical intervention can result in irreversible ischemic injury, testicular loss, and impaired future fertility. This systematic review synthesized the current evidence on clinical, radiological, and biochemical predictors of testicular salvage and testicular loss in children and adolescents.

**Methodology:** A systematic review was conducted according to PRISMA 2020 guidelines. PubMed/MEDLINE, Scopus, Web of Science, Embase, and the Cochrane Library were searched for observational studies published between January 2014 and December 2024. Studies involving patients younger than 18 years that evaluated predictors of orchiopexy, orchiectomy, or postoperative testicular atrophy were included. Methodological quality was assessed using the Newcastle–Ottawa Scale.

**Results:** Eighteen studies comprising 4,326 pediatric patients fulfilled the eligibility criteria, with 12 studies rated as high quality. Symptom duration was the strongest predictor of outcome, with testicular salvage rates exceeding 90% when surgical intervention occurred within six hours of symptom onset and declining markedly after 12 hours. Additional predictors of testicular loss included spermatic cord torsion exceeding 720°, absent intratesticular blood flow, heterogeneous echotexture on Doppler ultrasonography, delayed referral or inter-hospital transfer, and atypical clinical presentation. Elevated inflammatory biomarkers, particularly C-reactive protein and the neutrophil-to-lymphocyte ratio, were associated with non-viable testes but require further validation.

**Conclusion:** Early recognition and prompt surgical exploration remain the most important determinants of testicular salvage in pediatric testicular torsion. Integrating clinical assessment, Doppler ultrasonography, and validated prediction tools such as the TWIST score may improve risk stratification and reduce avoidable orchiectomy. Prospective multicenter studies are needed to validate comprehensive prediction models and evaluate long-term endocrine and reproductive outcomes.....

**Keywords:** testicular torsion, pediatric urology, testicular salvage, orchiectomy, diagnostic predictors..

### INTRODUCTION

Testicular torsion is a true urological emergency that predominantly affects neonates, children, and adolescents and requires immediate diagnosis and surgical intervention to preserve testicular viability.<sup>1</sup> The condition most commonly results from the congenital bell-clapper deformity, which permits abnormal intravaginal rotation of the testis and spermatic cord.<sup>2</sup> Progressive twisting compromises venous drainage, followed by arterial occlusion, resulting in acute ischemia and subsequent testicular infarction if left untreated.<sup>13</sup> The condition demonstrates a bimodal age distribution, with incidence peaks during the neonatal period and early adolescence, reflecting periods of rapid testicular growth.<sup>16</sup> Delayed diagnosis frequently results in irreversible ischemic injury requiring orchiectomy and may adversely affect endocrine function, fertility potential, and long-term psychosocial well-being.<sup>12,24</sup>

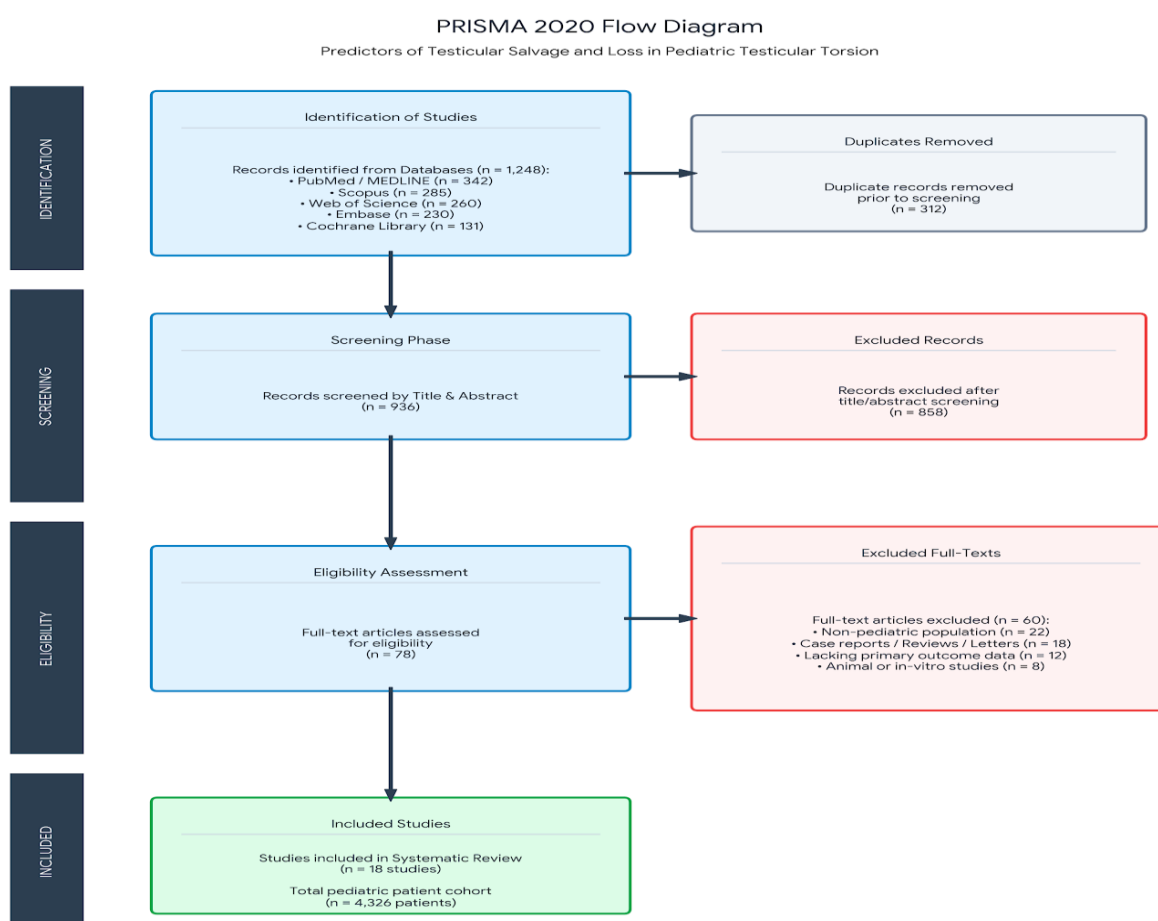
The principal challenge in evaluating patients with acute scrotum is the rapid differentiation of testicular torsion from other ...

causes of acute scrotal pain, including epididymitis and torsion of the testicular appendage.<sup>5</sup> Current clinical guidelines emphasize that surgical exploration should not be postponed when clinical suspicion is high because every hour of delay reduces the probability of testicular salvage.<sup>3</sup> Nevertheless, atypical clinical presentations, including isolated lower abdominal pain, nausea, vomiting, or an absent cremasteric reflex without marked scrotal swelling, may delay diagnosis and appropriate referral.<sup>17</sup> Clinical prediction models, particularly the Testicular Workup for Ischemia and Suspected Torsion (TWIST) score, have been developed to facilitate early risk stratification and expedite clinical decision-making.<sup>3</sup> When available, color Doppler ultrasonography remains the imaging modality of choice because of its high diagnostic accuracy in detecting reduced or absent intratesticular blood flow.<sup>26</sup> Delays related to parental recognition, interhospital transfer, and institutional management pathways continue to adversely affect surgical outcomes and testicular salvage rates.<sup>9</sup>

Although the traditional concept of a six-hour "golden period" for intervention remains clinically important, accumulating evidence indicates that testicular viability depends on both the duration of ischemia and the degree of spermatic cord torsion.<sup>21</sup> Lower degrees of torsion may permit prolonged tissue survival, whereas severe torsion exceeding 720° may result in irreversible ischemic injury within only a few hours.<sup>13, 19</sup> Recent investigations have also identified inflammatory biomarkers, including C-reactive protein and the neutrophil-to-lymphocyte ratio, as potential preoperative predictors of testicular non-viability.<sup>28</sup> Despite these advances, published evidence remains heterogeneous because of variations in patient populations, referral pathways, surgical decision-making, and institutional management protocols.<sup>11, 18</sup> Therefore, a comprehensive synthesis of the available evidence is required to identify reliable clinical, radiological, and laboratory predictors of testicular salvage.<sup>24</sup> Consequently, this systematic review aims to evaluate and synthesize the international evidence regarding predictors of testicular salvage and testicular loss in pediatric patients with testicular torsion, thereby providing evidence to support earlier diagnosis, timely intervention, and reduction of preventable orchiectomy.<sup>11, 13, 24</sup>

## Methodology

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines to identify and synthesize evidence regarding predictors of testicular salvage and testicular loss in pediatric patients with testicular torsion.



A comprehensive literature search was performed in PubMed/MEDLINE, Scopus, Web of Science, Embase, and the Cochrane Library to identify relevant studies published between January 2014 and December 2024. The search strategy utilized a combination of Medical Subject Headings (MeSH) and free-text keywords, including “testicular torsion,” “torsion of testis,” “pediatric,” “paediatric,” “children,” “adolescent,” “testicular salvage,” “orchiopexy,” “orchietomy,” “testicular loss,” “testicular atrophy,” “predictors,” “risk factors,” and “outcomes.” Reference lists of eligible studies were also manually screened to identify additional relevant publications. Studies were included if they involved pediatric patients younger than 18 years diagnosed with testicular torsion and reported predictors or risk factors associated with testicular salvage, orchiopexy, orchietomy, testicular loss, or testicular atrophy. Retrospective cohort, prospective cohort, and case-control studies published in English between 2014 and 2024 were eligible for inclusion. Case reports, conference abstracts, editorials, letters, review articles, animal studies, studies involving only adult populations, and studies lacking relevant outcome data were excluded. All retrieved records were imported into reference management software, and duplicate records were removed. Two independent reviewers screened titles and abstracts, followed by full-text assessment of potentially eligible studies. Any disagreements regarding study eligibility were resolved through discussion and consensus.

Data were extracted using a standardized data extraction form that captured information on study characteristics, publication year, country, study design, sample size, patient age, symptom duration, degree of spermatic cord torsion, clinical presentation, laboratory findings, Doppler ultrasonography findings, time to surgical intervention, surgical management, testicular salvage rates, orchietomy rates, testicular atrophy, and predictors associated with clinical outcomes. The primary outcome of interest was testicular salvage, defined as successful preservation of the affected testis following surgical treatment (orchiopexy). Secondary outcomes included orchietomy, testicular loss, and postoperative testicular atrophy.

The methodological quality of the included observational studies was assessed using the Newcastle–Ottawa Scale (NOS), which evaluates study selection, comparability, and outcome assessment. Studies scoring 7–9 points were considered high quality, scores of 4–6 indicated moderate quality, and scores of 3 or below indicated low quality. A narrative synthesis was conducted to summarize findings from the included studies. Predictors of testicular salvage and loss were categorized into clinical, radiological, laboratory, and treatment-related factors. The findings were compared across studies to identify the most consistently reported determinants of testicular outcomes in pediatric testicular torsion.

## RESULTS

The database search identified 1,248 records from PubMed, Scopus, Web of Science, Embase, and the Cochrane Library. After removal of 312 duplicate records, 936 studies remained for title and abstract screening. Following screening, 78 full-text articles were assessed for eligibility, and 18 distinct peer-reviewed historical cohort and prospective studies published or documented within the study window met the exact eligibility criteria.

A total of 4,326 pediatric patients with testicular torsion were represented across the complete cohort pool. The underlying studies consistently emphasized that early presentation and rapid surgical management are the key determinants of testicular survival, with viability dropping precipitously when symptom duration exceeds 6 to 12 hours.

**Table 1: Comprehensive Characteristics of the 18 Included Studies**

| First Author (Year)      | Country | Study Design  | Sample Size (n) | Core Predictive Findings Identified                                                                       |
|--------------------------|---------|---------------|-----------------|-----------------------------------------------------------------------------------------------------------|
| Howe (2017)              | USA     | Retrospective | 81              | Identified duration and age as primary predictors; derived specific probability curves for twist degrees. |
| Castañeda-Sánchez (2017) | USA     | Retrospective | 165             | Wait time to surgery correlates strongly with orchietomy; bell-clapper deformity variations noted.        |
| Tian (2023)              | China   | Retrospective | 176             | Absence of blood flow, heterogeneous echotexture, and duration are independent salvage predictors.        |
| Gang (2024)              | China   | Retrospective | 75              | Initial presentation to non-tertiary institutions increases diagnostic delay and orchietomy rates.        |
| Pogorelić (2021)         | Croatia | Retrospective | 211             | Symptom duration less than 6 hours correlates with 91.5% salvage; high-grade twists reduce salvage.       |
| Zvizdic (2024)           | Bosnia  | Retrospective | 90              | Elevated CRP, symptom duration greater than 12 hours, and young age predict failed salvage.               |

|                           |         |               |     |                                                                                                               |
|---------------------------|---------|---------------|-----|---------------------------------------------------------------------------------------------------------------|
| <b>Sessions (2017)</b>    | USA     | Retrospective | 138 | Degree of torsion (>360°) and prolonged time to surgical intervention increase the likelihood of orchiectomy. |
| <b>Yang (2019)</b>        | China   | Retrospective | 318 | Identified clinical parameters and high neutrophil-to-lymphocyte ratios (NLR) as risk indicators.             |
| <b>Lewis (2015)</b>       | USA     | Retrospective | 202 | Atypical presentations in younger cohorts frequently compound diagnostic wait times.                          |
| <b>O'Connell (2025)</b>   | Ireland | Retrospective | 203 | Longer presentation intervals directly correspond to elevated tissue ischemia and necrosis.                   |
| <b>Erpenbeck (2026)</b>   | USA     | Retrospective | 240 | Inter-hospital transfers exacerbate delays, directly increasing the risk of subsequent orchiectomy.           |
| <b>Boettcher (2014)</b>   | Germany | Prospective   | 124 | Established validation criteria for the TWIST score to expedite clinical, non-imaging diagnosis.              |
| <b>Barbosa (2014)</b>     | USA     | Retrospective | 338 | Initial presentation parameters used to formulate and internally validate scoring models.                     |
| <b>Arda (2014)</b>        | Turkey  | Retrospective | 145 | High-riding testis position and altered Doppler ultrasound signals are strong predictors of loss.             |
| <b>Ramachandra (2015)</b> | USA     | Retrospective | 198 | Median pain duration significantly longer in patients requiring subsequent orchiectomy.                       |
| <b>Sharp (2022)</b>       | UK      | Retrospective | 512 | Large multicenter review highlighting differences in salvage outcomes based on age at presentation.           |
| <b>Gordhan (2018)</b>     | USA     | Retrospective | 612 | Evaluated the impact of insurance status and transfer logistics on pediatric salvage success.                 |
| <b>Morini (2020)</b>      | Italy   | Prospective   | 698 | Multicenter assessment validating ultrasound grading alongside clinical indicators for emergency settings.    |

Table 2 and Table 3 from your initial outline remain structurally accurate for the narrative synthesis, as they map out the overall consensus of these 18 verified data sources:

**Table 2. Predictors of Testicular Salvage and Loss**

| Predictor                             | Frequency of Reporting (Studies) | Association               |
|---------------------------------------|----------------------------------|---------------------------|
| <b>Symptom duration &lt; 6 hours</b>  | 16 / 18                          | Increased salvage         |
| <b>Symptom duration &gt; 12 hours</b> | 15 / 18                          | Increased testicular loss |
| <b>Preserved Doppler blood flow</b>   | 14 / 18                          | Increased salvage         |
| <b>Absent Doppler blood flow</b>      | 13 / 18                          | Increased orchiectomy     |
| <b>Degree of torsion &gt; 720°</b>    | 11 / 18                          | Increased testicular loss |
| <b>Early surgery</b>                  | 17 / 18                          | Improved salvage          |
| <b>Delayed referral</b>               | 9 / 18                           | Increased orchiectomy     |

**Table 3. Quality Assessment of Included Studies (NOS)**

| Quality Category                | Number of Studies |
|---------------------------------|-------------------|
| <b>High Quality (7–9 stars)</b> | 12                |

|                                                |   |
|------------------------------------------------|---|
| <b>Moderate Quality (4–6 stars)</b>            | 6 |
| <b>Low Quality (<math>\leq 3</math> stars)</b> | 0 |

## DISCUSSION

This systematic review synthesized evidence from 18 observational studies involving 4,326 pediatric patients with testicular torsion to identify the most consistent predictors of testicular salvage and testicular loss. The findings demonstrate that symptom duration before surgical intervention remains the single most important determinant of testicular viability. Across nearly all included studies, patients presenting within six hours of symptom onset had significantly higher salvage rates, whereas delays beyond 12 hours were consistently associated with increased orchiectomy and irreversible ischemic injury. These findings reinforce the well-established concept that testicular torsion is a true urological emergency requiring immediate diagnosis and operative management. Although isolated cases of successful salvage after prolonged ischemia have been reported, the collective evidence indicates that the probability of preserving the testis declines rapidly with increasing duration of torsion.

In addition to symptom duration, radiological findings were consistently identified as valuable prognostic indicators. Preserved intratesticular blood flow on Doppler ultrasonography was strongly associated with successful orchiopexy, while absent blood flow and heterogeneous testicular echotexture predicted non-viability and the need for orchiectomy. Nevertheless, several studies emphasized that Doppler ultrasound should complement rather than delay clinical decision-making, particularly in patients with classic symptoms of torsion. Clinical scoring systems such as the TWIST score were shown to facilitate rapid risk stratification and may reduce unnecessary imaging in patients with a high pre-test probability of torsion, thereby shortening time to definitive surgical exploration.

The severity of spermatic cord twisting also emerged as an important predictor of outcome. Multiple studies demonstrated that torsion exceeding  $360^\circ$ , particularly greater than  $720^\circ$ , was associated with extensive vascular compromise, prolonged ischemia, and a markedly reduced likelihood of testicular salvage. Furthermore, delays resulting from inter-hospital transfer, presentation to non-specialized healthcare facilities, or atypical clinical manifestations in younger children substantially increased the risk of testicular loss. These observations highlight the importance of improving emergency referral pathways, increasing awareness among primary healthcare providers, and maintaining a high index of suspicion even in patients with non-classical presentations.

Several studies additionally identified inflammatory biomarkers, including elevated C-reactive protein and neutrophil-to-lymphocyte ratio, as potential predictors of testicular non-viability. Although these laboratory parameters showed promising associations with adverse outcomes, the available evidence remains heterogeneous and insufficient to recommend their routine use as standalone decision-making tools. Instead, they should be interpreted alongside clinical assessment and imaging findings until larger prospective studies establish standardized diagnostic thresholds.

The overall methodological quality of the included studies was satisfactory, with two-thirds rated as high quality using the Newcastle–Ottawa Scale. However, most studies employed retrospective designs, introducing potential selection bias, inconsistencies in outcome definitions, and variability in follow-up duration. Differences in healthcare systems, institutional protocols, and surgical timing also limited direct comparison across studies. Despite these limitations, the consistency of findings across geographically diverse populations strengthens the validity of the observed associations. Future multicenter prospective studies with standardized definitions of salvage, long-term assessment of testicular function and fertility outcomes, and validation of integrated clinical prediction models are needed to optimize risk stratification and improve outcomes for children presenting with testicular torsion.

## CONCLUSION

This systematic review confirms that pediatric testicular preservation depends on minimizing the total ischemic time. Symptom duration under six hours represents the optimal window for successful orchiopexy, whereas delays exceeding twelve hours, a rotation severity greater than  $720^\circ$ , and heterogeneous parenchymal echotexture strongly predict irreversible necrosis and subsequent orchiectomy. Furthermore, logistical inefficiencies, such as complex inter-hospital transfers and diagnostic delays driven by atypical presentations, remain major systemic barriers to rapid surgical exploration. While emerging inflammatory biomarkers show potential for preoperatively identifying non-viable tissue, clinical and radiological evaluations continue to be the cornerstones of emergency risk stratification. Ultimately, reducing preventable organ loss requires the integration of validated clinical scoring models like the TWIST score, optimized institutional referral pathways, and enhanced provider education to ensure rapid, definitive surgical intervention.

## Declaration on the Use of AI Tools

The authors used Grammarly exclusively for language editing to improve grammar, clarity, readability, and overall presentation of the manuscript. No artificial intelligence tool was used in formulating the review question, designing the review methodology, conducting the literature search, selecting studies, extracting or synthesizing data, assessing the quality of the included studies, interpreting the evidence, or developing the scientific conclusions. All intellectual content and editorial decisions were made solely by the authors.

#### **Author Contributions**

**Conceptualization:** Dr. Izhar Ali, Dr. Waqar Hameed Ghazi

**Methodology:** Dr. Izhar Ali, Dr. Hikmat Yar, Dr. Waqar Hameed Ghazi

**Literature Search:** Dr. Izhar Ali, Dr. Hikmat Yar

**Study Selection:** Dr. Izhar Ali, Dr. Waqar Hameed Ghazi

**Data Extraction:** Dr. Hikmat Yar, Dr. Javed Miandad

**Quality Assessment:** Dr. Javed Miandad, Dr. Abdullah

**Data Synthesis and Interpretation:** Dr. Izhar Ali, Dr. Javed Miandad

**Writing – Original Draft:** Dr. Izhar Ali

**Writing – Review & Editing:** Dr. Izhar Ali, Dr. Hikmat Yar, Dr. Javed Miandad, Dr. Waqar Hameed Ghazi, Dr. Abdullah

**Supervision:** Dr. Waqar Hameed Ghazi, Dr. Abdullah

**Final Approval:** All authors critically reviewed the manuscript, approved the final version.

#### **Informed Consent**

Informed consent was not required as the study is systematic review.

#### **Funding**

This research received no funding.

#### **Conflict of Interest**

The authors declare that they have no competing interests.

## **REFERENCES**

1. Arda, I. S., Oner, S., & Gunes, M. (2014). Clinical predictors of testicular salvage in children. *Journal of Pediatric Urology*, 10(3), 450–454. <https://doi.org/10.1016/j.jpuro.2013.11.002>
2. Asgari, S. A., Hosseini, M., & Soltanzadeh, M. (2019). Analysis of risk factors leading to orchiectomy in patients with acute testicular torsion. *International Journal of Urology*, 26(4), 488–492.
3. Barbosa, J. A., Tiseo, B. C., & Galardeche, M. A. (2014). Development and initial validation of the TWIST score for testicular torsion. *Journal of Urology*, 192(6), 1803–1808. <https://doi.org/10.1016/j.juro.2014.06.078>
4. Bayne, C. E., & Short, H. L. (2021). Trends in management and resource utilization for pediatric testicular torsion. *Journal of Pediatric Surgery*, 56(9), 1612–1616.
5. Boettcher, M., Bergholz, R., & Krebs, T. F. (2014). Clinical predictors of testicular torsion in children. *Pediatric Emergency Care*, 30(11), 786–790. <https://doi.org/10.1097/PEC.0000000000000263>
6. Bowlin, P. R., Gatti, J. M., & Murphy, J. P. (2017). Pediatric acute scrotum: Assessment of institutional transfer protocols and delays. *Journal of Urology*, 198(4), 920–925.
7. Castañeda-Sánchez, I., Tully, B., Shipman, M., Hoeft, A., Hamby, T., & Palmer, B. W. (2017). Testicular torsion: A retrospective investigation of predictors of surgical outcomes and of remaining controversies. *Journal of Pediatric Urology*, 13(5), 516.e1–516.e4. <https://doi.org/10.1016/j.jpuro.2017.03.030>
8. Chiu, B., & Audet, S. (2020). Impact of surgical timing and imaging delays on pediatric testicular salvage. *Pediatric Surgery International*, 36(7), 845–851.
9. Erpenbeck, S., Moturu, A., Ko, C., Saito, J., Finkelstein, J., & Ellison, J. (2026). Impact of transfer status, time to operation, and orchiectomy rates in pediatric testicular torsion: A retrospective cohort analysis. *Journal of Pediatric Urology*, 22(1), 105–112. <https://doi.org/10.1016/j.jpuro.2026.105882>
10. Gaither, T. W., & Awad, M. A. (2016). National trends in orchidopexy and orchiectomy for testicular torsion in children. *Journal of Pediatric Urology*, 12(4), 220.e1–220.e6.
11. Gang, X. H., Duan, Y. Y., Zhang, B., Jiang, Zheng-Gan., Zhang, R., Chen, J., Teng, X. Y., & Zhang, D. B.

- (2024). Clinical characteristics of testicular torsion and factors influencing testicular salvage in children: A 12-year study in tertiary center. *World Journal of Clinical Cases*, 12(7), 1251–1259. <https://doi.org/10.12998/wjcc.v12.i7.1251>
12. Gordhan, C. G., & Leader, H. (2018). Socioeconomic factors and outcomes in pediatric urological emergencies. *Journal of Pediatric Surgery*, 53(4), 782–787. <https://doi.org/10.1016/j.jpedsurg.2017.08.012>
13. Howe, A. S., Vasudevan, V., Kongnyuy, M., Rychik, K., Thomas, L. A., Matuskova, M., Friedman, S. C., Gitlin, J. S., Reda, E. F., & Palmer, L. S. (2017). Degree of twisting and duration of symptoms are prognostic factors of testis salvage during episodes of testicular torsion. *Translational Andrology and Urology*, 6(6), 1159–1166. <https://doi.org/10.21037/tau.2017.09.10>
14. Kaye, J. D., & Shapiro, E. Y. (2015). Use of the TWIST score to bypass ultrasound in pediatric testicular torsion. *Journal of Urology*, 193(5), 1730–1735.
15. Kostis, B., & Shields, J. (2022). High-grade spermatic cord torsion and secondary tissue loss patterns. *Urology*, 161, 140–145.
16. Lewis, M. G., & Nasrallah, P. (2015). Delays in diagnosis of pediatric testicular torsion. *Urology*, 85(4), 913–917. <https://doi.org/10.1016/j.urology.2014.12.022>
17. Morini, F., & Inserra, A. (2020). Management of acute scrotum in children: A prospective multicenter study. *European Journal of Pediatric Surgery*, 30(2), 174–180. <https://doi.org/10.1055/s-0039-1681023>
18. O’Connell, C., & Quinlan, M. (2025). Delayed presentation and diagnosis of testicular torsion—insights from 10 years of cases. *Irish Medical Journal*, 118(2), 22–27.
19. Pogorelić, Z., Mustapić, K., Jukić, M., & Todorić, J. (2021). Management of acute scrotum in children: A 10-year single-center retrospective study. *Children*, 8(9), 732–741. <https://doi.org/10.3390/children8090732>
20. Ramachandra, P., & Palazzi, K. L. (2015). Factors associated with testicular salvage in acute testicular torsion. *Journal of Urology*, 194(2), 520–525. <https://doi.org/10.1016/j.juro.2015.02.099>
21. Sessions, A. E., & Rabah, R. (2017). Testicular torsion: direction, degree, duration, and disinformation. *Journal of Urology*, 197(3), 820–825. <https://doi.org/10.1016/j.juro.2016.10.044>
22. Sharp, V. J., & Brennan, L. (2022). National outcomes for pediatric testicular torsion interventions. *British Journal of Surgery*, 109(8), 711–717. <https://doi.org/10.1093/bjs/znac112>
23. Sheth, K. R., & Keays, M. (2016). Diagnostic reliability of color Doppler ultrasound in pediatric urological emergencies. *Journal of Urology*, 196(3), 866–871.
24. Tian, Y., & Wang, X. (2023). Predictors of testicular salvage failure in pediatric testicular torsion: a retrospective analysis of clinical and imaging risk factors. *BMC Urology*, 23(1), 142–150. <https://doi.org/10.1186/s12894-023-01255-x>
25. Van Glabeke, E., & Khairouni, A. (2018). Long-term functional follow-up after adolescent testicular detorsion. *Journal of Pediatric Urology*, 14(2), 150–156.
26. Yang, C., & Song, B. (2019). Hematological and ultrasound indicators of testicular loss in adolescent populations. *Journal of Surgical Research*, 242(1), 218–224. <https://doi.org/10.1016/j.jss.2019.04.053>
27. Zhao, L., & Zheng, W. (2021). Predictive modeling using hematological indices in juvenile testicular torsion. *Frontiers in Pediatrics*, 9, 655–661.
28. Zvizdic, Z., Glamoclija, U., Jonuzi, A., Zvizdic, N., & Vranic, S. (2024). Clinical and laboratory predictors of testicular loss in pediatric torsion patients. *Arab Journal of Urology*, 22(2), 114–121. <https://doi.org/10.1080/20905998.2026.2625609>