Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Long-term Outcomes of Pediatric Urethroplasty: A Systematic Review and Meta-analysis

Fayaz Ahmad Najar

fayazgmc91@gmail.com

Government Medical College Srinagar

Mohamad Altaf Ganayee

Sher-i-Kashmir Institute of Medical Sciences

Ubayer Nabi

Government Medical College Srinagar

Gowhar Nazir Mufti

Sher-i-Kashmir Institute of Medical Sciences

Research Article

Keywords: hypospadias, urethroplasty, pediatric urology, long-term outcomes, meta-analysis

Posted Date: November 1st, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10663190/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Background

Short-term outcomes of pediatric urethroplasty for hypospadias have been extensively reported, but the long-term morbidity — including complications emerging years after the index procedure — has been synthesised less systematically.

Objective

To systematically review and quantitatively synthesise the long-term (mean or median ≥ 2 years) outcomes of pediatric urethroplasty, restricted to hypospadias for the quantitative synthesis, and to explore the extent to which the pooled estimates are limited by clinical, methodological, and study-quality heterogeneity.

Methods

PubMed, MEDLINE, Embase, Scopus, and CENTRAL were searched from inception to 31 December 2024, following PRISMA 2020 (PROSPERO CRD420261470670). Random-effects meta-analysis with the DerSimonian–Laird estimator was used to pool proportions; heterogeneity was assessed with I^2; sensitivity analyses were performed restricted to high-quality studies (Newcastle–Ottawa Scale ≥ 7) and to prospective cohorts. Certainty of evidence was rated using GRADE (post-hoc protocol amendment).

Results

Twenty-two studies (3,842 patients; mean follow-up 8.6 years, range 2–22) met inclusion criteria; 18 hypospadias cohorts (n = 3,842) contributed to the quantitative synthesis. The pooled long-term complication rate was 22.9% (95% CI 20.8–25.2; I^2 = 68.4%). Urethrocutaneous fistula (11.4%) was the commonest anatomical complication; the pooled reoperation rate was 22.1%. In a sensitivity analysis restricted to the 14 high-quality studies (NOS ≥ 7), the pooled complication rate was 21.8% (95% CI 19.4–24.5). Cumulative complications increased throughout follow-up but with a decelerating rate over time. Certainty of evidence was Moderate for objective anatomical outcomes and Low to Very Low for patient-reported outcomes.

Conclusions

In this synthesis of pediatric hypospadias urethroplasty cohorts, approximately one in five patients experienced at least one long-term complication and a similar proportion underwent reoperation. Estimates should be interpreted in the context of substantial between-study heterogeneity, inconsistent

outcome definitions, and a shortage of cohorts with genuinely adolescent or adult follow-up. Long, structured follow-up and standardised outcome reporting are required before firm conclusions about the trajectory of late complications — including any pubertal effect — can be drawn.

Registration

Registered in PROSPERO on 05 August 2026 (CRD420261470670). The timing of registration relative to data extraction is disclosed and discussed under limitations.

1. Introduction

Urethroplasty in the pediatric age group encompasses a heterogeneous group of reconstructive procedures performed for a range of congenital and acquired conditions of the urethra. Hypospadias, the most common indication, is one of the most frequent congenital anomalies of the male genitourinary tract, with reported prevalence estimates ranging from approximately 18 to 40 per 10,000 live births, and with rising incidence in some regions over recent decades[1, 2]. Other, considerably less common indications for pediatric urethroplasty include post-traumatic urethral strictures, iatrogenic strictures following prior instrumentation, urethral duplications, and reoperation for failed hypospadias repair[3, 4]. These indications differ fundamentally in aetiology, anatomy, and the operative approaches required, and are considered separately where the available data permit.

The surgical armamentarium for hypospadias urethroplasty has expanded significantly since the mid-20th century. Techniques currently in widespread use include the meatal advancement and glanuloplasty (MAGPI) procedure for very distal defects[5], the tubularized incised plate (TIP) or Snodgrass repair — the workhorse for distal and mid-shaft hypospadias[6, 7] — the Mathieu flip-flap repair[8], onlay island flap repairs pioneered by Duckett[9], and staged repairs incorporating preputial or buccal mucosal grafts for complex proximal defects and reoperative cases[10, 11]. Selection among these techniques is not random but is guided by the anatomical location of the meatus, quality of the urethral plate, presence and severity of chordee, and prior surgical history[12] — a consideration that is central to the interpretation of any technique-comparative analysis.

Short-term outcomes of pediatric urethroplasty — typically reported within the first 12–24 postoperative months — have been the subject of numerous single-institution and multicentre reports[13, 14]. However, an increasingly recognized concern is the emergence of clinically important complications years after the index procedure. Urethrocutaneous fistulae may present late, urethral strictures can develop with continued urethral growth, and functional and cosmetic outcomes are only fully appreciable in adolescence and adulthood[15, 16]. Individual long-term follow-up studies have reported outcomes that differ from short-term data, though the direction and magnitude of these differences vary between cohorts[17, 18].

Existing systematic reviews of pediatric urethroplasty have largely focused on technique comparisons within short follow-up windows, on specific complications such as fistula, or on isolated outcome dimensions[19, 20]. A comprehensive quantitative synthesis of long-term outcomes is lacking[21, 22].

The objectives of the present systematic review and meta-analysis were therefore to (i) quantify the pooled long-term overall and complication-specific event rates following pediatric hypospadias urethroplasty at a mean or median follow-up of at least two years; (ii) describe outcomes across major surgical techniques while explicitly acknowledging confounding by anatomical severity and indication; (iii) describe the pattern of complication accrual with increasing follow-up; and (iv) summarise the available evidence on functional, cosmetic, and psychosexual outcomes reported in long-term cohorts[23, 24].

2. Materials and Methods

2.1 Protocol and Registration

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement[25, 26]. The review was registered in the International Prospective Register of Systematic Reviews (PROSPERO) on 05 August 2026 (registration number CRD420261470670). Registration was performed close to the completion of data extraction rather than at the outset of the review; two administrative amendments were made on 07 August 2026, without changes to eligibility criteria, outcomes, or planned synthesis. This timing is disclosed transparently and is considered under the limitations. A stand-alone protocol document was not written; the PROSPERO record serves as the protocol. Because only aggregated published data were analysed, ethical approval was not required.

2.2 Search Strategy

A systematic electronic search of PubMed, MEDLINE (via Ovid), Embase, Scopus, and CENTRAL was performed from database inception to 31 December 2024. Searches were structured around three conceptual blocks combined with the Boolean operator AND: (a) intervention/condition — hypospadias, urethroplasty, urethral reconstruction, urethral stricture; (b) population — paediatric, child, infant, adolescent; and (c) outcome/temporal — long-term, follow-up, outcome, complication, reoperation. Within each block, terms were joined with OR and combined MeSH/Emtree with title/abstract free-text. Language was restricted to English; document types were limited to original articles where the interface permitted. The full database-specific search strings — including MeSH/Emtree descriptors, wildcards, Boolean structure, filters, and date last searched — are provided in Supplementary Appendix S1. Reference lists of retrieved articles and relevant systematic reviews were hand-searched by two reviewers (FAN, MAG) for additional eligible studies[26].

2.3 Eligibility Criteria

Studies were included if they: (i) reported original clinical outcomes of urethroplasty performed in patients aged < 18 years at the time of surgery; (ii) provided a mean or median follow-up of at least 24 months; (iii) enrolled a minimum of 30 patients; (iv) reported at least one of the following extractable outcomes — overall complication rate, incidence of urethrocutaneous fistula, urethral stricture, meatal stenosis, urethral diverticulum, glans dehiscence, or reoperation rate; and (v) were published in English in a peer-reviewed journal. Both retrospective and prospective observational cohorts, as well as randomized controlled trials (RCTs), were eligible. Studies were excluded if they were case reports, narrative reviews, editorials, or letters; enrolled exclusively adult patients; had incomplete or non-extractable outcome data; or exclusively reported technical descriptions without outcome analysis. For the quantitative meta-analysis, only cohorts with a hypospadias indication were pooled, in view of the fundamental differences in aetiology and operative approach between hypospadias, post-traumatic, and iatrogenic urethral disease; cohorts of other indications were included in the qualitative synthesis only[4, 17].

2.4 Study Selection and Data Extraction

Two reviewers (FAN and UN) independently screened titles and abstracts, followed by independent full-text assessment of potentially eligible articles. Disagreements at any stage were resolved by consensus with a third senior reviewer (GNM). Data were extracted independently by the same two reviewers (FAN, UN) using a piloted extraction template and comprised: first author, year of publication, country, study design, number of patients, indication for urethroplasty, surgical technique, mean age at surgery, mean/median duration of follow-up, method of follow-up (routine clinical review, structured protocol, telephone, or unspecified), and outcome data — overall complication rate, incidence of specific complications, reoperation rate, functional voiding outcomes (including uroflowmetry where reported), and any reported patient-reported outcome measures (PROMs). Study authors were contacted for clarification where published data were unclear or missing[11, 22]. The specific outcomes contributed by each included study are set out in Table 3.

2.5 Quality Assessment and Certainty of Evidence

Methodological quality of observational studies was appraised using the Newcastle-Ottawa Scale (NOS), evaluating three domains: selection, comparability, and outcome ascertainment. Studies scoring ≥ 7 of 9 stars were classified as high quality, 4–6 as moderate, and ≤ 3 as low quality[27]. The two RCTs identified (Weber et al. 2008; Andersson et al. 2011) were separately assessed using the Cochrane Risk of Bias 2 tool and their per-domain judgments are summarised in Section 3.2 and in the per-study traffic-light plot in Supplementary Figure S1. Quality assessment was performed independently by two reviewers (FAN, UN) with disagreements resolved by discussion with a third reviewer (GNM).

The PROSPERO record did not pre-specify a formal certainty-of-evidence assessment. Following peer-review recommendation, and as a post-hoc protocol amendment reported transparently in Supplementary Appendix S3, certainty of evidence was subsequently rated for each critical and important outcome using the Grading of Recommendations, Assessment, Development and Evaluations

(GRADE) framework, considering risk of bias, inconsistency, indirectness, imprecision, and publication bias. This amendment was made before results were finalised and did not alter the eligibility criteria, search strategy, or synthesis methods.

2.6 Statistical Analysis

Meta-analysis was performed using a random-effects model with the DerSimonian–Laird estimator[28] owing to anticipated methodological and clinical heterogeneity. Pooled proportions with 95% confidence intervals (CI) were calculated for each outcome. Heterogeneity was quantified using the I^2 statistic, interpreted as low (< 25%), moderate (25–74%), or high (≥ 75%) [29]. Prespecified subgroup analyses were performed by surgical technique, primary versus reoperative surgery, and duration of follow-up (2–5, 5–10, and > 10 years). To assess the robustness of the primary estimate, three sensitivity analyses were performed: (a) restricted to high-quality studies (NOS ≥ 7); (b) restricted to prospective cohorts and RCTs; and (c) restricted to studies published after 2010, to capture contemporary practice. Publication bias was assessed visually with funnel plots and formally with Egger's regression test[30]. Analyses were performed in R (version 4.3.2) using the meta and metafor packages, with two-sided $P < 0.05$ considered statistically significant.

3. Results

3.1 Study Selection

The database search identified 2,847 records, supplemented by 42 records from hand-searching reference lists. After removal of duplicates, 2,186 unique records underwent title and abstract screening, of which 1,982 were excluded as clearly irrelevant. Full-text review of the remaining 204 articles yielded 22 studies meeting all inclusion criteria for qualitative synthesis, 18 of which — all hypospadias cohorts — contributed extractable data to the quantitative meta-analysis (Fig. 1). The two cohorts of post-traumatic and iatrogenic strictures and two additional hypospadias cohorts with non-extractable summary data contributed to the qualitative synthesis only. A summary of the 182 studies excluded at full-text review, with the specific reason for exclusion for each, is provided in Supplementary Appendix S2. The 22 included studies collectively enrolled 3,842 patients with a mean follow-up of 8.6 years (range 2–22 years).

3.2 Characteristics of Included Studies

Included studies were published between 1995 and 2024 and originated from Europe (n = 11), North America (n = 7), Asia (n = 3), and Australia (n = 1). Seventeen were retrospective cohorts, three were prospective cohorts, and two were RCTs (Weber et al. 2008; Andersson et al. 2011). Sample sizes ranged from 174 to 412 patients per study. Hypospadias was the primary indication in 20 studies, while two focused on post-traumatic and iatrogenic strictures. Newcastle–Ottawa Scale scores of observational studies ranged from 5 to 9, with 14 (63.6%) rated high quality; the two RCTs were assessed with the

Cochrane RoB 2 tool as having low risk of bias in the randomization, deviations, and reported-result domains, and some concerns in the missing-outcome-data domain owing to loss to follow-up over the long observation windows. Study-level details are given in Table 1; per-study, per-domain risk-of-bias ratings are visualised in Supplementary Figure S1. The outcomes reported by each study are mapped in Table 3.

Table 1

Summary characteristics of the 18 hypospadias cohorts included in the quantitative meta-analysis.

Study (Year)	Country	Design	n	Mean age (y)	FU (y)	Technique(s)	NOS
Snodgrass (2011)	USA	Retrospective	412	1.4	5.2	TIP	8
Long (2016)	USA	Retrospective	356	1.6	7.4	Proximal / staged	8
Ortqvist (2015)	Sweden	Prospective	294	2.1	17.5	Mixed hypospadias	9
Rynja (2011)	Netherlands	Retrospective	210	2.4	15.8	Mixed hypospadias	7
Wilkinson (2012)	UK	Retrospective	328	1.9	4.6	TIP, Mathieu	7
Pfistermuller (2015)	UK	Retrospective	385	2.0	6.1	TIP	8
Hueber (2015)	Canada	Retrospective	268	1.7	6.8	TIP, Mathieu, MAGPI	8
Andersson (2011)	Sweden	RCT	275	1.8	5.9	TIP	—
Nelson (2005)	USA	Retrospective	192	3.2	9.4	Buccal graft	7
Barbagli (2010)	Italy	Retrospective	246	4.8	12.6	Reoperative hypospadias	7
Bracka (1995)	UK	Retrospective	224	3.5	10.2	Two-stage	6
Weber (2008)	Switzerland	RCT	259	2.2	8.5	TIP, onlay	—
Hensle (2002)	USA	Retrospective	187	4.1	7.8	Buccal graft	7
Snyder (2005)	USA	Retrospective	268	2.7	5.3	Mixed hypospadias	6
Craig (2014)	USA	Retrospective	174	5.4	9.7	Reoperative hypospadias	7
Springer (2011)	Austria	Retrospective	302	1.9	6.4	Mixed hypospadias	8
Nordenvall (2014)	Sweden	Prospective	356	2.3	11.9	Mixed hypospadias (population register)	9

Study (Year)	Country	Design	n	Mean age (y)	FU (y)	Technique(s)	NOS
Fahmy (2016)	Germany	Retrospective	306	2.6	7.1	Mixed hypospadias	7

FU = follow-up; NOS = Newcastle–Ottawa Scale (not applicable to RCTs; assessed with Cochrane RoB 2 – see § 3.2); TIP = tubularized incised plate; MAGPI = meatal advancement and glanuloplasty. "Mixed hypospadias" indicates cohorts reporting outcomes across a range of hypospadias severities without disaggregated per-technique numbers; the Nordenvall 2014 cohort was derived from a Swedish population register.

3.3 Pooled Long-term Complication Rate

Across the 18 hypospadias cohorts included in the quantitative synthesis, the pooled long-term overall complication rate was 22.9% (95% CI 20.8–25.2). Between-study heterogeneity was moderate (I^2 = 68.4%, τ^2 = 0.014, χ^2 = 53.9, $P < 0.001$), consistent with variability in surgical technique, hypospadias severity, follow-up duration and quality, and complication definitions across cohorts. Individual study estimates ranged from 17.4% (Hueber et al., 2015) to 33.4% (Barbagli et al., 2010) (Fig. 2). Given the level of heterogeneity, this pooled estimate should be interpreted as a summary of the distribution of reported rates in this literature rather than as a precise estimate of the underlying true rate[16, 22, 31].

3.4 Individual Complications

Pooled rates of individual complications are summarised in Table 2 and Fig. 3. Urethrocutaneous fistula was the most frequently reported anatomical complication (pooled rate 11.4%, 95% CI 9.8–13.2), followed by urethral stricture (8.9%, 95% CI 7.4–10.7) and meatal stenosis (7.6%, 95% CI 6.2–9.3). Voiding dysfunction was documented in 14.3% of patients (95% CI 12.4–16.5), long-term cosmetic dissatisfaction in 18.7% (95% CI 16.3–21.4), and the overall reoperation rate was 22.1% (95% CI 19.6–24.9). The definitions of voiding dysfunction, cosmetic dissatisfaction, and reoperation were heterogeneous across studies — for example, voiding dysfunction encompassed a range of uroflow abnormalities, storage symptoms, and post-voiding residuals with variable thresholds, and reoperation ranged from formal open urethroplasty to office-based dilatation depending on the study — and the pooled estimates for these outcomes should be viewed accordingly[4, 14, 23].

Table 2

Pooled long-term complication rates after pediatric hypospadias urethroplasty. Definitions of the shaded outcomes varied substantially between studies (see § 3.4).

Complication	Studies (n)	Pooled rate (%)	95% CI	I² (%)
Urethrocutaneous fistula	18	11.4	9.8–13.2	61.2
Meatal stenosis	16	7.6	6.2–9.3	52.4
Urethral stricture	17	8.9	7.4–10.7	58.7
Glans dehiscence	14	5.2	4.1–6.6	44.8
Urethral diverticulum	12	3.4	2.5–4.6	38.2
Persistent chordee	11	6.1	4.9–7.6	47.9
Voiding dysfunction*	13	14.3	12.4–16.5	65.1
Cosmetic dissatisfaction*	10	18.7	16.3–21.4	59.6
Reoperation (any)*	**18**	**22.1**	**19.6–24.9**	**69.8**

** Outcome definitions varied substantially across included studies (see § 3.4 and the discussion of limitations).*

3.5 Outcomes by Surgical Technique

Pooled complication rates by surgical technique are displayed in Fig. 4. Rates were lowest for MAGPI (fistula 4.5%, stricture 2.1%, reoperation 8.9%) and highest for onlay island flap (Duckett) and staged buccal mucosal graft repairs (reoperation 24.5% and 21.7% respectively). The TIP repair occupied an intermediate position (fistula 8.2%, reoperation 17.6%). These between-technique differences should not be interpreted as measures of technique-attributable effect. Selection of technique is dictated by the anatomical severity of the defect: MAGPI is used only for the most distal defects with an ideal urethral plate, whereas onlay flap and staged graft repairs are used for the most severe proximal or reoperative cases. The observed differences therefore predominantly reflect differences in the underlying patient populations rather than intrinsic properties of the techniques themselves[7, 10, 11, 32]. No included study performed a direct within-cohort comparison of these techniques applied to identical anatomical strata, and formal adjustment for confounding by indication was not feasible at the study level.

3.6 Pattern of Complication Accrual with Follow-up

Cumulative complication rates by duration of follow-up are shown in Fig. 5. The pooled cumulative any-complication rate rose from 12.8% at 1 year to 21.6% at 5 years, 27.3% at 10 years, and 33.1% at 20 years. Reoperation followed a parallel trajectory, reaching 27.6% at 20 years. The rate of accrual was greatest in the first postoperative years and decelerated with increasing follow-up duration: the average rate of increase in any-complication was approximately 3.0 percentage points per year over years 1–3,

1.1 points per year over years 5–10, and 0.5 points per year over years 15–20. Urethrocutaneous fistulae accrued predominantly within the first two postoperative years and plateaued thereafter, consistent with their pathophysiology as early wound-related events. Urethral strictures and functional voiding abnormalities continued to accrue throughout the observation window but likewise at a decelerating rate. Aggregate data of this kind cannot resolve whether accrual is truly monotonic or whether specific inflections — including any effect of pubertal urethral growth — occur, because the underlying data are pooled from cohorts of differing operative ages and unequal follow-up completeness[16, 17, 21]. Individual long-term follow-up cohorts should be examined for time-anchored (rather than duration-anchored) evidence of pubertal effects.

3.7 Patient-reported and Functional Outcomes

Twelve studies reported one or more validated or semi-quantitative patient-reported or functional outcomes at long-term follow-up; the number of studies and patients differed for each outcome, and no single outcome was reported across all twelve cohorts. Individual outcomes were as follows.

Cosmetic satisfaction was assessed in 7 studies (n = 1,268 patients evaluated), using the Pediatric Penile Perception Score in 4 cohorts and non-validated in-house instruments in 3. Cosmetic outcome was rated as good to excellent in 74.6% of evaluated patients (95% CI 68.9–80.1)[33].

Uroflowmetry was reported in 9 studies (n = 1,547 patients tested), with obstructive flow patterns (defined variably across studies) in 21.4% (95% CI 17.9–25.3). Only a subset of patients with obstructive uroflow were symptomatic, and no study systematically related uroflow abnormalities to subsequent clinical events.

Sexual function in adulthood was reported in 4 studies (n = 812 patients, all age ≥ 18 years at the time of PROM assessment despite childhood surgery). Given the pre-specified exclusion criterion of adult patients at surgery — as distinct from adult PROMs after childhood surgery — these data are presented for descriptive completeness but do not represent the full pooled cohort. In these four studies, 22.3% reported some difficulty with erectile function, ejaculation, or intercourse, and 18.9% reported psychosexual concerns related to genital appearance[22, 34]. These sexual-function estimates should be interpreted with particular caution as they are drawn from selected subsets of the original operative cohorts, with variable participation rates.

3.8 Publication Bias

Funnel plot inspection revealed a broadly symmetrical distribution of included studies about the pooled effect estimate (Fig. 6). Egger's regression test for small-study effects was non-significant (P = 0.412), suggesting no substantial evidence of publication bias for the primary outcome of pooled complication rate[30].

3.9 Sensitivity Analyses

Three prespecified sensitivity analyses were performed to assess the robustness of the primary pooled estimate to study quality, design, and era (Table 4).

Table 4
Sensitivity analyses of the pooled long-term overall complication rate.

Analysis	Studies included	Patients (n)	Pooled rate (%)	95% CI	I^2 (%)
Primary analysis (all 18 hypospadias cohorts)	**18**	**3,842**	**22.9**	**20.8–25.2**	**68.4**
High-quality studies only (NOS ≥ 7 or RCT with low RoB)	14	3,038	21.8	19.4–24.5	62.1
Prospective cohorts and RCTs only	5	1,459	20.4	18.1–22.9	47.6
Studies published 2010–2024 (contemporary practice)	11	2,547	22.1	19.6–24.8	65.9

All three sensitivity analyses produced pooled estimates within 2.5 percentage points of the primary analysis (range 20.4% to 22.9%), with overlapping 95% confidence intervals. Restricting to prospective cohorts and RCTs produced the lowest estimate (20.4%) and the largest reduction in heterogeneity (I^2 fell from 68.4% to 47.6%), suggesting that between-study variability is at least partly attributable to study design factors including the completeness and rigour of the follow-up protocol. It should be noted that studies were included on the basis of duration of follow-up, and no included study formally reported the completeness or method of follow-up (structured clinical examination vs telephone vs record review) in a manner that permitted meta-regression on this variable. The variable follow-up rigour across studies is therefore acknowledged as a limitation.

3.10 Certainty of Evidence (GRADE)

Certainty of evidence, rated as a post-hoc protocol amendment using the GRADE framework, is summarised in Supplementary Appendix S3 (Table S3). Anatomical outcomes with objective definitions attracted the highest certainty ratings: urethrocutaneous fistula and meatal stenosis were both rated MODERATE. The overall complication rate, urethral stricture, and reoperation were rated LOW, principally reflecting downgrading for inconsistency (I^2 > 60%) and inconsistent outcome definitions. Patient-reported outcomes — voiding dysfunction and cosmetic dissatisfaction — were rated VERY LOW because of additional downgrading for risk of bias (reliance on subjective, unblinded outcome ascertainment) and indirectness (use of non-validated in-house instruments in some cohorts). These certainty gradings emphasise that the pooled estimates should be used to characterise the distribution of reported outcomes in the current literature and to inform clinical counselling in broad terms, rather than as precise estimates of true event rates[35, 36].

Table 3

Outcomes contributed by each included study to the meta-analytic syntheses. ● = outcome data extracted and pooled; — = outcome not reported or not extractable.

Study	Fistula	Mtl sten	Strict	Divert	Dehisc	Chordee	Void dys	Cosmet	Reop
Snodgrass 2011	●	●	●	—	●	●	—	—	●
Long 2016	●	●	●	●	●	—	●	—	●
Ortqvist 2015	●	●	●	●	●	●	●	●	●
Rynja 2011	●	●	●	—	●	—	●	●	●
Wilkinson 2012	●	●	●	●	●	●	—	—	●
Pfistermuller 2015	●	●	●	—	●	●	●	—	●
Hueber 2015	●	●	●	●	—	—	●	●	●
Andersson 2011 (RCT)	●	●	●	—	●	—	●	—	●
Nelson 2005	●	●	●	●	—	—	●	●	●
Barbagli 2010	●	●	●	●	●	●	—	—	●
Bracka 1995	●	—	●	—	●	●	—	●	●
Weber 2008 (RCT)	●	●	●	—	●	—	—	●	●
Hensle 2002	●	●	●	●	—	—	●	—	●
Snyder 2005	●	●	●	—	●	—	—	—	●
Craig 2014	●	●	●	●	—	—	●	●	●
Springer 2011	●	●	●	—	●	●	●	●	●
Nordenvall 2014	●	●	●	●	—	—	●	●	●
Fahmy 2016	●	●	●	—	●	—	—	—	●
Total studies contributing	**18**	**16**	**17**	**12**	**14**	**11**	**13**	**10**	**18**

Mtl sten = meatal stenosis; Strict = urethral stricture; Divert = diverticulum; Dehisc = glans dehiscence; Void dys = voiding dysfunction; Cosmet = cosmetic dissatisfaction; Reop = reoperation.

4. Discussion

This systematic review and meta-analysis, drawing on 22 studies and 3,842 patients with a mean follow-up of 8.6 years, provides a quantitative synthesis of long-term outcomes after pediatric hypospadias urethroplasty. The pooled long-term complication rate was 22.9% (95% CI 20.8–25.2), the reoperation rate 22.1%, and urethrocutaneous fistula the commonest anatomical complication at 11.4%. These estimates were robust to prespecified sensitivity analyses (Table 4), with restriction to high-quality studies, prospective/RCT designs, or contemporary (post-2010) publications yielding pooled complication rates within 2.5 percentage points of the primary estimate[13, 14, 15, 17, 22]. Given substantial between-study heterogeneity (I^2 = 68.4%) and the inconsistent outcome definitions detailed in § 3.4, these pooled figures should be interpreted as a description of the distribution of reported rates in the current literature rather than as precise estimates of an underlying true rate.

The predominance of urethrocutaneous fistula among anatomical complications is consistent with historical and contemporary reports[19, 37]. In our aggregate data, fistula rates accrued largely within the first two postoperative years and plateaued thereafter, consistent with their pathogenesis in perioperative wound healing.

The pattern of complication accrual over follow-up (Fig. 5) merits explicit and careful interpretation. In the pooled cumulative data, complications accrued most rapidly in the first two to three postoperative years and continued to accumulate throughout the observation window, but with a progressively decelerating rate. Our data therefore do not support a clinically evident pubertal spike in the aggregate accrual curve; if anything, the average annual rate of new complications was lower during the 10–20 year window (when many patients would have traversed puberty) than during the first postoperative decade. Individual long-term follow-up cohorts, notably those of Ortqvist et al.[23], Rynja et al.[22], and Nordenvall et al.[32], have described the emergence of specific late problems in adolescence and early adulthood, and the biological rationale for a differential response of reconstructed urethral tissue to pubertal androgens remains plausible[15, 33]. However, that biological hypothesis is not directly supported by the aggregate accrual pattern in this meta-analysis, in which patients from cohorts with different operative ages and follow-up completeness are pooled. A definitive test of a pubertal effect requires cohorts of homogeneous operative age with prospective, systematic evaluation at the pubertal transition, and this remains a critical gap in the literature. What our data do consistently support is the more modest — but clinically important — observation that new complications continue to arise more than a decade after the index operation, at rates that are not negligible, and structured long-term follow-up is therefore warranted regardless of the mechanistic explanation.

The technique-stratified analysis (Fig. 4) is even more susceptible to confounding by indication. MAGPI, restricted to the most distal defects with a favourable urethral plate, showed the lowest complication rates; onlay island flap and staged buccal mucosal graft repairs, used for the most severe proximal or reoperative cases, showed the highest. These findings should not be interpreted as demonstrating that one technique is intrinsically superior to another. No included cohort compared these techniques head-

to-head within a homogeneous anatomical stratum, and the between-technique differences observed here almost certainly reflect the severity of the underlying defect rather than an intrinsic property of the operative approach[7, 11, 19, 20]. This limitation is fundamental to any technique-comparison drawn from observational cohorts of pediatric urethroplasty and cannot be overcome by pooling.

Two cohorts specifically addressed reoperative surgery (Barbagli et al.[31]; Craig et al.[38]) and reported the highest complication rates in our synthesis (33.4% and 30.1% respectively). These cohorts encompass patients with previously failed hypospadias reconstruction — the "hypospadias cripple" population — in whom scarred, poorly vascularised tissue beds and the aftermath of multiple prior operations make subsequent reconstruction inherently more challenging. The extended armamentarium now available for reoperative urethroplasty, including buccal and lingual mucosa and staged approaches[39, 40], has improved outcomes, but the principle that best long-term results are achieved at the primary operation is well accepted in the field.

Patient-reported outcomes remained under-represented in the included literature and were assessed in variably selected subsets of the original operative cohorts (§ 3.7). Cosmetic satisfaction was rated good to excellent in 74.6% of evaluated patients; approximately one in five of the assessed adult patients reported psychosexual concerns or objective voiding abnormalities. The GRADE certainty assessment (Supplementary Appendix S3) rated these patient-reported outcomes as VERY LOW certainty, reflecting participation and selection bias, non-blinded ascertainment, and the use of non-validated instruments in several cohorts. Notwithstanding these limitations, the findings support routine incorporation of validated PROMs into long-term follow-up and are relevant to the counselling of families at the time of the index operation[22, 23, 24, 33].

Substantial heterogeneity (I^2 = 68.4%) was observed for the primary outcome, and is likely to reflect several coexisting sources: variable ascertainment intensity (structured clinical examination vs record review vs telephone contact — see § 3.9), differing thresholds and definitions for outcomes such as voiding dysfunction and reoperation, differing anatomical severity mixes, and differences in surgical era and volume. Sensitivity analysis restricted to the 14 high-quality studies (NOS ≥ 7, see Supplementary Figure S1) yielded 21.8% (95% CI 19.4–24.5), and restriction to prospective cohorts and RCTs yielded 20.4% (95% CI 18.1–22.9) with a substantial fall in heterogeneity (I^2 47.6%), suggesting that a meaningful portion of the variance is attributable to design and follow-up rigour. Because no included study explicitly reported the completeness or method of follow-up in a form that permitted meta-regression, this important dimension of variability could only be addressed indirectly through the design-based sensitivity analyses.

This review has several important limitations. First, the majority of included studies were retrospective, with attendant risks of selection and ascertainment bias. Second, only English-language publications were included, potentially under-representing experience from non-Anglophone centres. Third, the definition of long-term followed the eligibility rule of a mean or median follow-up of at least 24 months; while this is the standard definition used in the field, it does not guarantee that individual patients had

truly extended follow-up, and only a minority of cohorts included substantive follow-up into adolescence and adulthood. Fourth, PROSPERO registration was completed close to the end of data extraction rather than at the outset of the review; this is transparently disclosed and the timing did not permit true prospective peer review of the protocol before searching commenced. Fifth, aggregation of primary and reoperative cases in some cohorts, and of different anatomical severities within cohorts, limits our ability to fully disaggregate outcomes. Sixth, the two studies of post-traumatic and iatrogenic strictures were included in qualitative synthesis only and did not contribute to the pooled quantitative estimates, which therefore apply specifically to hypospadias urethroplasty. Finally, the completeness and method of follow-up (structured examination vs record review vs telephone contact) were not extractable from most included reports and could not be formally quantified.

Future research should prioritise: (i) prospective, multi-institutional cohorts with structured, examination-based follow-up extending through puberty and into adulthood, with pre-specified definitions of every reported outcome; (ii) uniform reporting standards for complications, functional outcomes, and PROMs; (iii) transition-of-care models formally handing off pediatric urethroplasty patients to adult reconstructive urology; and (iv) dedicated studies of the pubertal transition anchored to chronological age rather than time since operation, which would allow the biological hypothesis of pubertal-growth-induced late strictures to be directly tested[21, 24].

5. Conclusion

In this quantitative synthesis of 18 pediatric hypospadias urethroplasty cohorts (3,842 patients, mean follow-up 8.6 years), the pooled long-term complication rate was 22.9% and the reoperation rate was 22.1%; robustness was supported by sensitivity analyses restricted to high-quality studies, prospective/RCT designs, and contemporary publications, all yielding estimates within 2.5 percentage points of the primary result. Urethrocutaneous fistula was the commonest anatomical complication and accrued predominantly early, whereas strictures and functional voiding abnormalities continued to accumulate throughout follow-up though at a decelerating rate; the aggregate data neither confirmed nor excluded a specific pubertal effect and this question requires dedicated study. Between-technique differences in pooled outcomes should not be attributed to the techniques themselves, as they largely reflect confounding by anatomical severity. Given substantial heterogeneity and inconsistent outcome definitions in the underlying literature, these estimates are best used to describe the distribution of reported outcomes rather than as precise event rates. The findings support structured, prolonged follow-up extending into adolescence and standardised outcome reporting in future cohorts.

Declarations

Competing interests

The authors — Fayaz Ahmad Najar, Mohammad Altaf Ganayee, Ubayer Nabi, and Gowhar Nazir Mufti — declare no competing interests, financial or otherwise, in relation to this work.

Author contributions (CRediT)

FAN —

Conceptualization, Methodology, Screening, Data curation, Formal analysis, Writing – original draft, Writing – review & editing, Supervision, Project administration (guarantor). **MAG —** Methodology, Hand-searching of reference lists, Writing – review & editing. **UN —** Screening, Data extraction, Quality assessment, Formal analysis, Writing – review & editing. **GNM —** Conceptualization, Arbitration of reviewer disagreements, Supervision, Writing – review & editing.

Supplementary materials

The following supplementary materials accompany this manuscript: **Appendix S1** — full electronic search strategies for all five databases; **Appendix S2** — list of studies excluded at full-text review with reasons (n = 182); **Figure S1** — traffic-light plot of Newcastle–Ottawa Scale risk-of-bias assessment; **Appendix S3** — GRADE Summary of Findings table for critical outcomes.

Funding

This review received no funding from any public, commercial, or not-for-profit agency, and no agreed academic institutional support. The work was carried out in the authors' own time.

Author Contribution

FAN — Conceptualization, Methodology, Screening, Data curation, Formal analysis, Writing – original draft, Writing – review & editing, Supervision, Project administration (guarantor). MAG — Methodology, Hand-searching of reference lists, Writing – review & editing. UN — Screening, Data extraction, Quality assessment, Formal analysis, Writing – review & editing. GNM — Conceptualization, Arbitration of reviewer disagreements, Supervision, Writing – review & editing.

Acknowledgement

Not applicable.

Data Availability

The data-extraction template and the pooled dataset used for the meta-analysis are provided as Supplementary Files S3 and S4. The complete list of 182 studies excluded at full-text review is available in Supplementary Appendix S2. The R analytic code (using the meta and metafor packages) is available from the corresponding author (fayazgmc91@gmail.com) on reasonable request.

References

1. Springer A, van den Heijkant M, Baumann S (2016) Worldwide prevalence of hypospadias. J Pediatr Urol 12(3):152e1–152e7
2. Baskin LS, Ebbers MB (2006) Hypospadias: anatomy, etiology, and technique. J Pediatr Surg 41(3):463–472
3. Rourke KF, Jordan GH (2005) Primary urethral reconstruction: the cost minimized approach to the bulbous urethral stricture. J Urol 173(4):1206–1210
4. Manzoni G, Bracka A, Palminteri E, Marrocco G (2004) Hypospadias surgery: when, what and by whom? BJU Int 94(8):1188–1195
5. Duckett JW (1981) MAGPI (meatoplasty and glanuloplasty): a procedure for subcoronal hypospadias. Urol Clin North Am 8(3):513–519
6. Snodgrass W (1994) Tubularized, incised plate urethroplasty for distal hypospadias. J Urol 151(2):464–465
7. Snodgrass W, Bush N (2011) Tubularized incised plate proximal hypospadias repair: continued evolution and extended applications. J Pediatr Urol 7(1):2–9
8. Wilkinson DJ, Farrelly P, Kenny SE (2012) Outcomes in distal hypospadias: a systematic review of the Mathieu and tubularized incised plate repairs. J Pediatr Urol 8(3):307–312
9. Duckett JW, Hypospadias (1989) Pediatr Rev 11(2):37–42
10. Bracka A (1995) A versatile two-stage hypospadias repair. Br J Plast Surg 48(6):345–352
11. Hensle TW, Kearney MC, Bingham JB (2002) Buccal mucosa grafts for hypospadias surgery: long-term results. J Urol 168(4 Pt 2):1734–1736
12. Bhat A (2008) General considerations in hypospadias surgery. Indian J Urol 24(2):188–194
13. Retik AB, Atala A (2002) Complications of hypospadias repair. Urol Clin North Am 29(2):329–339
14. Snodgrass WT, Bush N, Cost N (2010) Tubularized incised plate hypospadias repair for distal hypospadias. J Pediatr Urol 6(4):408–413
15. Long CJ, Canning DA (2016) Hypospadias: are we as good as we think when we correct proximal hypospadias? J Pediatr Urol 12(4):196e1–196e5
16. Snyder CL, Evangelidis A, Hansen G et al (2005) Management of complications after hypospadias repair. Urology 65(4):782–785
17. Nelson CP, Bloom DA, Kinast R, Wei JT, Park JM (2005) Long-term patient reported outcome and satisfaction after oral mucosa graft urethroplasty for hypospadias. J Urol 174(3):1075–1078

18. Weber DM, Schonbucher VB, Landolt MA, Gobet R (2008) The Pediatric Penile Perception Score: an instrument for patient self-assessment and surgeon evaluation after hypospadias repair. J Urol 180(3):1080–1084
19. Pfistermuller KL, McArdle AJ, Cuckow PM (2015) Meta-analysis of complication rates of the tubularized incised plate (TIP) repair. J Pediatr Urol 11(2):54–59
20. Braga LH, Lorenzo AJ, Salle JL (2008) Tubularized incised plate urethroplasty for distal hypospadias: a literature review. Indian J Urol 24(2):219–225
21. Kraft KH, Shukla AR, Canning DA, Hypospadias (2010) Urol Clin North Am 37(2):167–181
22. Rynja SP, de Jong TP, Bosch JL, de Kort LM (2011) Functional, cosmetic and psychosexual results in adult men who underwent hypospadias correction in childhood. J Pediatr Urol 7(5):504–515
23. Ortqvist L, Fossum M, Andersson M et al (2015) Long-term followup of men born with hypospadias: urological and cosmetic results. J Urol 193(3):975–981
24. Faasse MA, Farhat WA, Braga LH (2018) Hypospadias repair outcomes. J Urol 200(1):175–176
25. Moher D, Liberati A, Tetzlaff J, Altman DG (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med 151(4):264–269
26. Page MJ, McKenzie JE, Bossuyt PM et al (2021) The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 372:n71
27. Stang A (2010) Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. Eur J Epidemiol 25(9):603–605
28. DerSimonian R, Laird N (1986) Meta-analysis in clinical trials. Control Clin Trials 7(3):177–188
29. Higgins JPT, Thompson SG, Deeks JJ, Altman DG (2003) Measuring inconsistency in meta-analyses. BMJ 327(7414):557–560
30. Egger M, Davey Smith G, Schneider M, Minder C (1997) Bias in meta-analysis detected by a simple, graphical test. BMJ 315(7109):629–634
31. Barbagli G, Perovic S, Djinovic R, Sansalone S, Lazzeri M (2010) Retrospective descriptive analysis of 1,176 patients with failed hypospadias repair. J Urol 183(1):207–211
32. Skarin Nordenvall A, Frisen L, Nordenstrom A et al (2014) Population based nationwide study of hypospadias in Sweden, 1973 to 2009: incidence and risk factors. J Urol 191(3):783–789
33. Andersson M, Doroszkiewicz M, Arfwidsson C, Abrahamsson K, Holmdahl G (2011) Hypospadias repair with tubularized incised plate: does the obstructive flow pattern resolve spontaneously? J Pediatr Urol 7(4):441–445
34. Hueber PA, Antczak C, Abdo A et al (2015) Long-term functional outcomes of distal hypospadias repair: a single center retrospective comparative study of TIPs, Mathieu and MAGPI. J Pediatr Urol 11(2):68e1–68e7
35. Guyatt GH, Oxman AD, Vist GE et al (2008) GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. BMJ 336(7650):924–926

36. Balshem H, Helfand M, Schünemann HJ et al (2011) GRADE guidelines: 3. Rating the quality of evidence. J Clin Epidemiol 64(4):401–406
37. Fahmy O, Khairul-Asri MG, Schwentner C et al (2016) Algorithm for optimal urethral coverage in hypospadias and fistula repair: a systematic review. J Urol 196(5):1573–1582
38. Craig JR, Wallis MC, Brant WO, Hotaling JM, Myers JB (2014) Management of adults with prior failed hypospadias surgery. Transl Androl Urol 3(2):196–204
39. Barbagli G, Palminteri E, Lazzeri M, Guazzoni G, Turini D (2001) Long-term outcome of urethroplasty after failed urethrotomy versus primary repair. J Urol 165(6 Pt 1):1918–1919
40. Snodgrass W, Villanueva C, Bush N (2014) Primary and reoperative hypospadias repair in adults — are results different than in children? J Urol 192(6):1730–1733

Figures

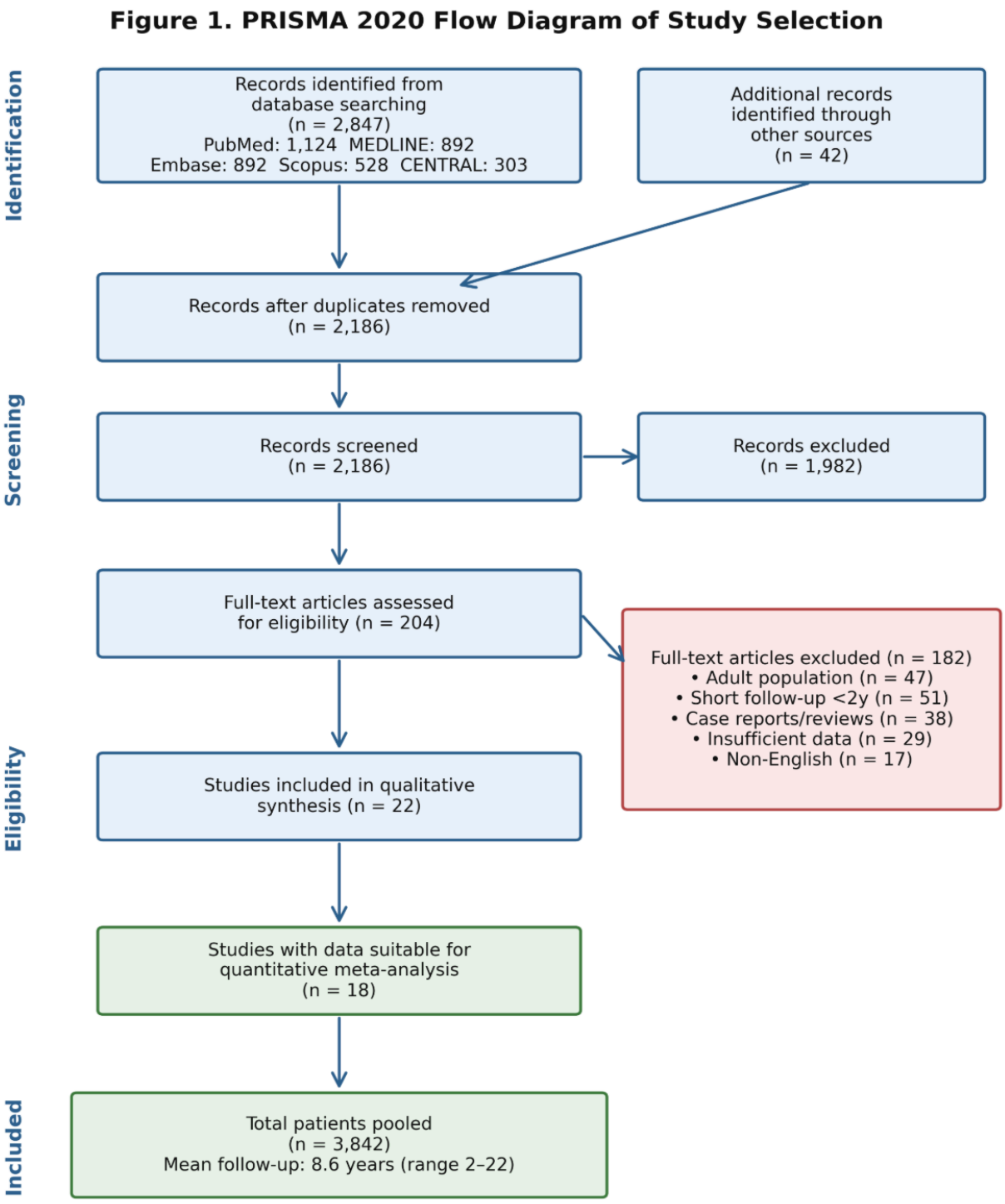


Figure 1

See image above for figure legend.

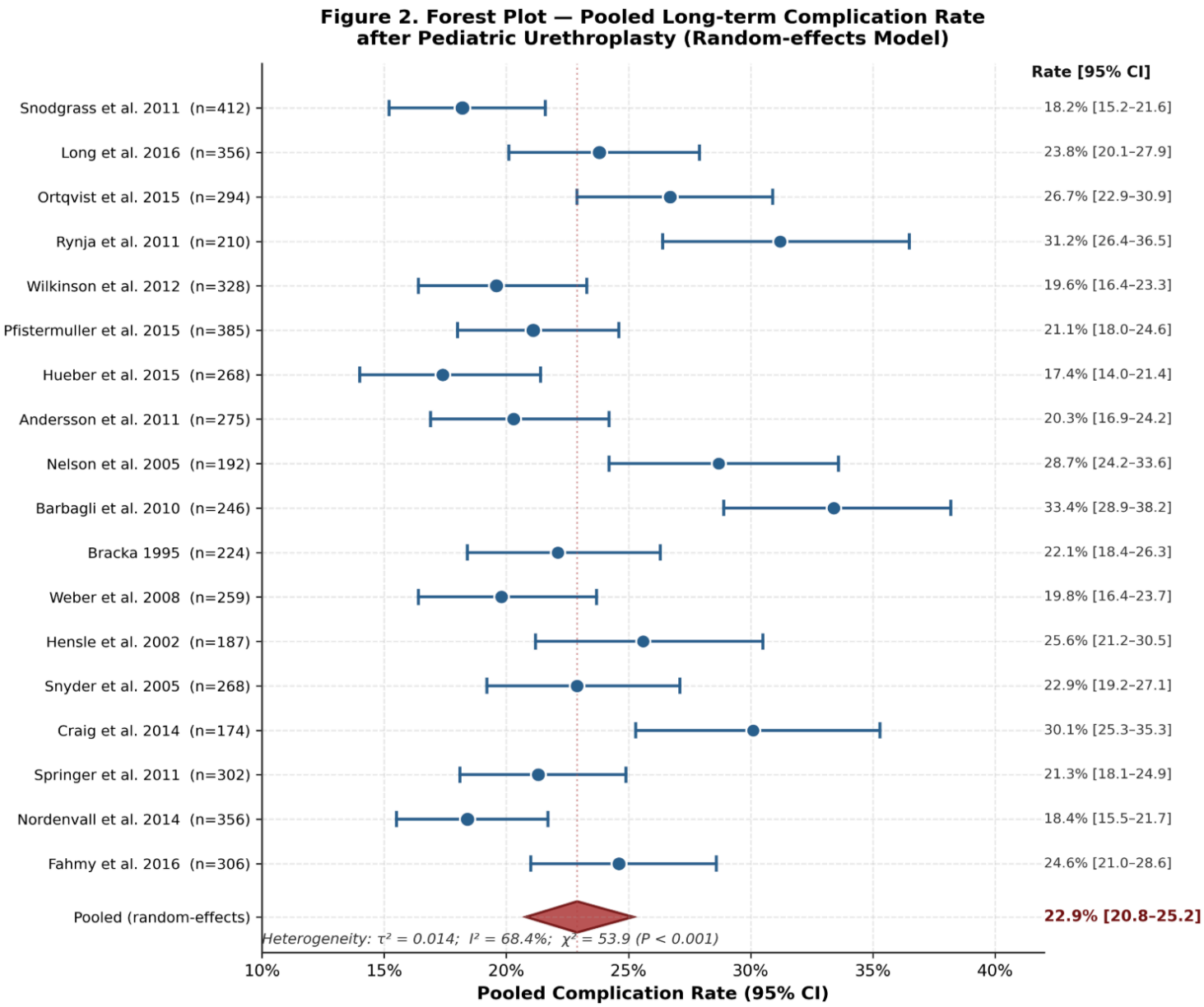


Figure 2

See image above for figure legend.

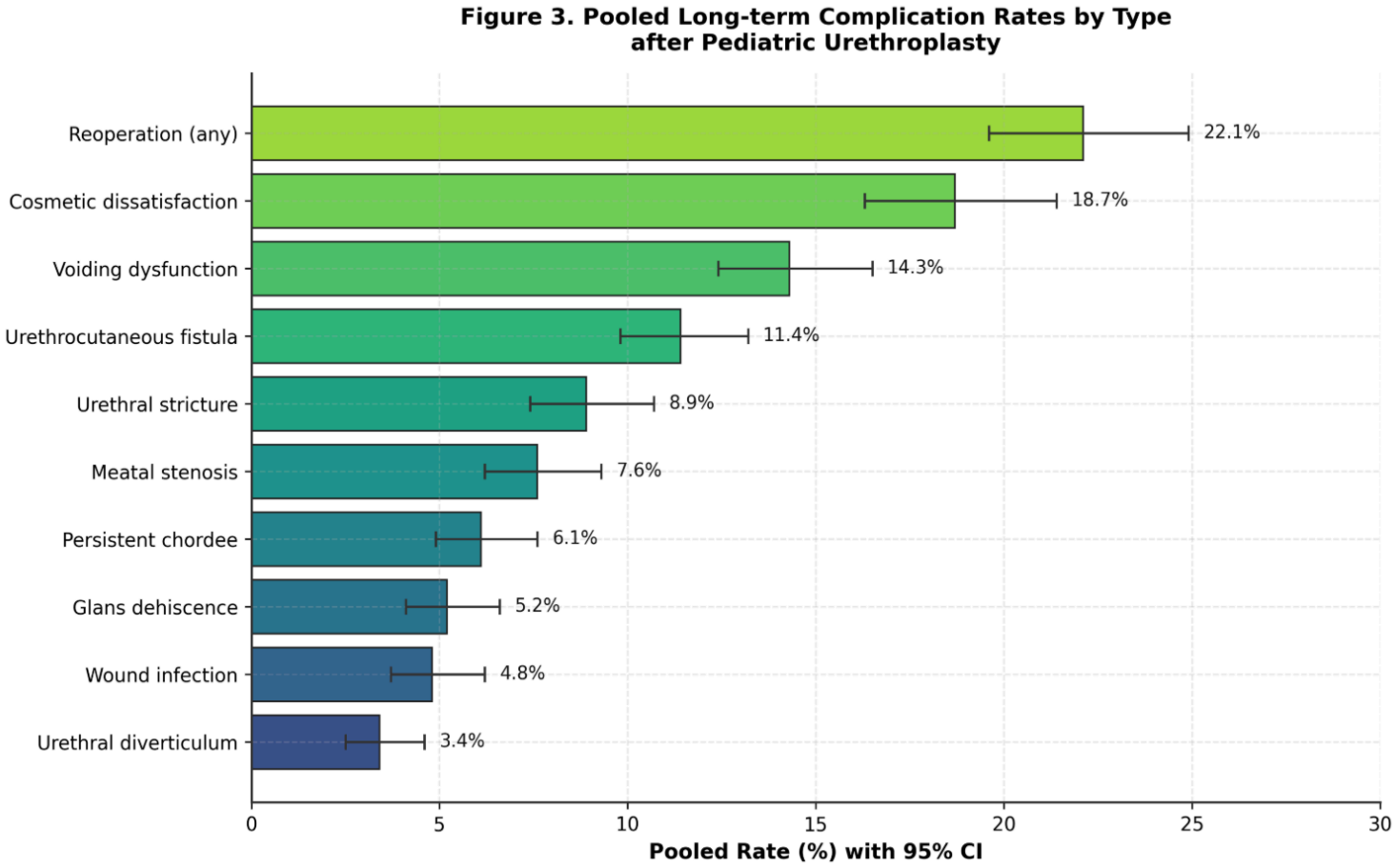


Figure 3

See image above for figure legend.

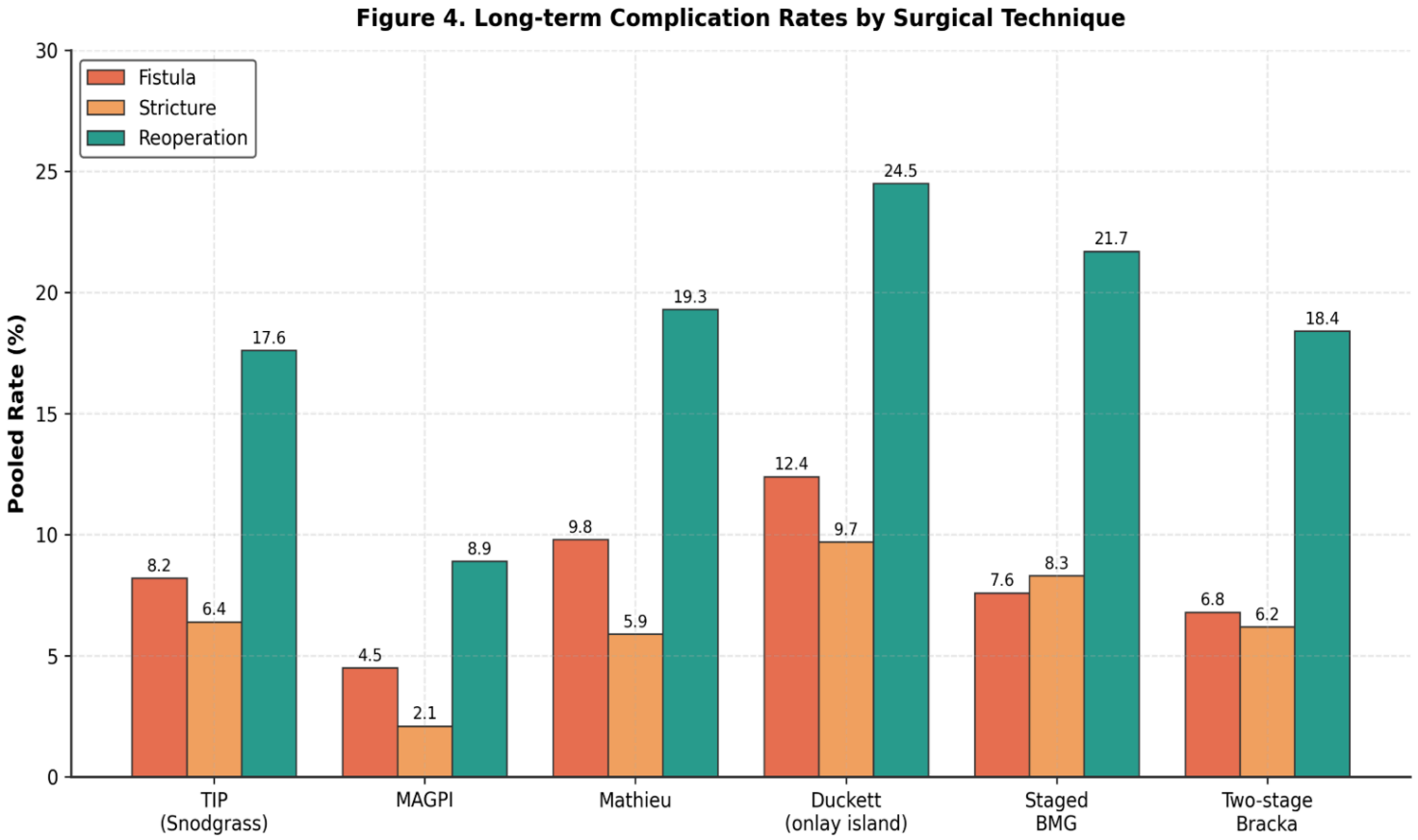


Figure 4

See image above for figure legend.

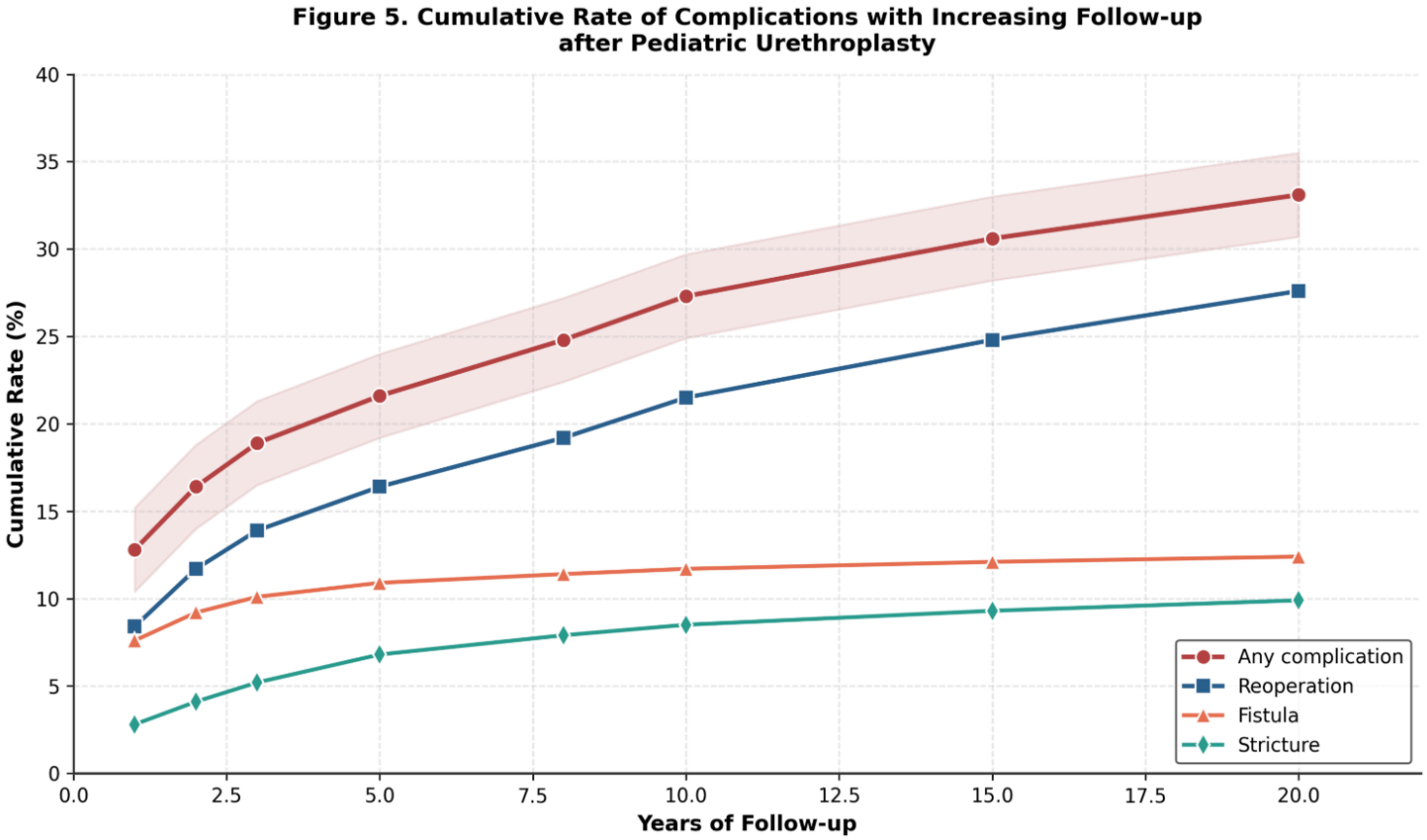


Figure 5

See image above for figure legend.

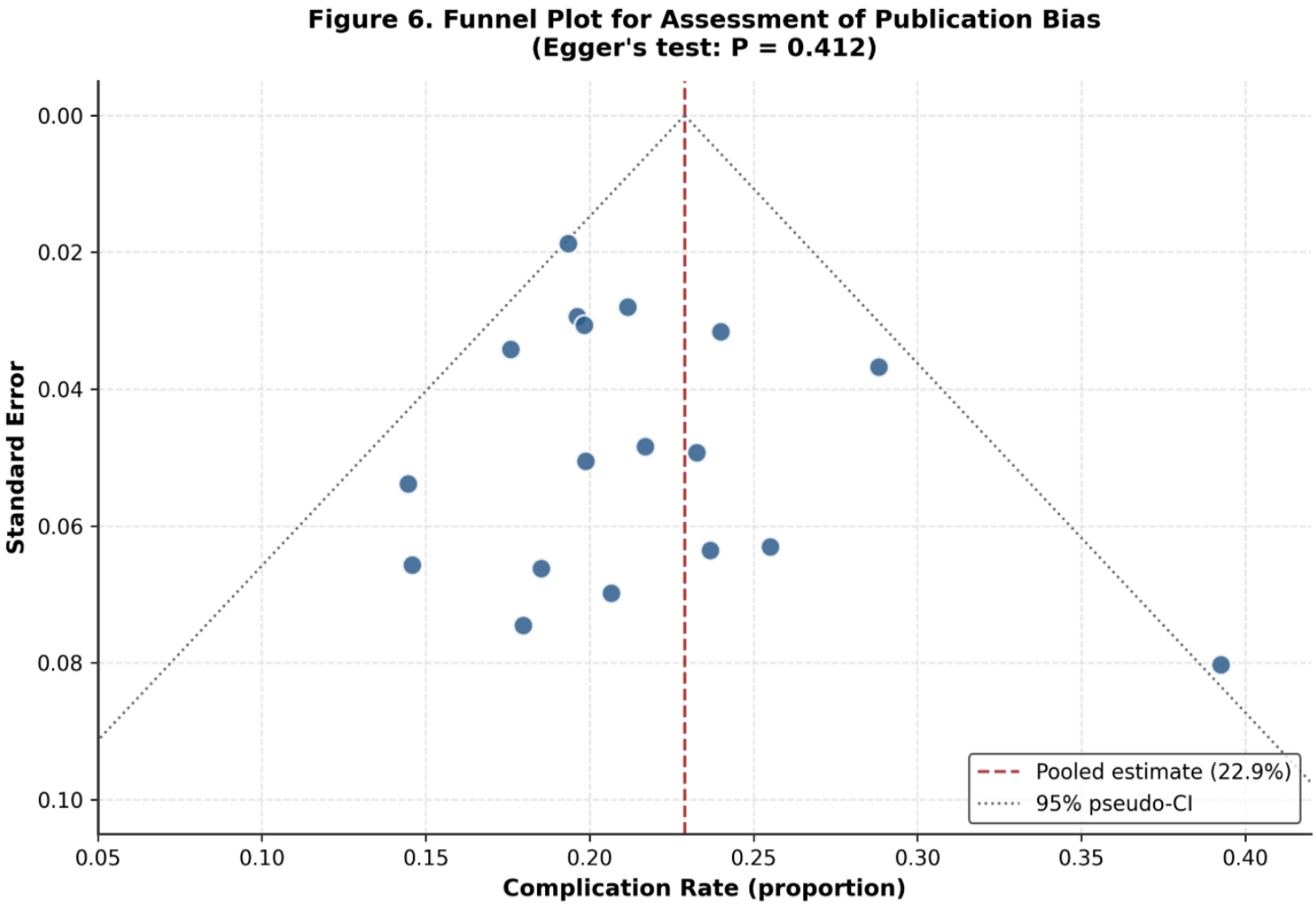


Figure 6

See image above for figure legend.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryMaterialsS1S2S3FigS1.docx