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Single-incision versus conventional multiport laparoscopic-assisted surgery for Meckel's diverticulum in children: a single-center propensity score analysis

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Abstract

Background Meckel's diverticulum (MD) is the most common congenital anomaly of the small intestine, and often leads to various complications in children. This study aims to compare the efficacy and safety of single-incision laparoscopic surgery (SILS) and conventional laparoscopic surgery (CLS) in the treatment of MD in children.

Methods Retrospective review of patients who underwent laparoscopic surgery for MD at a tertiary pediatric hospital from February 2017 to February 2023 was conducted with registered of demographic information, preoperative laboratory results, operative findings, and postoperative outcomes. Based on the surgical strategy, patients were classified into SILS and CLS groups. Propensity score matching (PSM) was employed to adjust for confounding factors, resulting in 188 matched pairs. Using PSM, the two groups were compared for baseline differences and postoperative outcomes.

Results Of the 561 patients, the SILS-to-CLS ratio was 301: 260. After one-to-one PSM, results showed that compared with the CLS group, the SILS group had a significantly shorter postoperative hospital stay ($P=0.004$), and earlier excretion time and fasting time ($P<0.05$). Furthermore, SILS resulted in better scar assessment and higher satisfaction score (both $P<0.05$). The two groups had no significant differences in the rates of postoperative complications ($P=0.439$) and readmission ($P=0.291$). Conversion to open surgery was more common in the SILS group (10.6%) than in the CLS group (6.4%), although this difference was not statistically significant after matching ($P=0.139$).

Conclusion Our study aimed to determine the superiority of SILS over CLS in the treatment of pediatric MD. SILS offers distinct advantages over CLS in managing MD in children, including shorter hospital stays and bowel function recovery, without increasing postoperative complications. These findings suggest that SILS may be a preferable approach, warranting its integration into standard clinical practice for MD treatment.

Keywords Meckel's diverticulum, Laparoscopic surgery; propensity score matching, Children

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Background

Meckel's diverticulum (MD) is the most common congenital anomaly of the small intestine, and can lead to various complications in children, often manifesting as abdominal pain, intestinal obstruction, intussusception, or gastrointestinal bleeding [1]. These symptoms could indicate the presence of a complicated MD [2, 3, 4]. Over the past few decades, there have been significant advancements in the field of minimally invasive surgery (MIS) for children [5, 6, 7]. With the advancement of MIS techniques in pediatric care, a growing body of literature has documented the application of laparoscopy in pediatric patients with MD, and laparoscopic surgery has become the preferred method for treating such conditions [2, 8, 9, 10].

Among the various laparoscopic techniques, single-incision laparoscopic surgery (SILS) and conventional laparoscopic surgery (CLS) are two prevalent approaches. These approaches not only facilitate precise identification of the condition but also allow for effective laparoscopic removal of the diverticulum, thus gaining widespread acceptance in pediatric surgical practice [11]. Previous research on SILS and CLS suggests that SILS offers notable benefits in terms of safety and postoperative recovery [12, 13, 14]. However, at present, reports on SILS for treating MD are relatively scarce, and there is a noticeable lack of case series studies regarding the application of SILS in MD. Isolated cases of SILS for MD have been documented within various research contexts, including studies that explore the utilization of SILS in pediatric patients, research examining its application in segmental small bowel resections, and investigations into its role in managing obscure gastrointestinal bleeding in children [15].

Although SILS is increasingly favored for its cosmetically appealing incisions and faster postoperative recovery, the current literature remains relatively limited regarding its efficacy in treating MD compared with CLS. Which surgical approach is more suitable for treating MD? Does SILS offer advantages over CLS in the treatment of MD? Can SILS replace CLS for this condition? Therefore, this study aims to compare the therapeutic effects of SILS and CLS in the treatment of pediatric MD, evaluate their respective advantages and limitations, and provide a scientific basis for optimizing surgical decision-making.

Materials and methods

Study population

Following institutional approval, one of the authors, WF, accessed the hospital's database via the big data center to identify patients diagnosed with MD who underwent laparoscopic surgery in the Gastrointestinal Neonatal Surgery Department between February 2017 and February 2023. The selection of participants for this study was based on specific inclusion and exclusion criteria. The inclusion criteria required participants to be 18 years of age or younger, with a preoperative diagnosis of Meckel's diverticulum confirmed by postoperative pathology. Additionally, all participants must have undergone laparoscopic surgery, including laparoscopically assisted procedures, and have complete clinical data available. The exclusion criteria included the presence of other gastrointestinal malformations, a history of previous abdominal surgery, or incomplete clinical data. These criteria were established to ensure the homogeneity of the included sample and the reliability of the study results.

Diagnosis

The diagnosis of MD was primarily established through a combination of clinical evaluation and imaging studies. Initially, patients presented with symptoms such as abdominal pain, gastrointestinal bleeding, or intestinal obstruction, prompting further investigation. Imaging modalities included: (1) Ultrasound: always used as a first-line imaging technique, especially in pediatric patients, to assess for any abdominal abnormalities; (2) Computed Tomography (CT) Scan: a non-invasive method that provides detailed cross-sectional images of the abdomen, helping to identify the presence of MD, particularly in older children; (3) Technetium-99 m Pertechnetate Scintigraphy: this nuclear medicine scan is specifically useful for diagnosing MD by detecting ectopic gastric mucosa, which is particularly effective for cases of gastrointestinal bleeding. In some cases, a definitive diagnosis was confirmed through intraoperative findings during laparoscopic surgery, where the diverticulum was identified and subsequently resected.

Surgical techniques

The surgical approaches were classified into two categories: SILS and CLS. All patients received standard preoperative care, and the surgeries were performed by a dedicated surgical team. The choice between SILS and CLS was based on a thorough preoperative evaluation that included the patient's clinical presentation, the anatomical considerations of the MD, and the surgeon's assessment of the complexity of the case. Specifically, SILS was generally considered in patients who presented with simpler cases of MD, with favorable anatomical features, and where the surgeon determined that SILS was feasible and safe. Conversely, CLS was employed for more complex cases or when the surgeon anticipated difficulties that could arise during a SILS approach.

SILS Technique: A 1–1.5 cm incision was made at the umbilicus, and a 5 mm trocar was inserted using the open Hasson technique. A 5 mm 30-degree camera was employed for the procedure. Two additional trocars

(3–5 mm) were placed at the 6:00 and 12:00 positions relative to the umbilicus cicatrix to establish a working channel (Fig. 1-supplement). Under laparoscopic guidance, the ileocecal region was located, and the MD was identified in the proximal small intestine. The umbilical incision was then extended to 2–2.5 cm for a transumbilical laparoscopically assisted approach, allowing for the removal of the diverticulum along with the adjacent bowel segment, followed by intestinal anastomosis. After completing the anastomosis, the bowel was inspected for leakage, and the umbilical cicatrix incision was sutured layer by layer.

CLS Technique: a 5–10 mm incision was made at the umbilical cicatrix to establish pneumoperitoneum, followed by laparoscopic exploration using 5 mm–3 mm cannulas placed in the left middle and lower abdomen (Fig. 1-supplement). The surgical procedure and techniques were consistent with those employed in the SILS group.

Clinical variables

In accordance with the relevant literature and clinical practice, we retrospectively collected the following variables as potential confounders. Clinical data included the following: (1) Demographic information: surgical age, sex, clinical findings (vomiting, abdominal pain, bloody stool, fever, abdominal distension, and symptom duration), and preoperative nutritional status; (2) preoperative laboratory results: white blood cell count (WBC), neutrophil count (Neut), lymphocyte count (LY), mononuclear cell count (MC), hemoglobin (HB), and C-reactive protein (CRP); and (3) operative variables: start time of operation before or after midnight, distance of the diverticulum to the ileocecal region, anesthesiologists' physical status classification (ASA class), and case type (elective, urgent, or emergent).

The primary outcomes of our study were surgical time, blood loss during surgery, length of postoperative hospital stay, postoperative complications within 30 days (graded based on the Clavien-Dindo classification system [CCS] [16]), laparoscopic conversion to open, excretion time, fasting time, readmission within 30 days, and scar assessment (Patient and Observer Scar Assessment Scale) [17]. Furthermore, Surveys assessed caregiver's satisfaction with the overall experience using a 5-point Likert scale (very dissatisfied, dissatisfied, neither, satisfied, and very satisfied).

Statistical analysis

Data were analyzed using IBM SPSS version 27.0 and R software (R Foundation for Statistical Computing, Vienna, Austria). Categorical data were presented as n (%) and analyzed using the chi-square test. Continuous variables were evaluated for normality using the Shapiro-Wilk test: normally distributed data are expressed as mean ± standard deviation (SD) and analyzed with Student's t-test; non-normally distributed data are expressed as median (interquartile range, IQR) and assessed with the Mann-Whitney test. Propensity score-matched (PSM) analysis was performed using nearest neighbor matching with a caliper of 0.25 to mitigate potential selection bias, and the quality of the match was evaluated using the absolute SMD, with a target of <0.20. Statistical significance was defined as $p<0.05$ (two-tailed). Regarding the PSM methodology, we matched patients from the CLS group with those from the SILS group based on several confounders that could influence surgical outcomes. The confounders used for matching included age, initial presentation (e.g., gastrointestinal bleeding, abdominal pain), and any previous surgical history. We employed a logistic regression model to calculate the propensity scores for each patient, and then we performed a 1:1 matching using the nearest neighbor method without replacement.

Results

Baseline characteristics

82 patients were excluded, and 561 subjects were enrolled in the following study, with 260 received CLS and 301 received SILS for MD (Fig. 1). Clinical data before and after PSM of these patients are presented in Table 1. Before PSM, the following variables were statistically different between CLS and SILS groups: duration of disease, case type, distance to the ileocecal region, Neut, and LY ($P<0.05$). Before PSM, balance test showed poor balance of variables between the two groups (Fig. 2).

Thus, we made PSM to minimize allocation bias and better represent the associations between surgical approaches and postoperative outcomes of MD after surgery. After 1:1 PSM, 188 of 260 patients in the CLS group (72.3%) were successfully matched to 188 patients of 301 in the female group (62.2%). The two groups were well balanced in their baseline characteristics after matching ($P>0.05$ and SMD <0.20, Table 1; Fig. 2).

Surgical outcomes

The contents in Table 2 demonstrates the effect of surgical approaches on postoperative outcomes in these patients, with results inevitably influenced by individual differences. Before PSM, the postoperative outcomes analysis showed that patients received CLS were significantly associated with longer length of postoperative hospital stay (median[IQR]: 7 [7, 9] vs. 7 [6, 7.7] days) and postoperative excretion time (median[IQR]: 24 (22, 30) vs. 22 (21, 27) hours), lower rate of conversion to open surgery (6.2% vs. 11.3%), and higher score of scar assessment (6.1 ± 1.4 vs. 4.5 ± 1.4) (all $P<0.001$), while there was no significant differences in surgical time, blood loss

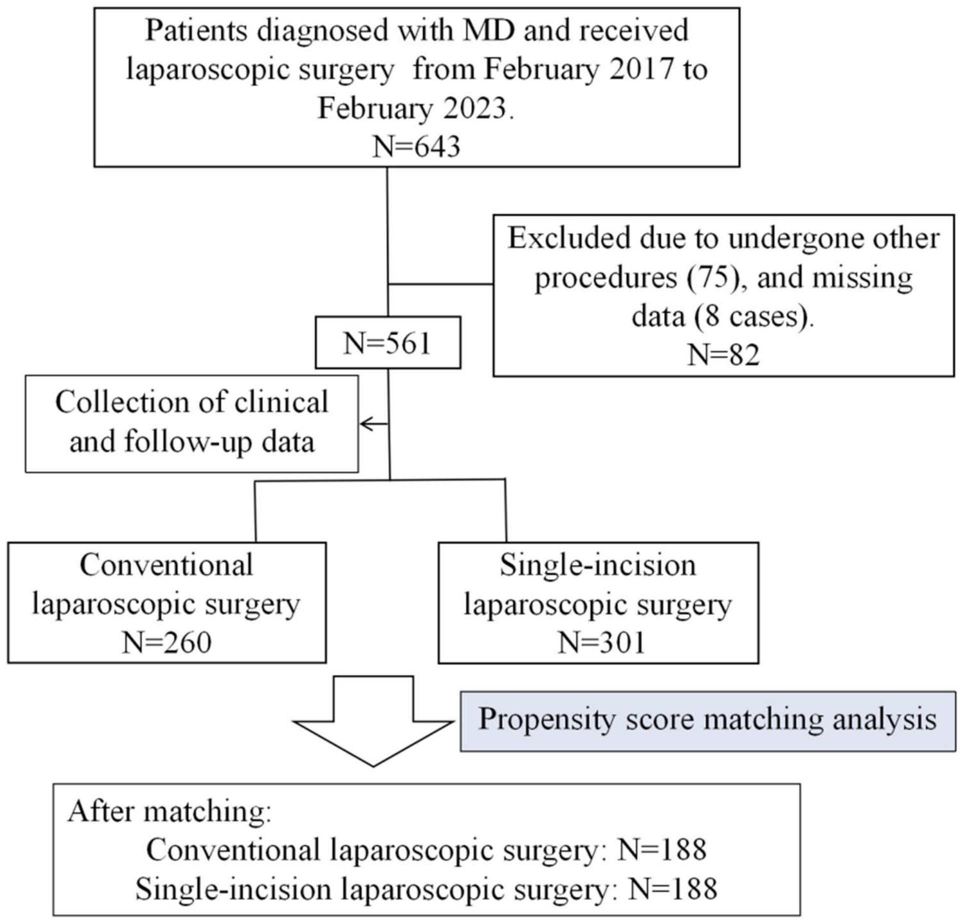

Fig. 1 Flow chart of the study population

during surgery, postoperative complications, postoperative fasting time, Re-admission within 30 day, and satisfaction score between the two groups ($P>0.05$).

After PSM, it found that patients received CLS still had a longer length of postoperative hospital stay (median[IQR]: 7 [7,9] vs. 7 [6,8] days), postoperative excretion time (median[IQR]: 24.50 [22, 30] vs. 22 [21, 27]) hours), and higher score of scar assessment (6.0 ± 1.3 vs. 6.0 ± 1.3) (all $P<0.001$), while the rates of conversion to open surgery were comparable between the two groups ($P>0.05$). In addition, compared with the CLS group, SILS were more likely to have higher satisfaction score (4.6 ± 0.7 vs. 4.4 ± 0.5) and shorter postoperative fasting time (median [IQR]: 54 [42, 63] vs. 55 [45, 66]) (both $P<0.05$).

Discussion

SILS has seen increasing adoption across various surgical fields, and its application to MD is gaining interest due to its potential for reduced invasiveness and improved cosmetic outcomes. Prior studies have demonstrated the feasibility and safety of SILS in different contexts, but comparative data on its efficacy for MD remain limited [18, 19, 20, 21]. Our study aimed to address this gap by comparing outcomes of SILS to those of CLS in pediatric patients with MD.

We found that SILS for MD in children resulted in shorter postoperative recovery times and a lower incidence of complications compared to CLS, suggesting that SILS may be a preferable option for this patient population, offering both enhanced recovery and safety. This finding is underscored by our analysis of real-world data from a PSM cohort treated at a single center, which highlights the advantages of SILS for MD relative to CLS, while ensuring comparable safety and efficacy. By conducting PSM, we have assessed baseline differences and matching quality, verified confounder control, and enhanced transparency and reproducibility. Presenting both pre- and post-matching results facilitates a comprehensive understanding of our analysis and underscores the integrity of our findings.

Postoperative impaired bowel function is a common issue following intraperitoneal surgery, often leading to discomfort characterized by nausea, vomiting, and bloating. These complications can prolong hospital stays, increasing the risk of nosocomial infections, deep vein

Table 1 Clinical data before and after PSM matching in different laparoscopic techniques

Variable	Before PSM					After PSM				
	Total ($n=561$)	CLS ($n=260$)	SILS ($n=301$)	*P*	SMD	Total ($n=376$)	CLS ($n=188$)	SILS ($n=188$)	*P*	SMD
Demographic information										
Sex, n (%)ǂ				0.426					0.553	
Female	136 (24.24)	59 (22.69)	77 (25.58)		0.066	95 (25.27)	45 (23.94)	50 (26.60)		0.060
Male	425 (75.76)	201 (77.31)	224 (74.42)		-0.066	281 (74.73)	143 (76.06)	138 (73.40)		-0.060
Age (year)#	6.10 (2.47, 9.63)	5.69 (2.24, 8.80)	6.49 (2.73, 10.19)	0.064	0.169	6.33 (2.72, 9.66)	6.21 (2.89, 9.27)	6.41 (2.59, 10.02)	0.942	0.027
Duration of disease, n (%)ǂ				0.019^					0.885	
< 1 day	196 (34.94)	107 (41.15)	89 (29.57)		-0.254	143 (38.03)	75 (39.89)	68 (36.17)		-0.077
1 ~ < 3 days	205 (36.54)	92 (35.38)	113 (37.54)		0.045	134 (35.64)	64 (34.04)	70 (37.23)		0.066
3 ~ < 7 days	119 (21.21)	46 (17.69)	73 (24.25)		0.153	74 (19.68)	37 (19.68)	37 (19.68)		00
≥ 7 days	41 (7.31)	15 (5.77)	26 (8.64)		0.102	25 (6.65)	12 (6.38)	13 (6.91)		0.021
Preoperative nutritional status, (n/%)ǂ				0.377					0.929	
Normal	490 (87.34)	226 (86.92)	264 (87.71)		0.024	333 (88.56)	166 (88.30)	167 (88.83)		0.017
Risk of malnutrition	58 (10.34)	30 (11.54)	28 (9.30)		-0.077	34 (9.04)	18 (9.57)	16 (8.51)		-0.038
Malnutrition	13 (2.32)	4 (1.54)	9 (2.99)		0.085	9 (2.39)	4 (2.13)	5 (2.66)		0.033
Surgery at midnight, n (%)ǂ				0.491					0.803	
Yes	118 (21.03)	58 (22.31)	60 (19.93)		-0.059	82 (21.81)	42 (22.34)	40 (21.28)		-0.026
No	443 (78.97)	202 (77.69)	241 (80.07)		0.059	294 (78.19)	146 (77.66)	148 (78.72)		0.026
Operation technique, n (%)ǂ				0.157					0.824	
Wedge resection	172 (30.66)	72 (27.69)	100 (33.22)		0.117	118 (31.38)	58 (30.85)	60 (31.91)		0.023
Ileal resection with end-to-end anastomosis	389 (69.34)	188 (72.31)	201 (66.78)		-0.117	258 (68.62)	130 (69.15)	128 (68.09)		-0.023
ASA Class, n (%)ǂ				0.464					0.808	
Grade 1	341 (60.78)	166 (63.85)	175 (58.14)		-0.116	229 (60.9)	116 (61.70)	113 (60.11)		-0.033
Grade 2	170 (30.3)	75 (28.85)	95 (31.56)		0.058	113 (30.05)	53 (28.19)	60 (31.91)		0.080
Grade 3	43 (7.66)	16 (6.15)	27 (8.97)		0.099	29 (7.71)	16 (8.51)	13 (6.91)		-0.063
Grade 4	7 (1.25)	3 (1.15)	4 (1.33)		0.015	5 (1.33)	3 (1.60)	2 (1.06)		-0.052
Case type, n (%)ǂ				0.002^^					0.759	
Elective	200 (35.65)	75 (28.85)	125 (41.53)		0.257	123 (32.71)	62 (32.98)	61 (32.45)		-0.011
Urgent	253 (45.1)	122 (46.92)	131 (43.52)		-0.069	180 (47.87)	87 (46.28)	93 (49.47)		0.064
Emergent	108 (19.25)	63 (24.23)	45 (14.95)		-0.260	73 (19.41)	39 (20.74)	34 (18.09)		-0.069
Distance to the ileocecal region (cm)*	76.35 ± 16.62	78.29 ± 14.75	74.67 ± 17.94	0.009^^	-0.202	77.78 ± 16.23	77.95 ± 14.78	77.61 ± 17.60	0.837	-0.020
Symptoms										
Vomiting, n (%)ǂ				0.952					0.833	
Yes	223 (39.75)	103 (39.62)	120 (39.87)		05	150 (39.89)	74 (39.36)	76 (40.43)		0.022
No	338 (60.25)	157 (60.38)	181 (60.13)		-05	226 (60.11)	114 (60.64)	112 (59.57)		-0.022
Abdominal pain, n (%)ǂ				0.704					0.458	
Yes	347 (61.85)	163 (62.69)	184 (61.13)		-0.032	231 (61.44)	119 (63.30)	112 (59.57)		-0.076
No	214 (38.15)	97 (37.31)	117 (38.87)		0.032	145 (38.56)	69 (36.70)	76 (40.43)		0.076

Table 1 (continued)

Variable	Before PSM					After PSM				
	Total (n = 561)	CLS (n = 260)	SILS (n = 301)	P	SMD	Total (n = 376)	CLS (n = 188)	SILS (n = 188)	P	SMD
Bloody stool, n (%)ǂ				0.870					0.074	
Yes	175 (31.19)	82 (31.54)	93 (30.90)		-0.014	116 (30.85)	66 (35.11)	50 (26.60)		-0.193
No	386 (68.81)	178 (68.46)	208 (69.10)		0.014	260 (69.15)	122 (64.89)	138 (73.40)		0.193
Fever, n (%)ǂ				0.269					0.325	
Yes	363 (64.71)	162 (62.31)	201 (66.78)		0.095	125 (33.24)	67 (35.64)	58 (30.85)		-0.104
No	198 (35.29)	98 (37.69)	100 (33.22)		-0.095	251 (66.76)	121 (64.36)	130 (69.15)		0.104
Abdominal distension, n (%)ǂ				0.704					0.753	
Yes	227 (40.46)	103 (39.62)	124 (41.20)		0.032	153 (40.69)	75 (39.89)	78 (41.49)		0.032
No	334 (59.54)	157 (60.38)	177 (58.80)		-0.032	223 (59.31)	113 (60.11)	110 (58.51)		-0.032
Laboratory parameters									0.691	
WBC ($\times10^9$/L)#	14.01 (11.10, 16.51)	13.68 (11.09, 16.12)	14.33 (11.36, 17.09)	0.140	0.076	13.52 (10.69, 16.27)	13.61 (10.79, 16.19)	13.12 (10.56, 16.30)	0.970	-0.040
Neut ($\times10^9$/L)#	9.14 (7.17, 11.49)	8.45 (6.90, 10.97)	9.84 (7.60, 11.87)	< 0.001^^^	0.267	8.70 (6.95, 10.98)	8.52 (6.93, 11.14)	9.16 (7.02, 10.62)	0.520	-0.002
LY ($\times10^9$/L)#	3.05 (2.07, 4.33)	3.52 (2.30, 4.82)	2.81 (1.93, 3.65)	< 0.001^^^	-0.407	3.06 (2.02, 4.41)	3.16 (2.22, 4.55)	3.02 (1.92, 4.17)	0.226	-0.077
MC ($\times10^9$/L)#	1.01 (0.74, 1.33)	1 (0.72, 1.22)	1.04 (0.77, 1.44)	0.080	0.133	0.95 (0.70, 1.22)	0.99 (0.71, 1.22)	0.92 (0.68, 1.26)	0.507	-0.031
HB (g/L)#	108 (92, 125)	107 (94, 126)	109 (92, 125)	0.948	-0.016	106.5 (92, 124)	106 (92.5, 122)	109 (92, 126)	0.443	0.077
CRP, n (%)ǂ				0.553					0.591	
< 8 mg/L	178 (31.73)	88 (33.85)	90 (29.90)		-0.086	131 (34.84)	67 (35.64)	64 (34.04)		-0.034
8 ~ < 20 mg/L	184 (32.8)	78 (30)	106 (35.22)		0.109	122 (32.45)	55 (29.26)	67 (35.64)		0.133
20 ~ < 50 mg/L	126 (22.46)	61 (23.46)	65 (21.59)		-0.045	78 (20.74)	42 (22.34)	36 (19.15)		-0.081
≥ 50 mg/L	73 (13.01)	33 (12.69)	40 (13.29)		0.018	45 (11.97)	24 (12.77)	21 (11.17)		-0.051

Note: ǂ Chi-square test; *Values are presented as mean ± SD and used Student's t test; #Values are presented as medians (IQR) and used Mann-Whitney U test

^ $P < 0.05$, ^^ $P < 0.01$, ^^^ $P < 0.001$

CLS, Conventional laparoscopic surgery; SILS, Single-incision laparoscopic surgery; WBC, white blood cell count; Neut, neutrophil count; Ly, lymphocyte count; MC, Monocyte count; HB, hemoglobin; CRP, c-reactive protein

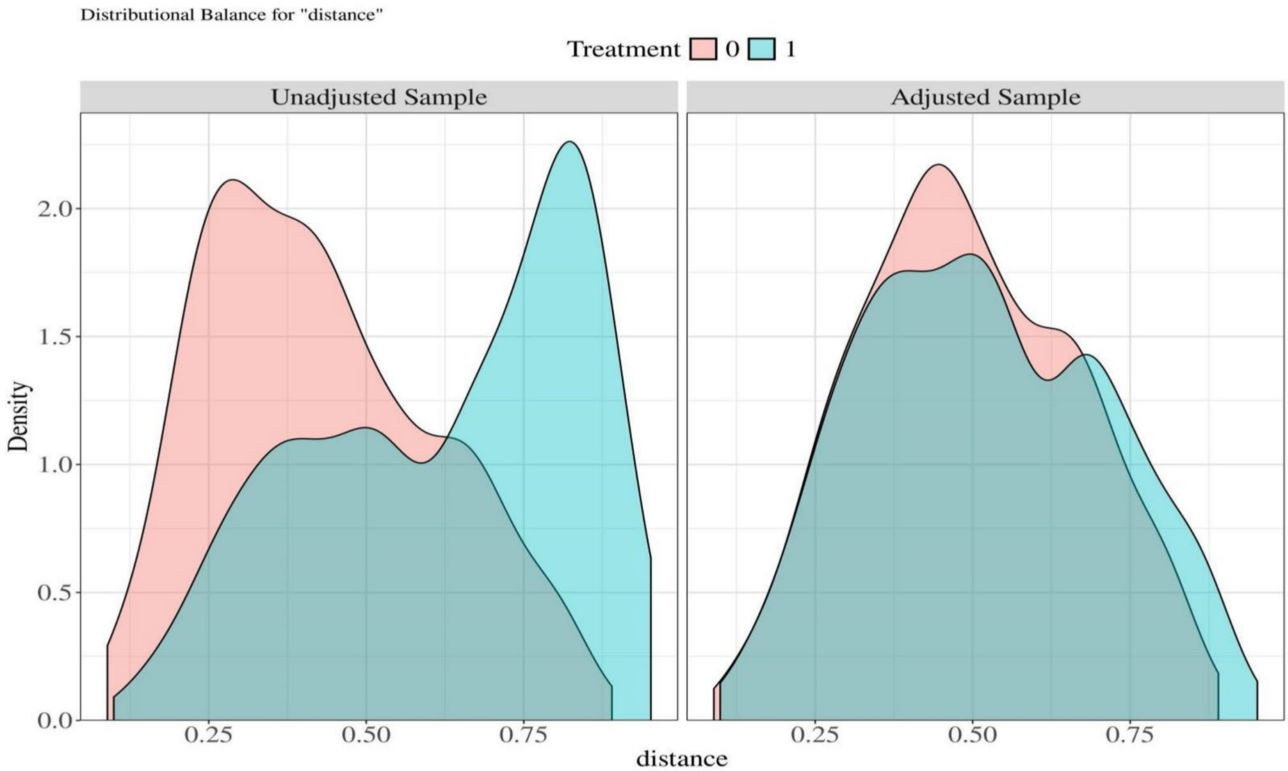

Fig. 2 Balance of covariates before and after propensity score matching. Unadjusted Sample: before matched covariate equalization; Adjust Sample: after matched covariate equalization (0-conventional laparoscopic surgery, 1-single-incision laparoscopic surgery)

thrombosis, and impaired lung function, ultimately raising hospitalization costs and 30-day readmission rates [22]. In our study, patients who underwent SILS experienced an earlier recovery of bowel function. The early recovery of bowel function suggests reduced surgical trauma and quicker restoration of gastrointestinal function, aligning with the principles of enhanced recovery after surgery (ERAS) protocols aimed at optimizing postoperative care [23]. A single-center study has demonstrated that implementing ERAS protocols for patients with MD requiring surgery is both safe and effective [24]. However, some researchers have noted the absence of a standardized framework for evaluating ERAS protocols, making it challenging to draw definitive conclusions about which factors most significantly impact outcomes after laparoscopic surgery [25, 26]. Consequently, the benefits of laparoscopic surgery, including faster bowel function recovery with SILS, require further validation within optimal ERAS programs. As for the observed readmission rates, these may be influenced by several clinical factors, such as the severity of the initial condition leading to surgery, postoperative complications such as infections or anastomotic leaks, and the overall health status of the patients prior to surgery.

Another significant finding of our study is the reduced length of hospital stay for patients undergoing SILS, which can be attributed to both the minimally invasive nature of the procedure and earlier recovery of bowel function. To clarify, the median stay of 7 days for both groups reflects the central tendency, while the IQRs indicate the spread of the data. The significant p-values suggest that the variability in hospital stay duration differs between the groups, which may have important clinical implications. Our results indicate a prolonged hospital stay for patients undergoing CLS, which can be attributed to several factors. Firstly, the CLS procedure typically involves multiple incisions, leading to greater tissue trauma and a longer recovery time compared to SILS, which uses a single incision. This increased trauma can result in a more extended postoperative recovery period for patients in the CLS group [27, 28]. Secondly, patients in the CLS group may experience higher levels of postoperative pain due to the nature of the multi-port technique, necessitating more intensive pain management strategies. This requirement can contribute to delayed discharge as medical staff monitor and manage pain levels [29, 30]. However, it is essential to consider that patient demographics and comorbidities may differ between the groups, potentially influencing recovery and discharge times [31, 32]. Although we adjusted for baseline characteristics using propensity score matching, residual confounding factors may still contribute to the

Table 2 Analysis of clinical outcomes

Variables	Before PSM				After PSM			
	Total ($n=561$)	CLS ($n=260$)	SILS ($n=301$)	P	Total ($n=376$)	CLS ($n=188$)	SILS ($n=188$)	P
Surgical time (minute)#	82 (65,105)	85 (65,105)	80 (61,103)	0.237	85 (65,109.25)	85.20 (65, 105.17)	85 (66.50, 110)	0.876
blood loss during surgery (ml)#	4 (3,5)	4 (3,5.25)	4 (3,5)	0.212	4 (3,5)	4 (3,6)	4 (3,5)	0.289
Length of postoperative hospital stay (day)#	7 (6,8)	7 (7,9)	7 (6,7.7)	< 0.001^^^	7 (6,8)	7 (7,9)	7 (6,8)	0.004^^
Postoperative complications, n (%)ǂ				0.515				0.439
No	499 (88.95)	227 (87.31)	272 (90.37)		330 (87.77)	163 (86.70)	167 (88.83)	
Mild	47 (8.38)	25 (9.62)	22 (7.31)		36 (9.57)	18 (9.57)	18 (9.57)	
Severe	15 (2.67)	8 (3.08)	7 (2.33)		10 (2.66)	7 (3.72)	3 (1.60)	
Conversion, n(%)ǂ				0.033^				0.139
No	511 (91.09)	244 (93.8)	267 (88.7)		344 (91.5)	176 (93.6)	168 (89.4)	
Yes	50 (8.91)	16 (6.2)	34 (11.3)		32 (8.5)	12 (6.4)	20 (10.6)	
Excretion time (hour)#	23 (21, 29)	24 (22, 30)	22 (21, 27)	< 0.001^^^	23 (21, 28)	24.50 (22, 29)	22 (21, 27)	< 0.001^^^
Fasting time (hour)#	54 (43, 64)	53.50 (44, 65)	55 (42, 64)	0.498	54 (44, 64)	55 (45, 66)	54 (42, 63)	0.013^
Re-admission within 30 days, n(%)ǂ				0.429				0.291
No	530 (94.47)	243 (93.46)	287 (95.35)		352 (93.62)	173 (92.02)	179 (95.21)	
Yes	31 (5.53)	17 (6.54)	14 (4.65)		24 (6.38)	15 (7.98)	9 (4.79)	
Scar assessment*	5.6 ± 1.3	6.1 ± 1.4	4.5 ± 1.4	< 0.001^^^	5.4 ± 1.5	6.0 ± 1.3	6.0 ± 1.3	< 0.001^^^
Satisfaction score*	4.6 ± 0.7	4.5 ± 0.7	4.6 ± 0.7	0.092	4.6 ± 0.6	4.4 ± 0.5	4.6 ± 0.7	0.003^^

Note: ǂ Chi-square test; *Values are presented as mean ± SD and used Student's t test; #Values are presented as medians (IQR) and used Mann-Whitney U test

^ $P < 0.05$, ^^ $P < 0.01$, ^^^ $P < 0.001$

CLS, Conventional laparoscopic surgery; SILS, Single-incision laparoscopic surgery observed differences. The reduction in hospital stay typically leads to less postoperative pain and a quicker recovery, facilitating earlier discharge and enhancing patient comfort while also reducing healthcare costs [33]. The length of hospital stay is often regarded as a surrogate marker for various key aspects of healthcare quality [34]. It reflects the overall quality of patient care, the management of complications, and the effectiveness of surgical practices. A shorter hospital stay may indicate efficient surgical procedures and effective postoperative care, potentially leading to improved patient outcomes. Conversely, prolonged hospital stays can suggest complications or suboptimal management strategies, making the length of hospitalization a critical benchmark for evaluating and improving surgical protocols and patient care standards [35]. This finding aligns with data from other surgical specialties [36, 37, 38, 39, 40].

Despite the promising results of SILS, there remains some controversy regarding its advantages over CLS in terms of short-term and long-term patient satisfaction and cosmetic outcomes. For instance, Lurje et al. conducted a double-blind randomized controlled trial (RCT) to assess cosmetic outcomes, body image, pain, and quality of life following single-port laparoscopic cholecystectomy (SPLC) compared to conventional 4-port laparoscopic cholecystectomy. They concluded that patients in the SPLC group reported superior cosmetic and body image outcomes at both 12 weeks and 1 year post-surgery compared to those in the 4-port laparoscopic group [41]. Similarly, a case study on appendectomy demonstrated that single-incision laparoscopic appendectomy significantly improved cosmetic satisfaction for both patients and their families when compared to open appendectomy [42]. Meta-analyses of SILS nephrectomy and colectomy have also shown better cosmetic outcomes with the single-incision approach [42, 43]. In our study, patient satisfaction was markedly higher in the SILS group, likely due to the cosmetic benefits of a single, hidden incision and the overall reduction in postoperative discomfort [44]. This aesthetic advantage, combined with a quicker recovery, significantly influences patient preference for SILS over traditional approaches [45].

Although the differences in surgical time and blood loss during surgery between the SILS and CLS groups were not statistically significant, these results could be influenced by factors such as the surgeon's experience and the teamwork during surgery. Objectively speaking, firstly, SILS has developed relatively late in the world, and its development maturity may still be slightly lower than CLS. Secondly, for the operability of surgery, CLS is indeed slightly higher than SILS, so logically CLS should have a shorter operation time. In our study, it is possible that the time difference between the two operations is not prominent due to the fact that the medical team in our hospital has experienced the initial stage of learning the operation when performing SILS, the proficiency and operability have reached a relatively high standard, and the improvement of the surgeon's level year by year. Additionally, accurately measuring blood loss during laparoscopic procedures is inherently challenging. Studies have reported that SILS is easier to conversion to open surgery in pediatric population due to attenuated visibility and maneuverability offered by a single incision [46, 47, 48]. In the present study, the elevated open conversion rates may be attributed to several factors, including complex anatomical variations, the presence of significant adhesions from previous surgeries, or unforeseen intraoperative complications that necessitated a transition to open surgery to ensure patient safety. Additionally, the learning curve associated with laparoscopic techniques may also play a role, especially in a single-institution study where the surgical team may encounter varied cases. In this study, the conversion rate of SILS was higher than that of CLS, but it was comparable. The following reasons may explain the discrepancy:1) the surgeon in this study, already has extensive clinical experience in the diagnosis and treatment of this disease and has passed the surgical qualification assessment of our institution before performing the surgeries; 2) all surgical procedures in this study were conducted by the permanent physician team, who has approached or reached the learning plateau period in his mastery of SILS and CLS. This may explain why there was no further significant improvement in these indicators.

Despite the identified advantages, the rates of postoperative complications did not significantly differ between the two surgical techniques, indicating that SILS is as safe as the CLS. This finding provides reassurance regarding the use of SILS in clinical practice, supporting its adoption as a viable alternative. We hypothesized that the observed effect might be attributed to the careful selection of cases deemed suitable for SILS by the physicians, alongside the implementation of appropriate treatment strategies that ensure smooth operations and minimize the risk of complications. With the evolution of medical devices and technological advancements, surgeons' expertise has progressively improved, mirroring the increasing volume of surgical procedures. Consequently, the rate of complications associated with SILS has become comparable to that associated with CLS [49].

However, several potential limitations should be noted in this study. First, this study is limited by its retrospective design, and non-standardization of data collection may have resulted in other statistically significant factors or potential confounders not being shown in this analysis. Although we minimized these allocation bias by using PSM method to adjust for significant differences in baseline characteristics, it is important to acknowledge that the selection of patients with MD in our study may be subject to selection bias. Additionally, the matching process may not have perfectly balanced all characteristics between groups, potentially leading to residual confounding. We recommend that future studies incorporate a more robust methodology for confounder selection and explore alternative statistical approaches to validate the findings. Meanwhile, we acknowledge the importance of stratification based on clinical presentations such as diverticular bleeding, diverticulitis, and intestinal obstruction to enhance the robustness of our comparisons. However, due to the limited sample size and the effect of stratification of these clinical features on the outcome (e.g., sample size reduction, multiple comparison issues, risk of selective bias, etc.), in view of our focus on the surgical approach of MD after surgical resection and some differences in postoperative manifestations, we will further consider these clinical manifestations into the analysis in future studies. Furthermore, we agree that the larger port size in SILS could potentially lead to increased postoperative pain at the umbilicus. However, our study focuses on a broader range of outcomes, such as surgical time, recovery, cosmetic results, and complications, rather than solely on pain. We have taken great care to analyze the data objectively and to adjust for confounding factors through PSM. And our results show a trend towards reduced postoperative pain and faster recovery in the SILS group when compared to CLS, supporting the notion of its clinical benefits. This observation aligns with previous literature has suggested that despite the larger port size, SILS may lead to less postoperative pain due to the reduced tissue trauma and manipulation associated with single-incision techniques [50]. Finally, the long-term efficacy of SILS has not been compared with CLS, suggesting that further studies are needed to investigate the long-term efficacy and potential long-term complications of SILS.

Conclusions

In conclusion, SILS presents distinct advantages in terms of faster recovery of bowel function, shorter hospital stays and greater patient satisfaction without an increase in postoperative complications. These findings advocate the integration of SILS into standard practice for managing MD, although further prospective studies are warranted to confirm these results and examine the long-term impact of this surgical approach.

Supplementary Information

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Supplementary Material 1

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Author contributions

ZX and WF drafted the manuscript, ZX and XD analyzed and collected the data, WF, JH, ZG and WL analyzed the data and drafted the manuscript, YW and ST critically reviewed the manuscript. All authors approved the final manuscript as submitted.

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Data availability

The datasets generated and analyzed during the current study are not publicly available due to the ongoing analysis in other directions but are available from the corresponding author (Shasha Tian) on reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the ethics committee of the Children's Hospital of Chongqing Medical University (Date: 2023/No: 01). All procedures in the study were carried out in accordance with national ethical guidelines for medical and health research involving human subjects, as well as the 1964 Helsinki Declaration and its subsequent amendments. Given the retrospective nature of this study, the requirement for informed consent was waived.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Clinical trial number

Not applicable.

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