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# Perioperative outcomes of single-port versus non-single-port laparoscopic cholecystectomy in children: a retrospective single-center comparative study

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# Perioperative outcomes of single-port versus non-single-port laparoscopic cholecystectomy in children: a retrospective single-center comparative study

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# Abstract

## Abstract

**Background** Single-incision laparoscopic cholecystectomy (SILC) is increasingly used in children for its cosmetic and minimally invasive potential, but direct comparisons with non-single-port techniques remain scarce in children.

**Methods** Children undergoing laparoscopic cholecystectomy at our institution between August 2018 and August 2026 were retrospectively reviewed. Patients were classified into a single-port group (n=33, completed via a single umbilical port without accessory trocars) or a non-single-port group (n=28, mainly the "single-port plus one" reduced-port technique). Maximum stone diameter and stone number were based on pathology reports, operative time and blood loss on anesthesia records, and discharge dates on the case summary. Comparisons used t, Mann-Whitney U, chi-squared, or Fisher exact tests.

**Results** Baseline characteristics were balanced (all $P>0.05$). Operative time was 111 (88, 162) versus 118 (99, 150) min ($P=0.558$); blood loss was 5 (2, 5) versus 5 (3, 10) mL ($P=0.223$); median time from operation to discharge was 4 days in both groups ($P=0.596$); and total hospitalization costs were similar ($P=0.389$). No gallbladder perforation, bile duct injury, or conversion to open surgery occurred in either group. Operative time did not differ between the

first 10 and the subsequent 23 single-port cases (P=0.666).

**Conclusions** In selected children, single-port cholecystectomy achieved operative time, blood loss, time to discharge, and costs comparable to those of the non-single-port approach, without severe intraoperative complications, supporting its safety and feasibility; the cosmetic advantage awaits prospective confirmation.

**Keywords (alphabetical): Cholecystectomy; Laparoscopy; Pediatrics; Single-port surgery; Surgical outcomes**

## Introduction

Pediatric cholelithiasis is being diagnosed with increasing frequency [1-3]. Population-based data from Ontario showed that the crude incidence of pediatric cholecystectomy rose from 8.8 to 13.0 per 100,000 person-years over two decades [2], with most operations performed in adolescent girls [2,3]. Similar upward trends, together with a shift from hemolysis-related pigment stones towards cholesterol stones in overweight adolescents, have been described in single-center series worldwide [1-4]. Laparoscopic cholecystectomy (LC) remains the standard operation for symptomatic pediatric gallstone disease. Contemporary reviews describe it as well tolerated, and use conversion to open surgery and bile duct injury as the main safety benchmarks [5,6]. Indications include calculous cholecystitis, recovery-stage biliary pancreatitis, gallbladder lesions associated with hemolytic disorders, and

gallbladder polyps [1,5]. In children with chronic hemolytic anemia who undergo splenectomy, concomitant cholecystectomy is advised even for asymptomatic stones [7]. For intermediate-probability choledocholithiasis, cost-effectiveness modeling favors laparoscopic cholecystectomy with intraoperative cholangiography, with therapeutic ERCP reserved for positive findings [8].

Single-incision laparoscopic cholecystectomy (SILC) is performed through a single hidden umbilical incision and was introduced into pediatric surgery as a natural extension of multiport LC [9,10]. However, the coaxial crowding of instruments and optics (the "chopstick effect") and the loss of triangular geometry may prolong operative time and steepen the learning curve, limiting its adoption [10,11]. In children, the technique has been documented most explicitly in the first 25 cases of a single-center series, in which exposure and suturing demands were identified as the principal hurdles [11], and early pediatric reports framed single-port surgery as feasible but technically demanding, with limited case numbers and no concurrent control [10]. Direct pediatric comparisons remain scarce. The only dedicated study compared a hybrid single-port technique (a single umbilical platform with percutaneous retraction instead of an accessory trocar) with four-port cholecystectomy in children; the technique proved feasible and perioperative outcomes were broadly comparable [12]. Reduced-port variants have also been developed to keep exposure while limiting parietal trauma, among them a single-port platform plus one accessory trocar and port-free organ retraction [12,13].

Recent pediatric comparative work has focused on robotic single-site platforms, which match multiport laparoscopy but take longer and cost more [14-16], and on feasibility in resource-limited settings with conventional instruments and no dedicated access device [17,18]. A direct comparison of conventional (non-robotic) single-port laparoscopy with the reduced-port techniques actually used in current practice is therefore still lacking.

Adult evidence sets the benchmark against which a pediatric technique should be judged. Meta-analyses of randomized trials report comparable safety for single-incision and conventional multiport cholecystectomy, with better body image and wound satisfaction but longer operative time [19-24]. This cosmetic and satisfaction advantage persists at long-term follow-up [25,26], and single-port surgery has been reported to be superior for early postoperative pain [27]. A network meta-analysis of 96 trials (11,083 patients) ranked five techniques by the parietal trauma they cause (needlescopic, single-incision, standard laparoscopic, mini-laparotomy and open) and found safety broadly comparable across the minimally invasive variants [28]. Reports on reduced-port surgery are consistent: fewer-than-four-port cholecystectomy performs much like the four-port operation [29], three-port and four-port cholecystectomy are clinically equivalent [30], and mini-laparoscopic cholecystectomy has been used in thousands of patients [31]. The largest single-center comparison, of 2908 transumbilical single-incision versus 1952 three-incision procedures, likewise reported a comparable safety profile [32], as did a recent meta-analysis [33].

Pediatric studies, however, usually group the comparator as "conventional multiport," which makes no distinction for the "single-port plus one" reduced-port technique (an umbilical platform plus one accessory trocar) that is widely used as an intermediate step. Taking "single-port plus one" as the main comparator better reflects the real-world spectrum of techniques and the clinical decision-making context, and sets a deliberately stricter benchmark than a four-port control.

In this study, based on a consecutive cohort of children undergoing LC at a single center, we compared perioperative outcomes between single-port and non-single-port techniques and evaluated the safety and feasibility of the single-port approach in children. The comparator mainly comprised the "single-port plus one" reduced-port technique. Although cosmetic outcomes were not measured in this cohort, previous literature consistently indicates that a single hidden umbilical incision is superior to multiple ports in body image, cosmesis, and wound satisfaction [19,20]; this existing evidence may be considered when selecting the technique. Our institution has previously reported its experience with laparoscopic combined choledochoscopic gallbladder-preserving stone extraction in children [34]; the present study addresses only cholecystectomy, with entirely independent patients and endpoints.

# Methods

## Study design and participants

This was a single-center retrospective cohort study reported in accordance with the STROBE statement [35]. Inclusion criteria were: (i) age <18 years; (ii) indication of gallstones with or without cholecystitis, gallbladder lesions associated with hemolytic disease, or recovery-stage biliary pancreatitis; and (iii) laparoscopic cholecystectomy. Records were excluded for the following reasons: age ≥18 years (3), gallbladder polyps without stones (2), conversion of the planned procedure because of a choledochal cyst (1), one conversion in which the final port configuration could not be verified (1), and operation outside the study period, in February 2012 (1). The final analytic cohort comprised 61 children (single-port, 33; non-single-port, 28), operated between August 2018 and August 2026; single-port procedures were introduced in March 2020.

## Indications for cholecystectomy and institutional context

Our institution runs an active gallbladder-preserving cholecystolithotomy program for children with a functioning, stone-containing gallbladder. Cholecystectomy was therefore reserved for children in whom the gallbladder was unlikely to remain functional or stone-free: those with poor gallbladder contractile function (reduced gallbladder ejection fraction on fatty-meal ultrasonography), gallbladder atrophy, or a gallbladder filled with stones, as

well as those with cholecystitis or other complicated biliary disease. This dual policy of gallbladder preservation versus cholecystectomy shapes the case mix of both groups and was accounted for by baseline balance testing and stratified analyses.

## Group definitions

The single-port group underwent the entire procedure through a single umbilical access device (e.g., TriPort) without any accessory trocars; in some of these cases a choledochoscope was introduced through the gallbladder for exploration, still via the single umbilical incision. The non-single-port group received one accessory trocar in addition to the umbilical device ("single-port plus one," 18 cases) or conventional 3- or 4-port cholecystectomy (10 cases, including cases converted intraoperatively from an intended single-port approach; patients were grouped by the actual total number of trocars). No patient received indocyanine green (ICG) fluorescence cholangiography or port-free organ retraction during the study period.

## Data collection and uniform definitions

Data were extracted with a standardized case-report form (66 variables). Because operative notes, anesthesia records, pathology reports, and the case-summary front sheet occasionally disagreed, uniform criteria were prespecified before analysis. Maximum stone diameter and stone number were taken from pathology reports; operative time and blood loss from anesthesia records; the

discharge date from the case-summary front sheet; and gallbladder size from both ultrasonography and pathology. Discrepancies were annotated case by case. Parameters documented only in operative notes, such as pneumoperitoneum pressure, were not compared between groups because documentation was inconsistent.

## Outcome measures

Baseline variables: age, sex, BMI, ASA class, acute versus elective presentation, gallbladder wall thickness, maximum stone diameter, hemolytic disease, and prior ERCP. Intraoperative outcomes: operative time, blood loss, gallbladder perforation, bile duct injury, conversion to open surgery, and days of antibiotic use; the complication definitions followed those used in the pediatric systematic review of Miura da Costa and Saxena [6]. Postoperative outcomes: time to oral intake, length of stay, days from operation to discharge, and complications graded by the Clavien-Dindo classification [36]. Time to first ambulation and time to flatus were extracted but not analysed because the nursing records documented them too inconsistently. Cost outcome: total hospitalization cost.

## Statistical analysis

Continuous variables were first tested for normality (Shapiro-Wilk) and homogeneity of variance. Normally distributed variables are presented as mean±SD and compared with t tests (Welch correction when variances were

unequal); otherwise they are presented as median (P25, P75) and compared with Mann-Whitney U tests. Categorical variables were compared with chi-squared tests, or Fisher exact tests when expected frequencies were <5. A two-sided α of 0.05 was used. Sensitivity analyses included: (i) the single-port learning curve (first 10 versus subsequent 23 cases by operative time); (ii) heterogeneity within the comparator ("single-port plus one" versus 3/4-port); and (iii) stratification by acute versus elective presentation. Analyses were performed with Python 3.13 (SciPy).

### Ethics statement

This retrospective observational study was reviewed and approved by the Medical Research Ethics Committee of Anhui Provincial Children's Hospital (approval No. EYLL-2026-123), and the requirement for informed consent was waived. All clinical data were anonymized.

## Results

### Baseline characteristics

The two groups were comparable in sex, age, BMI, gallbladder wall thickness, maximum stone diameter, ASA class, acute/elective composition, proportion of hemolytic disease, and prior ERCP (all P>0.05; Table 1).

**Table 1. Baseline characteristics of the children**

| Variable | Single-port (n=33) | Non-single-port (n=28) | Statistic | P |
|---|---|---|---|---|
| Male sex | 17/33 | 16/28 | $x^2$=0.03 | 0.856 |
| Age (years) | 11.3±3.5 | 11.7±3.7 | t | 0.609 |
| BMI (kg/m²) | 18.1 (15.5, 21.4) | 19.1 (15.9, 22.1) | Z | 0.453 |
| Gallbladder wall thickness (mm) | 3.2±1.0 | 2.9±1.2 | t | 0.328 |
| Maximum stone diameter (mm, pathology) | 10.0 (6.0, 12.5) | 8.0 (5.0, 15.0) | Z | 0.393 |
| Hemolytic disease | 6/32 | 3/27 | Fisher | 0.488 |
| Prior ERCP | 4/33 | 2/28 | Fisher | 0.678 |
| ASA class Ⅰ/Ⅱ/Ⅲ | 4/17/0 (n=21) | 6/13/0 (n=19) | Fisher | 0.473 |
| Acute/elective | 5/28 | 3/25 | Fisher | 0.715 |

Note: Normally distributed variables are mean±SD (t test); non-normally distributed variables are median (P25, P75) (Mann-Whitney U test); categorical variables are n/N, with Fisher exact tests when expected frequencies <5. Denominators reflect cases with available data for each variable.

## Perioperative outcomes

Operative time, blood loss, and days of antibiotic use did not differ between groups; no gallbladder perforation, bile duct injury, or conversion to open surgery occurred in either group (Table 2). Blood loss was low in most children, and the highest values were explained by case complexity rather than by technique: 1500 and 200 mL in the single-port group occurred during combined splenectomy, 500 mL in a child with adhesions after a previous

splenectomy, and 750 mL in the non-single-port group in a boy with severe obesity (BMI 38.2). Postoperative complications were minor and managed conservatively in both groups, and no patient required reoperation or endoscopic or radiological intervention (Clavien-Dindo grade III or higher).

Table 2. Perioperative outcomes

| Outcome | Single-port | Non-single-port | P |
|---|---|---|---|
| Operative time (min)* | 111.0 (88.0, 162.0) | 118.0 (99.2, 150.0) | 0.558 |
| Blood loss (mL)* | 5.0 (2.0, 5.0) | 5.0 (3.0, 10.0) | 0.223 |
| Gallbladder perforation | 0 | 0 | — |
| Bile duct injury | 0 | 0 | — |
| Conversion to open surgery | 0 | 0 | — |
| Days of antibiotics (d) | 6.0 (3.0, 8.0) | 6.0 (2.0, 10.0) | 0.882 |

Note: * Anesthesia-record criteria. Blood loss was evaluable in 33 and 20 children and antibiotic days in 25 and 20 children (single-port and non-single-port, respectively); cells annotated as discrepant in the source records were treated as missing. Composition of the non-single-port group: "single-port plus one," 18; 3/4-port, 10; all single-port cases were completed via a single umbilical incision.

## Postoperative recovery

Time to oral intake, total length of stay, time from operation to discharge, and total hospitalization costs did not differ between groups (Table 3). Time to first ambulation and time to flatus could not be analysed because they were documented too inconsistently in the nursing records.

Table 3. Postoperative recovery

| Outcome | Single-port | Non-single-port | P |
|---|---|---|---|
| Time to oral intake (h) | 21.0 (19.0, 42.0) | 25.0 (19.1, 39.0) | 0.747 |
| Length of stay (d) | 8.0 (6.0, 11.0) | 9.0 (7.0, 13.2) | 0.248 |
| Days to discharge after surgery (d) | 4.0 (3.0, 5.0) | 4.0 (3.0, 5.2) | 0.596 |
| Total hospitalization cost (CNY) | 17920.8 (15539.2, 21335.3) | 19073.0 (15810.8, 22190.0) | 0.389 |

Note: Time to oral intake was evaluable in 29 and 23 children and days to discharge in 22 and 24 children (single-port and non-single-port, respectively). Time to first ambulation and time to flatus were recorded in only a minority of children and in inconsistent form, and are therefore not reported. Pain scores were recorded with mixed VAS/FLACC scales in a few patients and were not analysed.

## Sensitivity and subgroup analyses

Operative time did not differ between the first 10 and subsequent 23 single-port cases; neither the learning curve nor heterogeneity within the comparator changed the main conclusions (Table 4, Fig. 1). The scatter plot and LOESS fit of operative time for the 33 single-port cases, ordered by date of surgery, showed no significant shortening over cumulative case volume; combined procedures with splenectomy (5 cases) are marked with open circles.

Table 4. Sensitivity and subgroup analyses

| Comparison | Group 1 | Group 2 | P |
|---|---|---|---|
| Single-port learning curve (first 10 vs subsequent 23), operative time (min) | 132.5 (94.0, 169.8) | 109.0 (85.5, 159.5) | 0.666 |

| Comparison | Group 1 | Group 2 | P |
|---|---|---|---|
| Within comparator: single-port+1 vs 3/4-port, operative time (min) | 114.0 (96.5, 141.0) | 136.5 (108.0, 168.5) | 0.350 |
| Elective subgroup: operative time (min) | 111.0 (86.5, 168.0) | 115.0 (97.0, 142.0) | 0.901 |
| Acute subgroup: operative time (min) | 109.4±42.7 | 181.7±47.4 | 0.067 |

Note: Values are median (P25, P75) except the acute subgroup, which is mean±SD. The acute subgroup comprised five single-port and three non-single-port children and is underpowered; its P value is therefore descriptive only. Group 1 is the first category named in each comparison.

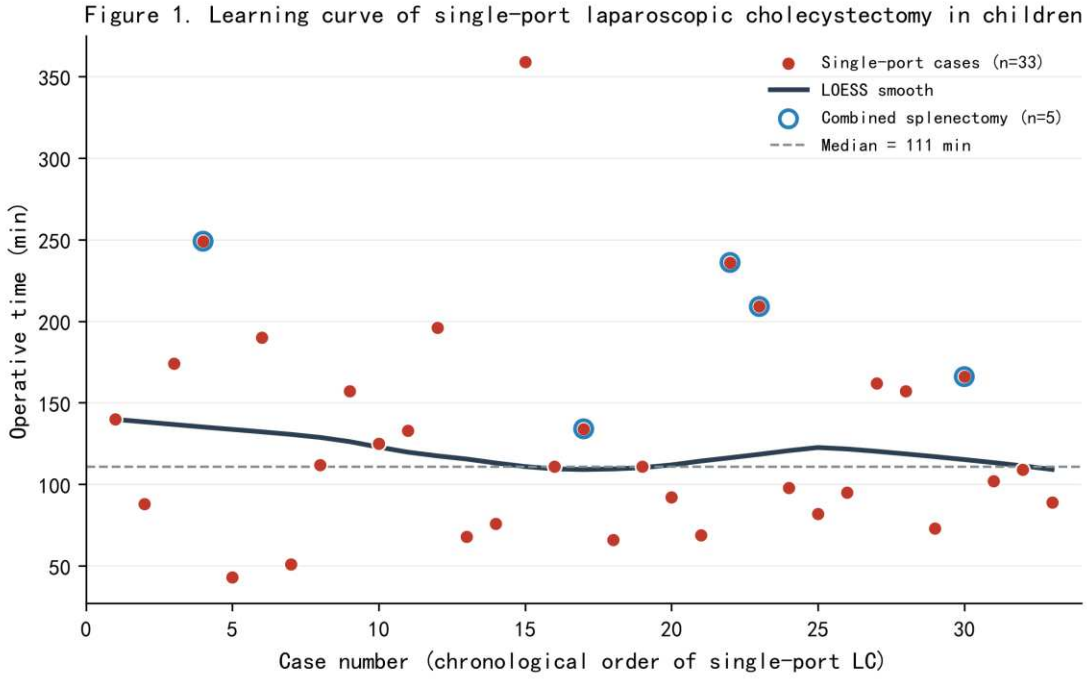



Fig. 1. Learning curve of the single-port group (dots represent operative time of individual cases; solid line, LOESS fit; open circles, combined procedures with splenectomy)

## Discussion

This study shows that, in selected children, single-port laparoscopic cholecystectomy achieved operative time, blood loss, postoperative recovery, length of stay, and hospitalization costs comparable to a non-single-port approach consisting mainly of the "single-port plus one" reduced-port technique. No gallbladder perforation, bile duct injury, or conversion to open surgery occurred in any patient. In a carefully selected pediatric population, therefore, the single-port technique did not come at the price of longer operations or greater intraoperative risk.

Pediatric comparative evidence remains sparse and has so far been framed as single-port versus four ports. The only dedicated pediatric comparison found a hybrid single-port technique feasible, with perioperative outcomes broadly similar to those of four-port cholecystectomy [12]. Our study differs in two respects. First, the comparator is not a four-port operation but predominantly the "single-port plus one" reduced-port technique, a deliberately stricter benchmark, because the additional 5-mm trocar already restores much of the triangulation that single-port surgery lacks. Equivalence against this comparator is therefore a better test of how difficult the technique really is. Second, we report the complete single-port experience of one center, including its early cases, together with a learning-curve analysis, rather than a selected mature series. Our data therefore add to reviews that describe LC as well tolerated but note how little evidence exists on technical

variants [5,6]. Single-port surgery with conventional straight instruments, and therefore without additional cost, has proved feasible in both high- and low-resource settings [17,18], consistent with our experience.

Adult data are consistent in showing that single-incision surgery is safe, cosmetically superior, and slower than the conventional four-port operation [19-24,28]. Our single-port group, by contrast, was not slower than its comparator. The explanation is probably ergonomic. The comparator already worked with the constraints of a reduced-port configuration (lost triangulation, crowded instruments, a narrower working angle) rather than with the roomier four-port arrangement [13]. Two findings in our data fit this explanation. Within our own comparator, the 3/4-port subgroup tended to require longer operations than the "single-port plus one" subgroup (136.5 versus 114.0 min, P=0.350), and three-port and four-port cholecystectomy are known to be clinically equivalent [30], so the extra port does not buy speed. Larger datasets show the same pattern: 2908 transumbilical single-incision procedures matched 1952 three-incision operations in safety [32], and fewer-port surgery in general does not appear to compromise safety [29,31,33].

That no learning curve was measurable needs some explanation. In the first pediatric SILC series, the technical hurdles of exposure and suturing were most evident within the first 25 cases [11], and single-port surgery in children is known to require advanced laparoscopic skills before it becomes efficient [10]. In our cohort, operative time in the first 10 single-port cases did not differ significantly from the subsequent 23 (132.5 versus 109.0

min, P=0.666), and the LOESS fit showed no significant downward trend (Fig. 1). Three factors may account for this. All operations were performed by surgeons already experienced in advanced pediatric laparoscopy, so the steep part of the curve probably lay before the study period. A further five combined splenectomies inflate operative time whatever the sequence, and with 33 cases the analysis cannot detect a moderate slope. The 24-minute difference nonetheless suggests an early-phase effect that a larger series might confirm. A study of operative time in SILC likewise found patient and disease factors, such as body mass index and acute inflammation, to matter more than case sequence [37]. The acute subgroup pointed in the same direction (181.7 versus 109.4 min), but held only eight children. These observations support proctoring and restrictive case selection while the technique is being introduced, rather than unrestricted adoption.

Technical adjuncts are likely to flatten this curve further. In a propensity-score analysis, indocyanine green fluorescence cholangiography improved intraoperative identification of biliary anatomy during single-port cholecystectomy [38]. Port-free organ retractors have provided exposure in reduced-port cholecystectomy with outcomes comparable to the four-port technique [13], and further modifications of the single-port set-up continue to be reported [39]. Bile duct injury is what most limits the adoption of a new biliary technique in children, and its baseline incidence after pediatric LC is low but not negligible [6]; these adjuncts are therefore more likely to improve safety than to shorten operating time. None were used in our cohort,

which should be read as a description of the unassisted technique.

The main anticipated advantage of the single-port approach is cosmetic. Owing to follow-up constraints, measured cosmetic endpoints (e.g., POSAS scores) and parental satisfaction were not included in this study. However, pooled randomized data and the largest single randomized trial consistently indicate superior scar appearance and greater satisfaction with the umbilical wound after single-incision surgery [19,20], and long-term follow-up of randomized cohorts shows that this advantage is sustained rather than a transient early impression [25,26]. In the pediatric SILC series performed with conventional instruments, 24 of 25 families rated the cosmetic result as very satisfactory [18], suggesting that the cosmetic benefit is not confined to adults or to specialized centers. Together with our finding of comparable operative time and safety, this evidence supports offering the single-port technique when scar outcome matters to parents and older children. Prospective follow-up with POSAS and satisfaction questionnaires is planned.

Postoperative pain is the outcome most likely to differ between techniques that differ in parietal trauma, but it could not be analyzed: VAS and FLACC scores were recorded in only a minority of patients and were not applied according to a single protocol. This is a methodological gap rather than a negative finding: a dedicated comparative study found single-port cholecystectomy superior to the standard operation for early postoperative pain [27], and procedure-specific recommendations now emphasize standardized multimodal analgesia with validated, age-appropriate pain metrics [40]. Such

metrics should be built into any prospective pediatric comparison of single-port and multiport techniques, and the absence of a pain difference in our data should not be interpreted as evidence of equivalence.

Body habitus also affects difficulty; a report on body mass index and single-port cholecystectomy found worse outcomes as BMI rose [41]. In our cohort BMI was balanced and the median was in the normal range, so the present findings apply mainly to non-obese children. The economic argument of our study is neutral: total hospitalization cost did not differ between techniques (P=0.389), so the choice can rest on cosmesis and surgeon preference rather than on cost. This also holds when the operation is performed with conventional instruments, which avoids the expense of a dedicated access platform [18].

Several limitations should be acknowledged. First, the retrospective design may have introduced selection bias, as the choice of technique could be influenced by the degree of inflammation, surgeon preference, and our institution's two-track policy of gallbladder preservation versus removal; baseline balance testing and acute/elective stratified analyses were used to support the comparability of groups. The groups were also not perfectly contemporaneous, because all single-port operations were performed from 2020 onwards whereas two children in the comparator were operated in 2018 and 2020, before the single-port programme began, so secular changes in perioperative care cannot be entirely excluded. Second, the single-center design and limited sample size left the study underpowered for rare complications such as bile

duct injury and incisional hernia, which are therefore reported descriptively. Incisional hernia is a recognized trade-off of the single-incision approach, with a higher rate after SILC in adult meta-analyses [19]. Because bile duct injury is uncommon after pediatric LC [6], a much larger cohort would be needed to exclude a clinically important difference. Third, cosmetic scores and parental satisfaction were not followed up; the cosmetic conclusion cited in this paper relies on existing literature rather than measurements in this cohort. Fourth, allocation was non-randomized and the surgeon's learning curve may confound the results; sensitivity analysis by cumulative case number (first 10 versus subsequent 23, P=0.666) was performed, but the analysis cannot exclude an early-phase effect. Fifth, the comparator was a heterogeneous "non-single-port" population (mainly "single-port plus one," with a minority of 3/4-port cases); an internal subgroup test was performed, and future prospective studies stratified by the number of ports are warranted. Sixth, pain scales were mixed and were not used for between-group inference. Seventh, ICG cholangiography and port-free retraction were not used, so the results describe unassisted single-port surgery.

## Conclusions

Among selected children, operative time, blood loss, time from operation to discharge, and costs after single-port laparoscopic cholecystectomy were comparable to those of a non-single-port approach dominated by the "single-port plus one" technique, and severe intraoperative complications were rare.

It appears safe and feasible, and its cosmetic advantage, supported by existing literature, awaits prospective confirmation.

## Declarations

**Ethics approval and consent to participate**: This study was performed in accordance with the Declaration of Helsinki and the relevant national regulations. It was reviewed and approved by the Medical Research Ethics Committee of Anhui Provincial Children's Hospital (approval No. EYLL-2026-123). Owing to the retrospective design and the use of de-identified patient data, the requirement for individual informed consent was waived by the Medical Research Ethics Committee of Anhui Provincial Children's Hospital.

**Clinical trial number**: not applicable.

**Competing interests**: The authors declare no conflict of interest.

**Consent for publication**: Not applicable; no identifiable individual data are reported.

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**Data availability**: The data are available from the corresponding author upon reasonable request, subject to patient privacy considerations.

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