

## Original Article

# Feasibility of Robot-Assisted Wedge Resection for Children with Meckel's Diverticulum

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### Abstract

**Introduction:** Meckel's diverticulum is a common gastrointestinal malformation in paediatrics, with limited literature on robotic surgical treatment in children. This study explores robotic surgery in Meckel's diverticulectomy. **Methods:** A study enrolled 84 children who underwent wedge resection for Meckel's diverticulum in our hospital over the past 6 years. It compared the clinical data, surgical details, and postoperative outcomes of traditional laparoscopic-assisted surgery and robot-assisted surgery. **Results:** Robot-assisted surgery showed advantages in blood loss and hospital stay duration ( $P < 0.05$ ). No significant differences were found in operative time, fasting time, or postoperative complications between the two types of surgery ( $P > 0.05$ ). Notably, robot-assisted surgery costs significantly more than laparoscopic-assisted surgery ( $P < 0.05$ ). **Conclusions:** Robot-assisted wedge resection for Meckel's diverticulum in children offers reduced bleeding, shorter hospital stays, and no additional complications. Nevertheless, its primary disadvantage is the high cost.

### Key words

Children; Da Vinci surgical robot; Laparoscopic-assisted surgery; Meckel's diverticulum; Robot-assisted surgery

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### Introduction

Meckel's diverticulum (MD) is a prevalent intestinal malformation observed in children, with an incidence rate ranging from 1% to 3% in the population.<sup>1</sup> While a considerable proportion of individuals with MD may remain asymptomatic, others may encounter complications such as gastrointestinal bleeding, inflammation, perforation, intussusception, intestinal obstruction, and hernia.<sup>2,3</sup> The clinical presentation of MD varies, making its diagnosis challenging. Nevertheless, in cases where patients exhibit clinical symptoms, surgical resection is the recommended treatment.<sup>4</sup>

The paediatric surgery community has widely embraced laparoscopic-assisted MD resection.<sup>5</sup> The introduction of the Da Vinci robotic surgical system has significantly impacted the field of surgery. Robot-assisted

surgery (RAS) offers improved accuracy and stability compared to conventional laparoscopic-assisted surgery (LAS).<sup>6</sup> However, there is limited documentation on robot-assisted MD resection.

This study collected all patients diagnosed with MD after surgery at our hospital over the past 6 years, compared differences between RAS and LAS in paediatric MD wedge resection, and examined postoperative outcomes. It evaluated the clinical value of RAS in paediatric MD patients. This study is also anticipated to broaden the range of robotic surgery applications.

## Methods

### **Clinical Data**

A cohort of 84 patients who underwent MD wedge resection at our hospital was enrolled in the study between June 2017 and May 2023. Patients excluded from the study were those who underwent emergency surgery or resection as a result of incidentally discovering MD during surgery. At the same time, patients whose postoperative pathology did not support MD, patients with underlying diseases, and patients who did not undergo wedge resection were also excluded. The patients' clinical data, surgical specifics, and postoperative results were collected. The study received approval from the local Ethics Committee. Information regarding the Da Vinci RAS option was disseminated to all patients' families, who autonomously selected without adherence to any predetermined grouping criteria. All procedures were performed by consultant surgeons who were systematically trained and certified.

### **Data Processing**

Continuous data were reported as median and standard deviation, whereas nominal variables were presented as frequencies and percentages. The data were subjected to statistical analysis utilising IBM SPSS software (version R27.0.1). Chi-square tests or Fisher's exact tests are utilised for nominal variables, whereas Student's t-tests or Mann-Whitney U tests are employed for continuous variables. A P-value lower than 0.05 typically suggests a statistically significant distinction.

### **Surgical Procedure**

#### *Da Vinci Robot-assisted Surgery*

The patient was positioned in a supine manner, and an 8 mm incision was performed at the central location of the umbilicus. A pneumoperitoneum needle was inserted to

create a pneumoperitoneum at a pressure of 6-12 mmHg, based on the patient's age and weight. An 8 mm trocar was utilised to puncture the umbilical incision before the insertion of a Da Vinci endoscope. An 8 mm trocar puncture was employed as the primary operating aperture in the right upper abdomen and left lower abdomen, respectively. Instruments such as forceps and electrocoagulation hooks were used. The surgical procedure was designated as "lower abdominal surgery," with the umbilical incision connected to the No. 2 arm and the left lower abdominal and right upper abdominal incisions connected to the No. 1 and No. 3 robotic arms, respectively (Figure 1).

With the camera's assistance, each mechanical arm and surgical device was installed. The ileum was examined in a retrograde manner, starting from the ileocecal region. Following identifying the diseased intestinal segment (as illustrated in Figure 2A), a hook claw needle was inserted at the designated mapping point on the individual's body surface (MD) and firmly fixed in position. The diverticulum vessels were cauterised using electrocoagulation (Figure 2B), followed by removal of the diverticulum and a few intestinal tubes at the base by wedge resection (Figure 2C). The diverticulum was placed in a retrieval bag and removed (Figure 2D). A 4-0 absorbable suture was utilised to continuously suture the entire intestinal tube (Figure 2E), with the serosal muscle layer wrapped around the anastomosis (Figure 2F). After verifying the absence of visible abdominal bleeding, retract the lens and proceed with abdominal closure.

#### *Laparoscopic-assisted Surgery*

The patient was positioned in a supine manner, and 5 mm incisions were performed above and below the umbilicus. Subsequently, pneumoperitoneum was achieved following the puncture of the pneumoperitoneum needle. The lens and forceps were introduced after inserting a 5 mm Trocar punctured at the two umbilical incisions. Starting at the ileocecal region, perform a retrograde search for the affected segment of the intestine. After identifying the MD, grasp it with forceps, enlarge the two umbilical incisions, combine them into a single incision, and extract the affected intestinal segment through the umbilical incision. Then, a wedge resection of the MD and suture of the intestinal tube will be performed. Patency, absence of leakage, and absence of bowel bleeding were assessed before it was returned to the abdominal cavity, and the abdomen was closed.

## Results

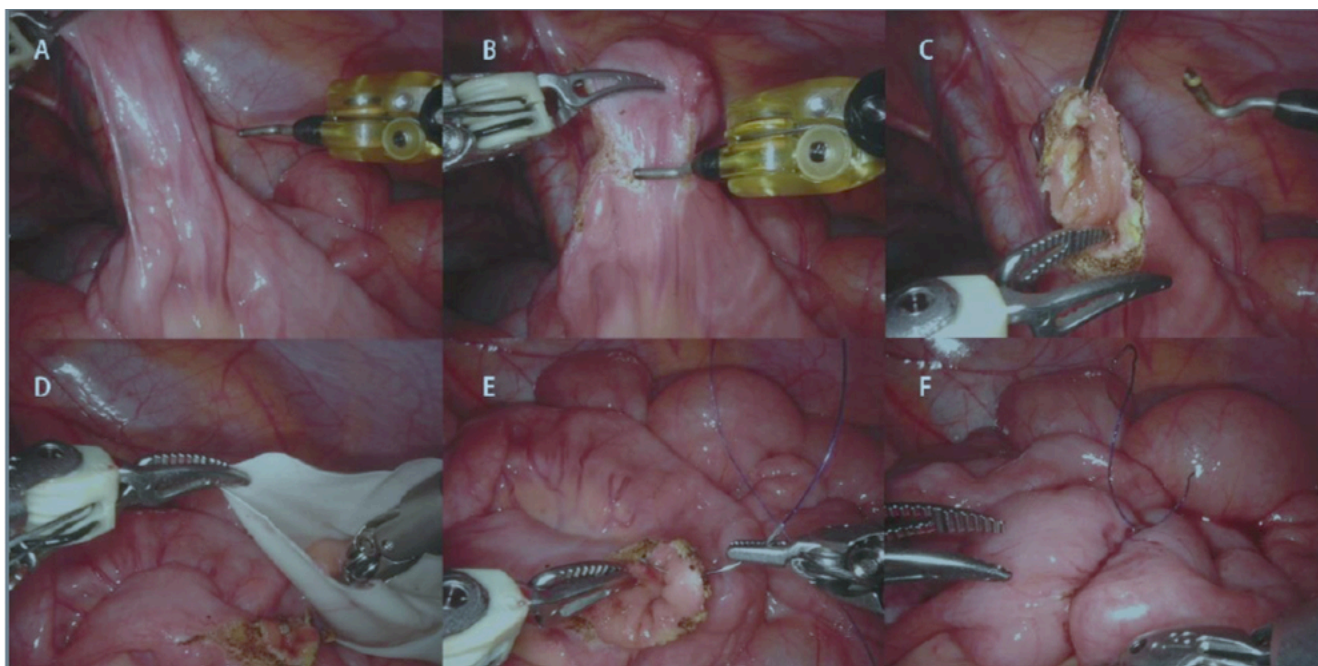
In our dataset, 32 patients (26 males and six females) underwent RAS. The mean age of the individuals in this study was 63.37 months, with an average weight of 20.66 kg. The mean operation time was 81.25 minutes, with an average blood loss of 2.16 ml. The mean duration of postoperative fasting was 3.91 days, the average length of postoperative hospital stay was 7.03 days, and the average hospitalisation expenses amounted to \$8760.

Among the patients in our study, 52 individuals (39 males and 13 females) underwent LAS. The mean age of the individuals in this study was 75.13 months, with an average weight of 21.11 kg. The mean operation time was 90.25 minutes, and the average blood loss was 4.69 ml. The mean duration of postoperative fasting was 3.92 days, the average length of postoperative hospital stay was 8.81 days, and the mean hospitalisation expenses amounted to \$2636.

In this study, none of the patients received blood transfusion therapy during their surgical procedures. Patients who underwent RAS had all surgical procedures conducted within the abdominal cavity. Conversely, patients who underwent LAS pull out the MD through a larger umbilical incision for wedge resection and intestinal anastomosis. In the RAS cohort, one patient developed a postoperative respiratory tract infection, while in the LAS



**Figure 1.** The positioning of the puncture instrument for the robotic-assisted resection of Meckel's diverticulum using the Da Vinci Surgical System.



**Figure 2.** The procedure of Da Vinci Robot-assisted Meckel's diverticulum resection.

group, one patient experienced residual abdominal infection after being discharged, which was effectively managed upon readmission for anti-infective treatment. Postoperative complications, such as elevated levels of abdominal fluid, increased infection markers, and the simultaneous presence of symptoms like abdominal pain and fever, are commonly classified as residual abdominal infections. The primary treatment strategy consists of anti-infective therapy, routine blood testing, abdominal ultrasound for ascites, and observation of abdominal symptoms in paediatric patients. Once the parameters return to normal and symptoms alleviate, the patient is deemed to have recovered. Additionally, another patient in the LAS group developed a postoperative incision infection.

Two surgeons performed the RAS procedures, while six performed the LAS procedures, including the two from the RAS group. No significant differences in surgical outcomes were observed among different surgeons within the same approach. Upon comparing preoperative clinical data between the two groups, no significant differences were found in gender distribution, age, or weight. Patients in the RAS group showed a notably higher prevalence of a history of blood in their stool. When examining surgical-related data for the two patient groups, it was noted that individuals in the RAS group had lower blood loss and a shorter postoperative hospital stay ( $P<0.05$ ). However, there was no significant difference in the rate of gastric mucosa detection or in fasting time after surgery, whereas patients undergoing RAS had notably higher hospitalisation costs ( $P<0.05$ ) (Table 1).

## Discussion

MD is a prevalent anomaly in the gastrointestinal tract. Our collected data indicates a higher prevalence of male patients, with a ratio of 3-5 times that of female patients.<sup>7,8</sup> Haematochezia, characterised by significant rectal bleeding, is the primary symptom that drives patients with MD to seek medical assistance.<sup>9,10</sup> In our study cohort, the RAS group exhibited a notably higher frequency of bloody stools. This observation suggests that parents may be more inclined to select RAS as a treatment option when confronted with severe manifestations of the disease, possibly due to heightened concerns regarding disease severity.

The preoperative diagnosis of a complete MD can be challenging. Due to the relatively high cost associated with RAS, a standard laparoscopy and grasp forceps are typically utilised through a minimally invasive umbilical incision to investigate the bowel. RAS is only conducted upon the identification of MD. In cases where MD is not detected, RAS is discontinued, and the umbilical incision is enlarged. Subsequently, the intestinal tube is extracted from the incision to examine an endogenic diverticulum.

MD is generally associated with the gastrointestinal tract. It has the same wall structure as the intestinal tube<sup>11</sup> and often contains ectopic gastric mucosa, which is the primary cause of gastrointestinal bleeding in patients.<sup>12</sup> We typically opt for wedge resection for MD with a distinct basal structure. Wedge resection can minimise intestinal damage and the extent of intestinal anastomosis, thereby lowering the risk of postoperative intestinal fistula or

**Table 1** Comparison of clinical data between Robot-assisted surgery (RAS) and laparoscopic-assisted surgery (LAS) patients

Group	RAS mean $\pm$ SD or N (%)	LAS mean $\pm$ SD or N (%)	P-value
Male	26 (81.25)	39 (75)	0.506
Age (month)	63.37 $\pm$ 44.46	75.13 $\pm$ 44.27	0.241
Weight (kg)	20.66 $\pm$ 13.07	21.11 $\pm$ 10.91	0.864
Haematochezia	31 (96.88)	36 (69.23)	0.002
Surgical duration (minute)	81.25 $\pm$ 23.31	90.25 $\pm$ 32.25	0.143
Intraoperative bleeding volume (mL)	2.16 $\pm$ 1.32	4.69 $\pm$ 3.64	<0.001
Ectopic Gastric Mucosa	31 (96.88)	47 (90.38)	0.4
Postoperative fasting time (day)	3.91 $\pm$ 0.73	3.92 $\pm$ 0.76	0.921
Postoperative hospitalisation time (day)	7.03 $\pm$ 1.28	8.81 $\pm$ 2.43	<0.001
Postoperative complications	1 (3.22)	2 (3.85)	1
Hospitalisation expenses (dollar)	8760 $\pm$ 771	2636 $\pm$ 1328	<0.001

adhesions. For individuals with MDs with unclear basal structure or structural disorder due to infection, simple wedge resection may leave residual MD tissue, especially the residual ectopic gastric mucosa, leading to incomplete symptom relief. In such cases, the diseased bowel containing MD is usually excised and anastomosed.<sup>4,5</sup>

Compared with traditional laparoscopic surgery, the Da Vinci robot offers greater stability and accuracy, and its primary lens provides a 3D field of view and higher resolution, which supports delicate intra-abdominal operations.<sup>13</sup> On the other hand, in paediatric surgery, the narrow abdominal space often poses challenges for laparoscopic surgery, and the Da Vinci robot's operating device can bend and deflect at the head end, which also provides excellent convenience for paediatric surgery operators.<sup>14,15</sup>

In our study, most RAS chose wedge resection, while LAS patients did not have a high wedge resection rate. We believe the reason may be that RAS is performed in the abdominal cavity, while LAS is performed extracorporeally, and different surgical methods affect the surgeon's choice of resection method. If we directly compared the patient data from these two groups, it could introduce significant bias into the results. Therefore, we selected wedge resection cases from both groups for our study. We followed up with all patients three months after discharge, and no complications were found except for one LAS patient who was hospitalised for a second time due to residual abdominal infection. It has been reported that wedge resection is a safe choice for all types of MD except for patients with intestinal complications;<sup>7</sup> our study's high wedge resection rate for RAS may also support this view. Compared with complete intraperitoneal surgery, extracorporeal bowel resection and anastomosis could increase the risk of intestinal adhesions and incisional infection.<sup>16</sup>

However, Da Vinci's RAS also has its drawbacks. Firstly, Da Vinci RAS has a high surgical cost. Beyond the substantial expense of the robotic system itself, there are high costs for specialised consumables. For instance, the additional cost of consumables for a single MD wedge resection – such as limited-use instruments and robotic arm sterile sleeves – can alone exceed 2,000 dollars. In this study, the average hospitalisation cost for patients in the RAS group reached 8,760 dollars, while that of the LAS group was only 2,636 dollars. Moreover, medical insurance does not cover most of the costs associated with Da Vinci robot procedures. Our hospital has many sponsorship funds for treating congenital malformations,

allowing patients to waive most of their uninsured expenses. Still, we are not sure if this applies equally to other hospitals. Secondly, the Da Vinci RAS has higher requirements for the robotic arm's placement and spacing than the LAS. A small operating space can significantly increase the difficulty of the operation.

Moreover, the Da Vinci surgical robot's operating devices are 5 mm and 8 mm, lacking the 3 mm devices of traditional laparoscopy. The operating device is too large for small-weight children (<5 kg), making the surgery difficult.<sup>17</sup> We attempted a Da Vinci RAS on a 1.6 kg patient, but despite using flexible robotic arms, the surgery remained complicated. In traditional LAS, the operator directly holds the forceps and is more sensitive to force feedback. However, the operator of the Da Vinci robot cannot receive force feedback from the forceps during remote control via the operating table. Therefore, excessive clamping force can cause tissue damage, particularly during intestinal surgery in newborns. Finally, the installation and disassembly of the Da Vinci robot surgical device are more complex than traditional LAS and are constrained by the Da Vinci robot's arm structure. Operations such as abdominal irrigation, extraction, and suspension often require additional auxiliary devices.

With the continued expansion of the RAS application range, we believe its use cost will continue to decline. Moreover, RAS is a future-oriented technology, and its application will enable remote surgery and AI-operated surgery.<sup>18,19</sup> We should actively expand the scope of application for this technology and further explore the potential of applying robots to new diseases or surgical procedures.

This study is a single-centre retrospective study with a small sample size and fewer surgical operators. The duration of Da Vinci RAS at our centre is short, and there may be deviations in the conclusions. It is necessary to conduct prospective, multicenter, larger-scale, and more extensive period studies.

## Conclusion

The Da Vinci Robot-assisted MD wedge resection in children is safe and feasible. It can reduce intraoperative blood loss and postoperative hospitalisation time for patients, without increasing the incidence of postoperative complications. However, it has a higher hospitalisation cost, which needs to be made known to patients and their families.

## Declarations

### Authors' Contributions

Binbin Yang and Yueling Zhu analyzed the data and wrote the manuscript. Duote Cai, Zhigang Gao, and Qingjiang Chen contributed to clinical and instrumental data collection. All authors read and approved the final manuscript.

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### Competing Interests

The authors declare that they have no competing interests.

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