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Original Research

Laparoscopic management of intra-abdominal undescended testes: Diagnostic limitations, technique variability, and risk factors for postoperative testicular atrophy

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Keywords
Laparoscopic orchiopexy; Intra-abdominal undescended testis; Testicular atrophy; Fowler-Stephens; Traction orchiopexy; Cryptorchidism outcomes

Abbreviation
AUA, American Urological Association; aHR, adjusted hazard ratio; CI, confidence interval; FS, Fowler-Stephens (orchiopexy); IAT, intra-abdominal undescended testis (or testes); IQR, interquartile range; mL, millilitre; p, p-value (statistical significance); SD, standard deviation; Shehata, Shehata traction technique (staged traction orchiopexy); STROBE, Strengthening the Reporting of Observational Studies in Epidemiology; TVR, testicular volume ratio; US, ultrasound; UDT, undescended testis (or testes); κ, Cohen's kappa (agreement statistic); postop, postoperative

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Summary

Background
Intra-abdominal undescended testes (IAT) are the most challenging form of cryptorchidism, with high risks of impaired fertility and postoperative atrophy. Laparoscopy is the standard approach, but preoperative imaging is unreliable, intraoperative volume assessment is often difficult, and technique selection varies. Comparative outcome data and the prognostic value of real-world diagnostic limitations remain limited.

Objective
To identify diagnostic and anatomical predictors of testicular atrophy after laparoscopic management of IAT and compare outcomes among one-stage vessel-preserving, Fowler-Stephens (FS), and traction techniques over 10 years.

Methods
A retrospective cohort of boys <18 years undergoing laparoscopic orchiopexy for non-palpable testes from 2015 to 2025 was analyzed. Preoperative imaging availability, intraoperative volume assessment (measurable adequate for age, small for age, non-measurable), subjective appearance, and vas/epididymal anomalies were recorded. Primary outcome was clinical atrophy. Kaplan–Meier and multivariable Cox regression assessed predictors.

Results
Of 332 cases, 282 met criteria (53 one-stage, 128 FS, 101 traction). Clinical atrophy occurred in 65 cases (23.0%): 13.2% one-stage, 29.7% FS, 19.8% traction ($p < 0.001$). Independent predictors included FS technique (aHR 2.61), volume small for age (aHR 3.45), non-measurable volume (aHR 2.41), hypoplastic appearance (aHR 2.62), and vas/epididymal anomalies (aHR 4.28). Age and surgeon experience were not significant. Clinical and ultrasound assessments showed substantial agreement ($\kappa = 0.78$).

Conclusions
Atrophy risk after laparoscopic management of IAT is driven by testicular size relative to age-appropriate norms, vas/epididymal anomalies, intraoperative volume, and surgical technique. FS orchiopexy carries significantly higher risk than vessel-preserving approaches. Inability to measure volume and subjective hypoplastic appearance are meaningful high-risk indicators. Structured intraoperative documentation and technique-specific family counseling are essential, while postoperative surveillance can rely primarily on clinical examination.

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Introduction

Cryptorchidism affects 1—3% of full-term male newborns and up to 30% of premature infants, with approximately 1% persisting beyond 6 months of age [1]. Early orchiopexy between 6 and 18 months is recommended to optimize fertility potential and reduce malignancy risk [1,2]. Among cryptorchid testes, approximately 30% present as non-palpable, with roughly 55% representing true intra-abdominal testes (IAT)—the most surgically challenging subgroup [1].

IATs carry higher risks of impaired fertility, germ cell depletion, and postoperative atrophy, largely due to compromised vascular development and prolonged thermal injury, with fertility potential compromised in 20—25% of boys despite early orchiopexy [3,4]. Laparoscopy has become the definitive diagnostic and therapeutic modality for non-palpable testes, enabling precise localization, vascular assessment, and immediate operative planning [5,6]. Surgical options include laparoscopic one-stage vessel-preserving orchiopexy, two-stage Fowler-Stephens (FS) orchiopexy with testicular vessel division, and traction-based staged procedures such as the Shehata technique [7—9].

Despite widespread adoption, substantial heterogeneity persists in technique selection, with limited evidence guiding decision-making. The American Urological Association (AUA) guideline advises against routine preoperative ultrasound due to poor sensitivity (45%) and specificity (78%) for non-palpable testes [1,10]. Consequently, many patients lack objective preoperative volumetric data, and even intraoperative measurement may be difficult. Surgeons often rely on subjective assessments, yet existing literature rarely integrates these real-world diagnostic limitations into outcome analyses [11,12].

The current evidence base is fragmented. Most studies focus on single techniques, involve small cohorts, and apply restrictive inclusion criteria, limiting generalizability [13,14]. Available comparative data suggest one-stage vessel-preserving orchiopexy achieves atrophy rates of approximately 5—7% in selected favorable-anatomy cases, reflecting preservation of testicular vascular supply [14,15], while two-stage FS orchiopexy reports rates of 8—30% reflecting its dependence on collateral circulation [13,14]. Traction-based approaches achieve intermediate rates of 15—25% but carry a substantial redo-procedure burden [8]. Comparative data across all three laparoscopic techniques within anatomically similar IAT cohorts remain scarce, making risk stratification and evidence-based counseling challenging.

This study was designed to address several key gaps: (1) to determine the incidence of postoperative testicular atrophy following laparoscopic management of IAT across all commonly used techniques; (2) to evaluate the impact of diagnostic limitations, including absence of preoperative measurements and reliance on subjective intraoperative assessment, on outcomes; and (3) to compare technique-specific outcomes within a homogeneous cohort of intra-abdominal testes. By analyzing a large, unselected laparoscopic cohort over a 10-year period, this study provides a comprehensive assessment of risk factors for atrophy and offers insight into the diagnostic and operative determinants influencing outcomes in IAT.

Methods

Study design and population

This retrospective cohort study included all laparoscopic procedures for congenital undescended testis performed at our tertiary pediatric surgery center between January 2015 and July 2025. The study adhered to STROBE guidelines and received institutional ethics approval (IRB: Ped_-Surg_98Med). Informed consent was waived given the retrospective nature and anonymized data.

Inclusion criteria: boys $<$18 years at surgery, laparoscopic orchiopexy for congenital undescended testis, minimum postoperative follow-up $\geq$6 months, and complete operative documentation. Exclusion criteria: retractile, ascending, or acquired undescended testis; vanishing testis/testicular agenesis at exploration; acute testicular torsion; previous ipsilateral orchiopexy; insufficient follow-up ($<$6 months, n = 22); incomplete operative documentation (n = 12); prior ipsilateral surgery identified retrospectively (n = 5); other non-congenital pathology including suspected disorders of sex development, associated hypospadias requiring DSD evaluation, and testes found to be canalicular or peeping at laparoscopy rather than truly intra-abdominal (n = 11, of whom n = 8 were canalicular/peeping). In bilateral cases, each testis was analyzed independently with clustered standard errors.

All cases confirmed as truly intra-abdominal at laparoscopy were eligible. The cohort assembly and final case distribution are described in the Results section and illustrated in Fig. 1.

Operative techniques

Three laparoscopic approaches were utilized based on vascular anatomy and testicular position:

One-stage vessel-preserving orchiopexy involved standard laparoscopic mobilization with preservation of testicular vessels when adequate vessel length permitted scrotal placement (n = 53 analyzable cases). Adequate vessel length was defined intraoperatively as the ability to achieve tension-free scrotal placement with testicular vessels intact, confirmed by demonstrating that the mobilised testis reached the contralateral hemiscrotum without vascular tension.

Two-stage Fowler-Stephens orchiopexy included first-stage laparoscopic clipping of testicular vessels to promote collateral circulation, followed by second-stage orchiopexy 6—8 months later (n = 128 analyzable cases, generating 256 operative episodes). Stage-completion failure occurred in 13 cases (10.2%) due to inadequate collateral development.

Staged traction technique (Shehata) involved first-stage fixation of testis to the anterior abdominal wall using a non-absorbable suture passed through the anti-mesorchial pole of the testis (not circumferentially) for gradual vessel elongation over 12 weeks, followed by second-stage orchiopexy (n = 101 analyzable cases, generating 226 operative episodes including 24 redo procedures for suture slippage or insufficient elongation). Stage-completion failure in the FS group (13 cases, 10.2%) was defined as inability

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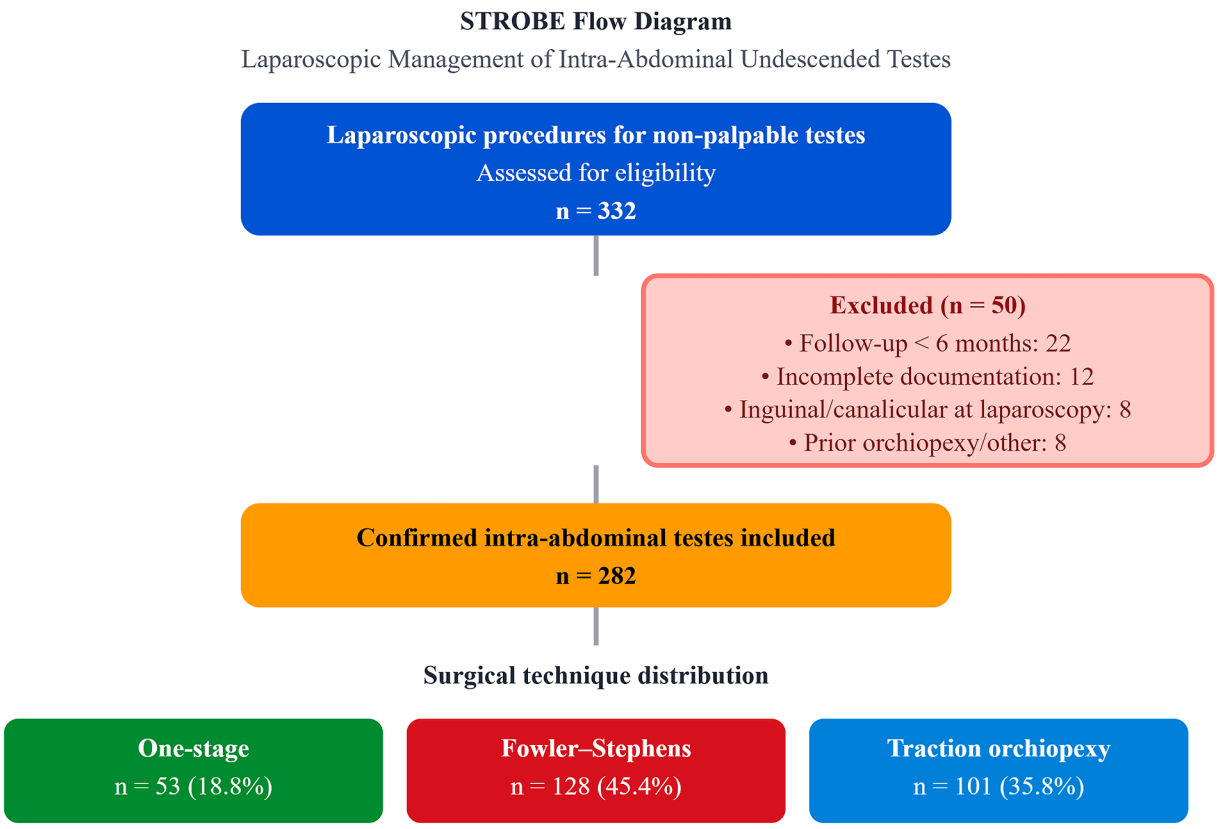


Fig. 1 STROBE flow diagram of the laparoscopic cohort.

to complete second-stage orchiopexy due to insufficient collateral vascular development, precluding safe scrotal placement and resulting in orchiectomy or ongoing observation.

Diagnostic assessment

Consistent with AUA guidelines [1,10], routine preoperative ultrasound was not performed; its selective use in 25.5% of cases arose from pre-referral clinical uncertainty and itself formed part of the diagnostic-limitation analysis. Where preoperative ultrasound was obtained, inguinoscrotal scanning confirmed absence of a detectable inguinal or scrotal testis; cases in which ultrasound identified a peeping or canalicular testis were excluded at laparoscopy (n = 8). Among the 72 analyzed cases with ultrasound, volume was not reliably characterized in most. A hierarchical volumetric assessment strategy was employed: (i) preoperative ultrasound volume if available, (ii) intraoperative measurement using a sterile ruler or laparoscopic caliper to record three orthogonal dimensions (length, width, height), or (iii) subjective intraoperative evaluation (normal/adequate size; slightly small; markedly small/hypoplastic) when the testis was too small or inaccessibly positioned for reliable dimensional measurement.

Volume was assessed using age-appropriate reference values [16,17]. Testicular volumes remain stable at approximately 0.6–0.7 mL from ages 0–4 years, increase to 0.7–1.0 mL at ages 5–8 years, with progressive growth beginning around age 11 years, reaching 14–16 mL in adolescence [16,17]. Volume was categorized as: (1) adequate for age (≥10th percentile for age-matched reference or testicular volume ratio ≥0.70 relative to contralateral testis), (2) small for age (<10th percentile or volume ratio 0.50–0.69), or (3) not measurable (testis too small, atrophic, or positioned such that reliable measurement was not feasible). The "not measurable" category was retained as an informative risk variable. All measurable volumes used the Lambert formula ($L \times W \times H \times 0.71$), selected for its established use in paediatric testicular volumetry and compatibility with linear intraoperative measurements; ellipsoid formulas yield comparable results in this size range [16,17]. Vas/epididymal anomalies were defined as intraoperatively documented absence, hypoplasia, or disjunction of the vas deferens or epididymis, or epididymal-testicular non-fusion, as recorded in the operative note. Surgeon experience was dichotomised as senior (≥5 years of independent paediatric laparoscopic practice) versus junior (≤5 years or supervised), based on operative records; cases with exactly 5 years of experience were classified as senior. Case allocation was not protocolized and reflected routine clinical practice at the institution.

Follow-up and outcomes

Patients were examined at 1, 3, 6, and 12 months postoperatively, then annually. Each visit documented testicular position, palpability, volume relative to contralateral

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side, and consistency. Ultrasound was selectively performed for equivocal examinations. Although testicular position was documented at each visit, final scrotal position and re-ascent were not analyzed as formal outcomes; the study focused exclusively on atrophy-related endpoints. Future prospective studies should incorporate postoperative position as a secondary outcome.

The primary outcome was clinical testicular atrophy, defined as: non-palpable testis on follow-up examination, OR marked reduction in size and firmness on $\geq$2 consecutive visits, OR orchiectomy for non-viability. Non-palpable testes on follow-up were further evaluated by ultrasound and, where indicated, examination under anaesthesia or re-exploration to distinguish atrophy from re-ascent; testes confirmed as re-ascended or malpositioned but viable were not classified as atrophy events.

Orchiectomy was performed for non-viability defined as complete testicular non-palpability with absence of Doppler flow on ultrasound or confirmed fibrotic replacement on re-exploration. Clinical atrophy was selected as the primary endpoint because it was uniformly available in all 282 cases, thereby avoiding the differential verification bias inherent to selective imaging. This definition aligns with AUA guideline emphasis on clinical examination [1,18].

Secondary outcomes included ultrasound-confirmed atrophy ($\geq$50% volume reduction from preoperative or intraoperative baseline; where both were unavailable, reduction relative to age-appropriate normative values was used), redo procedures, stage-completion failure, and orchiectomy rate.

Statistical analysis

Continuous variables are presented as median (IQR) and compared using Kruskal—Wallis test. Categorical variables are presented as n (%) and compared using chi-square or Fisher's exact test. Kaplan—Meier survival analysis estimated time-to-atrophy to account for variable follow-up duration across cases, with log-rank test for group comparisons including pre-specified pairwise comparison of FS versus traction.

Multivariable Cox proportional hazards regression identified independent predictors of clinical atrophy. Variables included: surgical technique, age-stratified volume category, subjective appearance, vas/epididymal anomalies, age at surgery, and surgeon experience. Adjusted hazard ratios (aHR) represent the instantaneous relative risk of atrophy compared to the reference category after simultaneous adjustment for all covariates; values greater than 1 indicate higher risk. The proportional hazards assumption-that each predictor's hazard ratio remains approximately constant over follow-upwas tested using Schoenfeld residuals (global $p = 0.42$, no detected violation; limited power cannot exclude a true violation). Cohen's kappa (κ) quantifies diagnostic agreement beyond chance (0 = none, 1 = perfect; $\geq$0.61 = substantial). Bilateral cases used cluster-robust standard errors with patient as the clustering unit (n = 38 bilateral patients, 76 testes, representing 27.0% of the cohort). No a priori sample-size calculation was performed given the retrospective complete-cohort design; the cohort represents all eligible cases over the 10-year period.

Results

Study cohort and baseline characteristics

From 332 laparoscopic orchiopexy cases performed during the study period, 282 cases (85%) met inclusion criteria with adequate follow-up (median 18 months, IQR 12—36 months; range 6—96 months). The cohort comprised 53 one-stage vessel-preserving (18.8%), 128 Fowler-Stephens (45.4%), and 101 traction procedures (35.8%). Cases found canalicular or peeping at laparoscopy were excluded prior to analysis (n = 8); all 282 analyzed cases were confirmed true intra-abdominal testes.

Table 1 summarizes baseline characteristics and outcomes by technique. The cohort had a median age of 18 months at surgery. Preoperative ultrasound was available in one-quarter of cases, more frequently in the one-stage group, likely reflecting selection of favorable anatomy for vessel-preserving approaches. Testicular volume assessment revealed significant heterogeneity, with adequate age-appropriate volumes identified in just over one-third of cases overall, while two-fifths had testes too small or poorly positioned for reliable measurement. Subjectively hypoplastic appearance and vas/epididymal anomalies were most prevalent in cases managed with Fowler-Stephens technique.

Primary outcome: testicular atrophy

Clinical atrophy developed in 65 cases (23.0%) over a median 13 months (Table 1). Atrophy rates varied significantly by technique, with one-stage vessel-preserving orchiopexy demonstrating the lowest rate and Fowler-Stephens the highest ($p < 0.001$). Kaplan—Meier analysis confirmed significantly lower atrophy-free survival in the FS group compared to one-stage procedures (log-rank $p < 0.001$). Direct comparison between FS and traction also demonstrated significantly lower atrophy-free survival in the FS group (log-rank $p = 0.03$). At 12 months, atrophy-free survival estimates were 90.2% (95% CI 80.1—95.4) for one-stage, 74.6% (95% CI 66.1—81.4) for FS, and 82.4% (95% CI 73.5—88.6) for traction procedures.

Volume category was strongly associated with atrophy risk. Among testes with adequate age-appropriate volume, atrophy occurred in 11.3%, compared to 38.0% for those with volume small for age and 23.7% for non-measurable testes ($p < 0.001$).

Independent predictors of atrophy

Multivariable Cox regression (Table 2) identified five independent risk factors after adjusting for all covariates. Fowler-Stephens technique carried 2.6-fold higher atrophy risk compared to one-stage vessel-preserving orchiopexy (aHR 2.61, 95% CI 1.12—6.08, $p = 0.027$), while traction technique showed a non-significant trend toward increased risk (aHR 1.78, 95% CI 0.71—4.44, $p = 0.22$). Direct comparison of FS versus traction as reference yielded aHR 1.47 (95% CI 0.77—2.79, $p = 0.24$), confirming a numerically higher but not statistically significant difference between these two staged approaches.

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Table 1 Baseline characteristics and outcomes by surgical technique.

Variable	One-stage (n = 53)	Fowler-Stephens (n = 128)	Traction (n = 101)	Total (n = 282)	p-value
Patient characteristics					
Age at surgery, months (IQR)	15 (11–30)	20 (12–38)	18 (12–36)	18 (12–36)	0.12
Right laterality, n (%)	27 (50.9)	66 (51.6)	52 (51.5)	145 (51.4)	0.98
Preoperative ultrasound, n (%)	21 (39.6)	26 (20.3)	25 (24.8)	72 (25.5)	0.01
Testicular characteristics					
Volume category, n (%)					<0.001
Adequate for age	28 (52.8)	38 (29.7)	31 (30.7)	97 (34.4)	
Small for age	12 (22.6)	39 (30.5)	20 (19.8)	71 (25.2)	
Not measurable	13 (24.5)	51 (39.8)	50 (49.5)	114 (40.4)	
Hypoplastic appearance, n (%)	5 (9.4)	38 (29.7)	20 (19.8)	63 (22.3)	<0.001
Vas/epididymal anomaly, n (%)	4 (7.5)	15 (11.7)	16 (15.8)	35 (12.4)	0.27
Outcomes					
Clinical atrophy, n (%)	7 (13.2)	38 (29.7)	20 (19.8)	65 (23.0)	<0.001
Time to atrophy, months (IQR)	12 (8–18)	14 (10–22)	13 (9–20)	13 (9–20)	0.21
US-confirmed atrophy, n (%)	4 (7.5)	23 (18.0)	9 (8.9)	36 (12.8)	0.02
Redo procedure, n (%)	–	13 (10.2)[a]	24 (23.8)[b]	37 (13.1)	–
Orchiectomy, n (%)	0 (0)	4 (3.1)	1 (1.0)	5 (1.8)	0.24

IQR = interquartile range; US = ultrasound. All 282 cases represent confirmed intra-abdominal testes managed laparoscopically; cases found canalicular or peeping at laparoscopy were excluded prior to analysis (n = 8, within the 'other non-congenital pathology' exclusion category).

Clinical-ultrasound concordance (n = 66 selectively imaged cases): $\kappa = 0.78$ (95% CI 0.61–0.95); sensitivity 86% (95% CI 72–94%); specificity 91% (95% CI 82–96%). These metrics derive from cases where ultrasound was predominantly applied for equivocal clinical findings; verification bias cannot be excluded and results should not be generalised to the full cohort.

[a] FS stage-completion failure: inability to complete second-stage orchiopexy due to insufficient collateral development.

[b] Redo traction: suture slippage or insufficient vessel elongation.

Testicular volume assessment emerged as a critical predictor. Compared to adequate age-appropriate volume, testes with volume small for age demonstrated the highest independent risk (aHR 3.45), while those classified as not measurable showed intermediate elevation (aHR 2.41). In this retrospective cohort, inability to measure testicular volume was associated with higher atrophy risk; this may partly represent surgeon-dependent measurement

Table 2 Multivariable predictors of testicular atrophy Cox proportional hazards model.

Predictor	Univariable		Multivariable	
	Crude HR (95% CI)	p	Adjusted HR (95% CI)	p
Surgical technique reference: One-stage vessel-preserving				
Fowler-Stephens	2.25 (1.00–5.03)	0.049	**2.61 (1.12–6.08)**	0.027
Traction	1.50 (0.63–3.55)	0.36	1.78 (0.71–4.44)	0.22
FS vs traction (ref: traction) *	*1.50 (0.87–2.58)*	*0.14*	1.47 (0.77–2.79)	0.24
Volume category reference: adequate for age				
Small for age	3.35 (1.66–6.76)	0.001	**3.45 (1.42–8.40)**	0.006
Not measurable	2.09 (1.04–4.21)	0.039	**2.41 (1.05–5.53)**	0.039
Testicular characteristics				
Hypoplastic appearance	2.03 (1.23–3.37)	0.006	**2.62 (1.29–5.33)**	0.007
Vas/epididymal anomaly	2.70 (1.57–4.65)	<0.001	**4.28 (2.06–8.89)**	<0.001
Other factors				
Age at surgery (per 6 months)	1.08 (0.95–1.23)	0.24	1.05 (0.92–1.20)	0.47
Junior surgeon	2.14 (1.21–3.78)	0.009	1.52 (0.83–2.78)	0.17

HR = hazard ratio; CI = confidence interval. Adjusted HRs derive from a single multivariable Cox model including all listed predictors simultaneously. Crude HRs derive from separate univariate Cox models.

282 cases, 65 atrophy events; median follow-up 18 months (range 6–96 months).

Bilateral cases: n = 38 patients (76 testes, 27.0% of cohort); cluster-robust standard errors applied with patient as clustering unit.

Proportional hazards assumption: global Schoenfeld test p = 0.42; covariate-specific residual plots for surgical technique showed no systematic departure.

Bold adjusted HRs = independent significant predictors ($p < 0.05$). Italic row (*) = pre-specified pairwise comparison with traction as reference; same multivariable model re-parameterised.

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variability rather than intrinsic testicular biology alone, and prospective recording is needed to distinguish these possibilities.

Subjective intraoperative assessment retained independent prognostic value. Hypoplastic appearance conferred 2.6-fold increased risk beyond objective volume measurements, supporting the clinical utility of experienced intraoperative surgical assessment. Vas or epididymal anomalies emerged as the strongest single predictor (aHR 4.28), consistent with their role as markers of testicular maldevelopment.

Neither patient age at surgery nor surgeon experience demonstrated independent associations after adjustment. The attenuation of the surgeon-experience effect after covariate adjustment suggests that experience differences may partly reflect differential case-complexity assignment, though this cannot be confirmed without objective severity data stratified by surgeon. The proportional hazards assumption was satisfied (global Schoenfeld test $p = 0.42$); covariate-specific residual plots for technique showed no systematic departure. These findings support reporting a single adjusted hazard ratio for each predictor as a time-constant summary across the observed follow-up period.

Secondary outcomes and validation

Ultrasound-confirmed atrophy occurred in 36 cases (12.8%), lower than clinical detection due to selective ultrasound use. Among the 66 cases with ultrasound follow-up, clinical examination showed substantial concordance with ultrasound assessment ($\kappa = 0.78$, 95% CI 0.61—0.95; sensitivity 86%, 95% CI 72—94%; specificity 91%, 95% CI 82—96%), supporting clinical examination as a useful surveillance modality. These metrics apply to the selectively imaged subset only and may not generalise to all cases; verification bias cannot be excluded given that ultrasound was predominantly applied in clinically equivocal cases.

Technique-specific complications included redo traction procedures in 23.8% of cases due to suture slippage or inadequate vessel elongation, and Fowler-Stephens stage-completion failure in 10.2% due to insufficient collateral development.

Of the 24 traction redo procedures, 22 (91.7%) ultimately achieved successful second-stage orchiopexy (20 after a single repeat traction attempt and 2 after a further redo), 1 (4.2%) was converted to a Fowler-Stephens approach for persistent inadequate vessel length, and 1 (4.2%) underwent orchiectomy for confirmed non-viability at redo exploration; among the 22 redo cases achieving successful orchiopexy, 3 (13.6%) subsequently developed clinical atrophy, though formal comparison with non-redo traction cases was limited by small subgroup numbers. Of the 13 Fowler-Stephens stage-completion failures, 4 underwent orchiectomy for confirmed non-viability, 6 were managed with continued clinical surveillance and remained palpable, though small, without developing clinical atrophy over available follow-up, and 3 became non-palpable and were classified as clinical atrophy events; none underwent delayed salvage orchiopexy. Stage-completion failures therefore accounted for 7 of the 38 FS atrophy events (18.4%). Five patients (1.8%) underwent orchiectomy for non-viability during follow-up. Histopathological examination of all five excised specimens revealed no malignancy. Each specimen consisted grossly of a blind-ending vas deferens with a markedly diminished (vestigial) testicular remnant; microscopically, all five showed extensive fibrosis and hyalinization of the seminiferous tubules with complete germ cell absence, and rare residual, non-functional Leydig cells were identified in 2 of 5 specimens, with no residual functioning testicular tissue in any case.

Sensitivity analyses using complete-case analysis, missing-indicator models, and extreme-case reassignment yielded hazard ratios within 10—15% of primary estimates, confirming the robustness of findings.

Discussion

This 10-year retrospective evaluation of 282 laparoscopic orchiopexy cases provides one of the most comprehensive analyses to date examining diagnostic limitations, operative strategies, and postoperative outcomes in laparoscopic management of intra-abdominal undescended testes. The overall clinical atrophy rate of 23.0% reflects the inherently challenging nature of IAT and is consistent with recent literature reporting atrophy rates between 6 and 37% following laparoscopic management of intra-abdominal testes [19].

Consistent with AUA guideline recommendations, preoperative ultrasonography was not routinely employed in this cohort due to well-documented limitations in localizing and assessing non-palpable testes [1,10,20].

Only 25.5% of patients had preoperative ultrasound, and even intraoperative measurements were not consistently feasible in 40.4% of cases. Critically, this study demonstrates that absence of objective volume data—often interpreted as missing information—is itself a clinically meaningful indicator of high-risk anatomy. Testes classified as "not measurable" showed 2.4-fold increased atrophy risk compared to those with adequate volume for age, while those with volume small for age demonstrated 3.5-fold increased risk.

It should be noted that the "not measurable" category may partly represent surgeon-dependent measurement variability rather than intrinsic testicular biology alone, and its association with atrophy should be interpreted accordingly.

A key methodological innovation in this study is the use of age-stratified volume assessment rather than a universal absolute threshold. As described in the Methods section, testicular volumes were benchmarked against published normative references [16,17]. Application of a single volume cutoff (such as 0.15 mL) across all ages would inappropriately classify many developmentally normal testes in young infants as "adequate" while misclassifying proportionally small testes in older children. Our approach using the 10th percentile as a cutoff for age-matched reference ranges provides more accurate risk stratification and accounts for normal developmental variation [21].

The testicular volume ratio (TVR)—calculated as the affected testis volume divided by the contralateral normal

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testis volume—provides an additional dimension for assessing cryptorchid testicular health independent of absolute volume measurements. Studies demonstrate that cryptorchid testes consistently exhibit smaller volumes than contralateral descended testes, with ratios typically ranging from 0.67 preoperatively to 0.76—0.84 at 1—5 years postoperatively [22,23]. Volume ratios below 0.7 indicate significant asymmetry warranting heightened surveillance, while ratios below 0.5 combined with high testicular location and epididymal anomalies predict substantially increased atrophy risk [24]. Importantly, the TVR increases progressively following orchiopexy, rising from 0.67 preoperatively to 0.84 at five years postoperatively, suggesting continued catch-up growth well beyond the immediate postoperative period [22]. This finding reinforces the importance of early surgical intervention and supports the use of both absolute volume percentiles and volume ratios as complementary metrics in preoperative risk assessment and postoperative surveillance [25].

This finding emphasizes the need to incorporate structured subjective assessments into operative documentation. Surgeons' intraoperative judgment regarding testicular size ("hypoplastic" vs. "normal") was independently predictive of atrophy (aHR 2.62), supporting the clinical utility of experienced intraoperative assessment [26,27].

The distribution of operative techniques—128 Fowler-Stephens, 101 traction, and 53 one-stage procedures—mirrors real-world decision-making where anatomic characteristics determine surgical approach. Within the intra-abdominal stratum, one-stage vessel-preserving procedures demonstrated the lowest atrophy rates (13.2%), whereas FS procedures exhibited significantly higher rates (29.7%, adjusted HR 2.61), consistent with their dependence on collateral vasculature [7,13,15]. Alagaratnam et al. [13] reported 8.8% atrophy following laparoscopic two-stage FS orchiopexy in 102 intra-abdominal testes, lower than our finding but confirming substantial risk even with staged approaches.

Recent large-scale meta-analyses have clarified technique-specific outcomes. Yu et al. [14] analyzed 60 studies involving 1991 operated testes and found overall success rates for one-stage and two-stage FS orchiopexy of 85% and 87% respectively, with corresponding atrophy rates of 10% for both approaches overall. Notably, two-stage laparoscopic FS demonstrated the highest success rate (89%) and lowest atrophy rate (8%), supporting its status as the preferred approach when vessel division is necessary. The Shehata traction technique, which maintains vascular continuity while promoting vessel elongation, achieved intermediate outcomes in our series (19.8%) but was associated with a 23.8% redo rate due to technical challenges such as suture slippage [8]. The technical demands and redo burden of the traction technique are well-documented in the original description and subsequent series of the Shehata approach [8].

These findings underscore that technique-specific risks inherently reflect vascular and anatomic limitations of IAT rather than surgical preference. After adjustment for measured confounders including testicular size, anomalies, and surgeon experience, FS technique remained independently associated with higher atrophy risk; however, residual confounding by unmeasured anatomic factors (true IAT height, vessel length and tension, collateral adequacy) cannot be excluded in this observational cohort. The discrepancy between Kaplan—Meier and adjusted Cox regression findings for FS versus traction (significant unadjusted log-rank $p = 0.03$, non-significant adjusted aHR 1.47, $p = 0.24$) likely reflects differences in time-to-event distribution and the influence of covariates accounted for in multivariable analysis. Specifically, small-for-age testicular volume (30.5% in FS versus 19.8% in traction; aHR 3.45, Table 2) and hypoplastic appearance (29.7% in FS versus 19.8% in traction; aHR 2.62) both strong independent predictors of atrophy were more prevalent in the FS group (Table 1), and adjustment for these anatomical risk markers is the most likely explanation for the attenuation of the unadjusted association. Vas/epididymal anomaly was the strongest individual predictor (aHR 4.28) but was, if anything, more prevalent in the traction group (15.8% versus 11.7% in FS) and therefore does not account for the attenuation in the same direction. Surgeon experience did not remain an independent predictor after adjustment (aHR 1.52, $p=0.17$) and is an unlikely major contributor. Limited statistical power for this specific pairwise comparison (128 FS versus 101 traction, 65 total atrophy events) cannot be excluded.

Vas or epididymal anomalies demonstrated the strongest association with atrophy (aHR 4.28), consistent with prior reports identifying anatomical defects as markers of testicular maldevelopment [28,29]. Such anomalies may reflect broader developmental disturbances affecting both ductal and gonadal tissue, contributing to compromised viability independent of surgical technique. Favorito et al. [28] documented a strong relationship between undescended testis position and prevalence of testicular appendices and epididymal anomalies, supporting the concept that these represent markers of overall testicular developmental compromise.

By prioritizing clinical examination as the primary outcome, this study aligns with current practice patterns, though guideline recommendations regarding postoperative imaging vary. The 2014 AUA guideline does not specifically address postoperative surveillance imaging [1]. More recent expert consensus suggests annual clinical examinations and ultrasonography to measure testicular volume, though this is based on expert opinion rather than patient-oriented evidence [30]. Ultrasound was selectively applied in equivocal cases in our series and showed substantial concordance with clinical atrophy detection within the imaged subset ($\kappa = 0.78$, 95% CI 0.61—0.95), supporting its role as a confirmatory rather than primary surveillance tool. However, because ultrasound was not applied uniformly, these concordance metrics are subject to verification bias and should not be interpreted as a formal validation of clinical examination across the full cohort [18,31].

Although surgeon experience influenced outcomes in univariable analysis, its effect attenuated after adjusting for anatomical severity and technique selection. This attenuation may reflect differential case-complexity assignmentwhereby more experienced surgeons are allocated more anatomically challenging casesthough this hypothesis cannot be confirmed without objective severity

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data stratified by surgeon. This confounding by indication is well-recognized in surgical outcomes research [32]. Importantly, subjective intraoperative assessment remained independently predictive even after adjustment for surgeon experience, supporting the value of structured surgical documentation.

The demonstration that "not measurable" volume is an independent risk factor has not been previously described in the literature, likely because most studies exclude cases with incomplete preoperative imaging. This real-world inclusion strengthens external validity and clinical applicability. Similarly, the use of age-stratified volume assessment rather than universal thresholds represents a methodological advance with direct clinical relevance.

These findings support several practice recommendations: (1) Routine preoperative imaging should be avoided in non-palpable undescended testis, as imaging rarely changes management [1,10]. (2) Structured intraoperative documentation is essential—surgeons should consistently record subjective testicular appearance and assess volume relative to age-appropriate norms, as these provide prognostic information independent of objective measurements. (3) Inability to measure testicular volume should be documented as a potential risk indicator, while recognising that in retrospective data this may partly represent surgeon-dependent measurement variability rather than intrinsic testicular biology alone; prospective recording is encouraged. (4) Families should be counselled that surgical technique is determined by intraoperative anatomy and vessel length, not surgeon preference; each approach carries specific risks that should be disclosed preoperatively: vessel-preserving approaches have the lowest atrophy risk when anatomy permits; staged traction offers moderate risk but requires redo procedures in approximately one-quarter of cases; FS carries higher inherent risk reflecting dependence on collateral circulation. (5) Vas/epididymal anomalies (ductal anomalies) warrant heightened postoperative surveillance given a 4-fold increased atrophy risk in this cohort. (6) Clinical examination is appropriate for surveillance in most cases, with selective ultrasound for equivocal findings; concordance metrics should be interpreted within the limitations of selective imaging. A graphical summary of the operative techniques, principal risk factors, and postoperative outcomes identified in this cohort is provided in Fig. 2.

This retrospective design has inherent selection and documentation biases. Selective postoperative ultrasound use creates verification bias; concordance metrics apply to the imaged subset only. Limited statistical power exists for some subgroup comparisons, particularly between traction and FS techniques. Median follow-up of 18 months (range 6—96 months) may not capture late atrophy events, though most atrophy is detected within the first year [5]; the proportion followed beyond 3 years was limited, and informative censoringparticularly if atrophic testes were lost to follow-up earliercannot be excluded. No objective positional severity variable was recorded (e.g., distance from the internal ring or high versus low intra-abdominal classification); outcomes therefore could not be stratified by intra-abdominal position, and residual confounding by positional severity cannot be excluded. Long-term fertility and hormonal outcomes were not assessed and represent important endpoints for future prospective studies.

Key strengths include a large, unselected laparoscopic cohort representing a wide spectrum of IAT managed over a decade; inclusion of all contemporary laparoscopic techniques; integration of diagnostic limitations into analysis; use of age-appropriate volume assessment reflecting developmental physiology; standardized subjective intraoperative descriptors; adjustment for surgeon experience; and use of clinically validated atrophy definitions enhancing practical relevance.

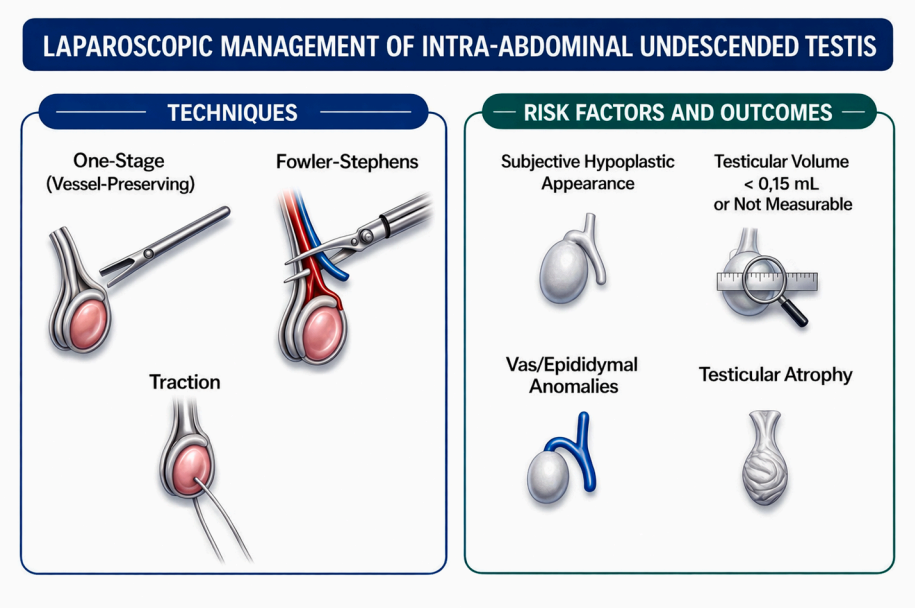


Fig. 2 Graphic abstract showing key findings and risk factors of the study.

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Conclusions

In laparoscopic management of confirmed intra-abdominal undescended testes, postoperative atrophy risk is independently driven by testicular size relative to age-appropriate norms, vas/epididymal anomalies, intraoperative volume measurability, subjective hypoplastic appearance, and surgical technique. Fowler-Stephens orchiopexy is associated with significantly higher atrophy risk compared to vessel-preserving approaches, reflecting reliance on collateral circulation; direct comparison with traction showed a numerically higher but non-significant difference. Age-stratified volume assessment could be more clinically meaningful than absolute cutoffs for risk stratification, and vas/epididymal anomalies are the strongest single predictor, warranting heightened postoperative surveillance. Structured intraoperative documentation of testicular appearance and volume should be routine, and families should be counselled that technique selection is anatomy-driven rather than based on preference. Clinical examination showed substantial agreement with ultrasound within the selectively imaged subset and remains a practical primary surveillance tool, with selective ultrasound reserved for equivocal findings; formal validation across the full cohort is limited by selective imaging.

Consent for publication

Written informed consent for publication of clinical details was obtained from patients' legal guardians where applicable.

Ethical approval

The institutional review board approved the protocol for retrospective record review and waived informed consent. The study adhered to STROBE guidelines for observational studies. All data were de-identified for analysis and stored according to institutional privacy regulations.

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Competing interests

The author declares no competing interests, financial or otherwise, related to this study.

References

[1] Kolon TF, Herndon CD, Baker LA, Baskin LS, Baxter CG, Cheng EY, et al. Evaluation and treatment of cryptorchidism: AUA guideline. J Urol 2014;192(2):337—45. https://doi.org/10.1016/j.juro.2014.05.005.

[2] Fahmy MAB. Positional Anomalies of the Scrotum "Scrotal Transposition". In: Normal and Abnormal Scrotum. Chapter 12. Springer; 2022. p. 143—71. https://doi.org/10.1007/978-3-030-83305-3_12.

[3] Tasian GE, Copp HL, Baskin LS. Diagnostic imaging in cryptorchidism: utility, indications, and effectiveness. J Pediatr Surg 2011;46(12):2406—13. https://doi.org/10.1016/j.jpedsurg.2011.08.008.

[4] Hildorf S, Clasen-Linde E, Cortes D, Fossum M, Thorup J. Fertility potential is compromised in 20% to 25% of boys with nonsyndromic cryptorchidism despite orchiopexy within the first year of life. J Urol 2020;203(4):832—40. https://doi.org/10.1097/JU.0000000000000615.

[5] Gates RL, Shelton J, Diefenbach KA, Arnold M, St Peter SD, Renaud EJ, et al. Management of the undescended testis in children: an American Pediatric Surgical Association Outcomes and Evidence Based Practice Committee Systematic Review. J Pediatr Surg 2022;57(7):1293—308. https://doi.org/10.1016/j.jpedsurg.2022.01.003.

[6] Skott M, Kennedy U, Gnech M, van Uitert A, Bujons A, Hoen L, et al. European Association of urology-european Society of Paediatric Urology Guidelines on paediatric urology: summary of 2024 updates. Part II. Eur Urol 2025;88(2):190—203. https://doi.org/10.1016/j.eururo.2025.02.022.

[7] Dawood W, Youssif M, Badawy H, Ghozlan A, Orabi S, Fahmy A. Laparoscopic staged management of high intrabdominal testis: a prospective randomized study. J Pediatr Surg 2021;56(12):2385—91. https://doi.org/10.1016/j.jpedsurg.2021.02.066.

[8] Shehata S, Shalaby R, Ismail M, Abouheba M, Elrouby A. Staged laparoscopic traction-orchiopexy for intraabdominal testis (Shehata technique): stretching the limits for preservation of testicular vasculature. J Pediatr Surg 2016;51(2):211—5. https://doi.org/10.1016/j.jpedsurg.2015.10.063.

[9] Schneuer FJ, Milne E, Jamieson SE, Pereira G, Hansen M, Barker A, et al. Association between male genital anomalies and adult male reproductive disorders: a population-based data linkage study spanning more than 40 years. Lancet Child Adolesc Health 2018;2(10):736—43. https://doi.org/10.1016/S2352-4642(18)30254-2.

[10] Kanaroglou N, To T, Zhu J, Braga LH, Wehbi E, Hajiha M, et al. Inappropriate use of ultrasound in management of pediatric cryptorchidism. Pediatrics 2015;136(3):479—86. https://doi.org/10.1542/peds.2015-0222.

[11] Tasian GE, Copp HL. Diagnostic performance of ultrasound in nonpalpable cryptorchidism: a systematic review and meta-analysis. Pediatrics 2011;127(1):119—28. https://doi.org/10.1542/peds.2010-1800.

[12] Krishnaswami S, Fonnesbeck C, Penson D, McPheeters ML. Magnetic resonance imaging for locating nonpalpable undescended testicles: a meta-analysis. Pediatrics 2013;131(6):e1908—16. https://doi.org/10.1542/peds.2013-0073.

[13] Alagaratnam S, Nathaniel C, Cuckow P, Duffy P, Mushtaq I, Cherian A, et al. Testicular outcome following laparoscopic second stage Fowler-Stephens orchidopexy. J Pediatr Urol 2014;10(1):186—92. https://doi.org/10.1016/j.jpurol.2013.08.005.

[14] Yu C, Long C, Wei Y, Tang X, Liu B, Shen L, et al. Evaluation of Fowler-Stephens orchiopexy for high-level intra-abdominal cryptorchidism: a systematic review and meta-analysis. Int J Surg 2018;60:74—87. https://doi.org/10.1016/j.ijsu.2018.10.046.

[15] Braga LH, Farrokhyar F, McGrath M, Lorenzo AJ. Gubernaculum Testis and cremasteric vessel preservation during Laparoscopic orchiopexy for intra-abdominal testes: effect on testicular atrophy rates. J Urol 2019;201(2):378—85. https://doi.org/10.1016/j.juro.2018.07.045.

[16] Goede J, Hack WW, Sijstermans K, van der Voort-Doedens LM, Van der Ploeg T, Meij-de Vries A, et al. Normative values for testicular volume measured by ultrasonography in a normal population from infancy to adolescence. Horm Res Paediatr 2011;76(1):56—64. https://doi.org/10.1159/000326057.

[17] Joustra SD, van der Plas EM, Goede J, Oostdijk W, Delemarre-van de Waal HA, Hack WW, et al. New reference charts for testicular volume in Dutch children and adolescents allow the

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calculation of standard deviation scores. Acta Paediatr 2015; 104(6):e271—8. https://doi.org/10.1111/apa.12972.

[18] Elzeneini WM, Eldiasty SE, Nasser HM, Elzeneini AM. Role of ultrasound in the follow-up of intra-abdominal testes post Fowler-Stephens orchiopexy. J Pediatr Surg 2020;55(9):1925—32. https://doi.org/10.1016/j.jpedsurg.2019.11.016.

[19] Radmayr C, Dogan HS, Hoebeke P, Kocvara R, Nijman R, Silay S, et al. Management of undescended testes: European Association of Urology/European Society for Paediatric Urology Guidelines. J Pediatr Urol 2016;12(6):335—43. https://doi.org/10.1016/j.jpurol.2016.07.014.

[20] Diamond DA, Chan IHY, Holland AJA, Kurtz MP, Nelson C, Estrada Jr CR, et al. Advances in paediatric urology. Lancet 2017;390(10099):1061—71. https://doi.org/10.1016/S0140-6736(17)32282-1.

[21] Oehme NHB, Roelants M, Saervold Bruserud I, Madsen A, Eide GE, Bjerknes R, et al. Reference data for testicular volume measured with ultrasound and pubic hair in Norwegian boys are comparable with Northern European populations. Acta Paediatr 2020;109(8):1612—9. https://doi.org/10.1111/apa.15159.

[22] He YY, Ke ZC, Li SL, Guo HJ, Zhang PL, Chen PY, et al. Trend in testicular volume change after orchiopexy in 854 children with cryptorchidism. Asian J Androl 2025;27(6):723—7. https://doi.org/10.4103/aja202527.

[23] You JH, Zhuang YF, Lu MZ, Chen L, Chen ZK, Chen XK. Three-Dimensional ultrasonography in preoperative and post-operative volume assessment of the undescended testicle. Med Sci Monit 2020;26:e924325. https://doi.org/10.12659/MSM.924325.

[24] Ok F, Durmus E, Ayaz M. The role of the resistive index in predicting testicular atrophy after orchiopexy in unilateral undescended testis. Pediatr Surg Int 2022;39(1):38. https://doi.org/10.1007/s00383-022-05336-3.

[25] Tseng CS, Chiang IN, Hong CH, Lu YC, Hong JH, Chang HC, et al. Advantage of early orchiopexy for undescended testis: analysis of testicular growth percentage ratio in patients with unilateral undescended testicle. Sci Rep 2017;7(1):17476. https://doi.org/10.1038/s41598-017-17825-w.

[26] Braga LH, Lorenzo AJ, Romao RLP. Canadian Urological Association-Pediatric Urologists of Canada (CUA-PUC) guideline for the diagnosis, management, and followup of cryptorchidism. Can Urol Assoc J 2017;11(7):E251—60. https://doi.org/10.5489/cuaj.4585.

[27] Elder JS. Ultrasonography is unnecessary in evaluating boys with a nonpalpable testis. Pediatrics 2002;110(4):748—51. https://doi.org/10.1542/peds.110.4.748.

[28] Favorito LA, Riberio Julio-Junior H, Sampaio FJ. Relationship between undescended testis position and prevalence of testicular appendices, epididymal anomalies, and patency of Processus Vaginalis. Biomed Res Int 2017;2017:5926370. https://doi.org/10.1155/2017/5926370.

[29] Niedzielski J, Nowak M, Kucharski P, Marchlewska K, Slowikowska-Hilczer J. Testicular, epididymal and vasal anomalies in pediatric patients with cryptorchid testes and testes with communicating Hydrocele. J Clin Med 2022;11(11). https://doi.org/10.3390/jcm11113015.

[30] Nguyen V, Ngo L, Jaqua EE. Cryptorchidism (Undescended Testicle). Am Fam Physician 2023 Oct;108(4):378—85. https://pubmed.ncbi.nlm.nih.gov/37843945/.

[31] Jedrzejewski G, Wieczorek AP, Osemlak P, Nachulewicz P. The role of ultrasound in the management of undescended testes before and after orchidopexy - an update. Medicine (Baltim) 2016;95(51):e5731. https://doi.org/10.1097/MD.0000000000005731.

[32] Tseng CS, Huang KH, Kuo MC, Hong CH, Chen CH, Lu YC, et al. The impact of primary location and age at orchiopexy on testicular atrophy for congenital undescended testis. Sci Rep 2019;9(1):9489. https://doi.org/10.1038/s41598-019-45921-6.

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