Pediatric Surgery International (2020) 36:591–596
https://doi.org/10.1007/s00383-020-04646-8

ORIGINAL ARTICLE

Differential advantage of liver retraction methods in laparoscopic fundoplication for neurologically impaired patients: a comparison of three kinds of procedures

Toshio Harumatsu[1] · Taichiro Nagai[1] · Keisuke Yano[1] · Shun Onishi[1] · Koji Yamada[1] · Waka Yamada[1,2] · Makoto Matsukubo[1] · Mitsuru Muto[1] · Tatsuru Kaji[1,2] · Satoshi Ieiri[1]

Accepted: 5 March 2020 / Published online: 20 March 2020

Abstract

Aim of the study Liver retraction during laparoscopic fundoplication is important for obtaining an optimal space. Several methods have been developed, but the risks and benefits are unclear. We compared three different approaches and evaluated their safety and utility.

Methods Forty-three neurologically impaired patients who underwent laparoscopic fundoplication between 2005 and 2018 were classified into three groups: A, snake retractor method, $n = 18$; B, crural suture method, $n = 13$; C, needle grasper method, $n = 12$. Patients' characteristics and outcomes were reviewed.

Main results The liver retraction time was significantly shorter in group C than in A or B ($p < 0.05$). The operative times were shorter in groups B and C than in A. There were no significant differences in the liver enzyme levels. The liver enzyme levels increased temporarily but improved within a week. The C-reactive protein levels were significantly lower in group B than in A or C ($p < 0.05$).

Conclusions The most convenient method was the needle grasper method, as the other two approaches create conflict with the operator's forceps. The crural suture method damages the liver less, but requires higher surgical skill levels. It is important to select the appropriate method according to the operator's skill and the patient's size and deformity.

Keywords Laparoscopic surgery · Liver retraction methods · Needle grasper · Crural suture · Children

Introduction

It is very important to maintain a good operative field during laparoscopic upper abdominal surgery, especially when performing gastric cancer surgery, bariatric surgery, and anti-reflux surgery. Anti-reflux surgery requires more extensive liver retraction to obtain sufficient exposure of the esophagogastric junction than other types of upper abdominal surgery, but such extensive retraction may result in hepatic cell damage [1–4].

To reduce the extent of liver damage, many different techniques have been developed for lifting the liver. These methods include the Nathanson liver retractor method, the Penrose drain method, the disk method, and the adhesive glue method [5–8]. However, the use of these protective devices makes the procedure much more complicated and increases the preparation time to retract the liver [9]. We perform three types of procedures at our institution: the snake retractor method, crural suture method, and needle grasper method. However, the risks and benefits of these different retraction methods have not been fully analyzed and evaluated.

We compared these three liver retraction methods to evaluate their safety and utility at our institution.

✉ Satoshi Ieiri
sieiri@m.kufm.kagoshima-u.ac.jp

[1] Department of Pediatric Surgery, Research Field in Medical and Health Sciences, Medical and Dental Area, Research and Education Assembly, Kagoshima University, 8-35-1, Sakuragaoka, Kagoshima City 890-8520, Japan

[2] Clinical Training Center, Kagoshima University Hospital, Kagoshima, Japan

Materials and methods

Patients and characteristics

We conducted a retrospective review of all patients who underwent anti-reflux surgery at Kagoshima University Hospital in Japan from January 2005 to December 2018. Forty-three patients who underwent Nissen fundoplication surgery at our institution were enrolled. Our inclusion criteria were neurologically impaired patients with gastroesophageal reflux who underwent laparoscopic fundoplication at our institution. Many pediatric surgeons, including attending and pediatric surgery fellows, performed these operations, but the operative procedure of laparoscopic fundoplication aside from the liver retraction method was fixed. The patients' characteristics, operative results, postoperative complications, and serum laboratory data were reviewed based on their medical records and operative videos and were analyzed retrospectively. The serum laboratory data included measurements of aspartate aminotransferase (AST), alanine aminotransferase (ALT), total bilirubin, and C-reactive protein (CRP) preoperatively as well as on postoperative days 1, 3, 5, and 7.

This study was performed in accordance with the Ethical Guidelines for Medical and Health Research Involving Human Subjects by the Ministry of Health, Labour, and Welfare of Japan in 2014. The study complied with the 1964 Declaration of Helsinki (revised in 2013) and was approved by the local ethics committee of Kagoshima University Hospital (registration number: 27-119). All of the participants or their parents provided their informed consent to be included in this study.

Statistical analyses were performed using Wilcoxon's test and Fisher's exact probability. Probability values of less than 0.05 were considered to be statistically significant. The data are expressed as the mean ± standard deviation.

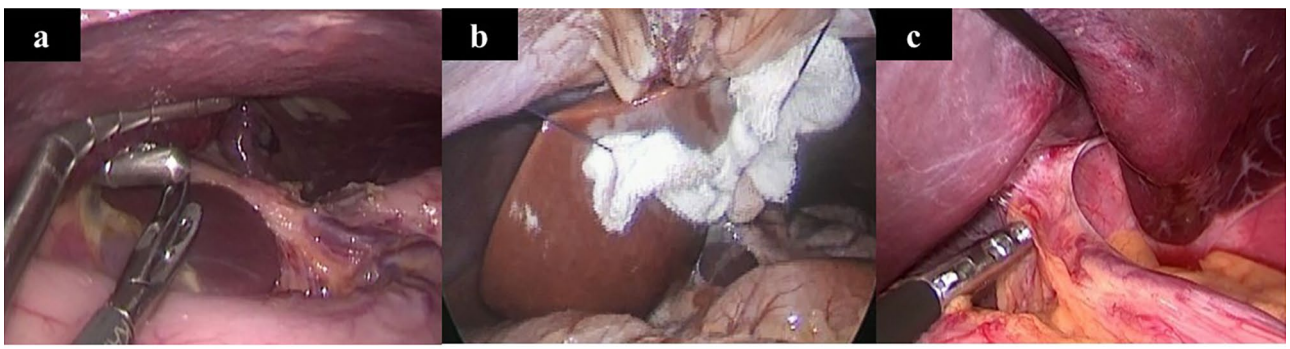
Liver retraction methods

Snake retractor method

The snake liver retractor was used as shown in Fig. 1a. This procedure requires three steps to lift the liver. The first step is to insert a trocar through the right upper abdomen. The second step is to insert the liver retractor and change the shape from straight to circular while being careful not to injure the organs in the small abdominal cavity. The last step is to fix the position for the operation so that we are able to lift the left lobe of the liver. The time required to perform liver retraction was measured from the insertion of the 5-mm trocar until the liver had been lifted into its correct position.

Crural suture method

Stitching with 3-0 monofilament sutures (Proline; Ethicon Endo-Surgery, Cincinnati, OH, USA) and gauze was performed as shown in Fig. 1b. The crura of the diaphragm was sutured using 3-0 monofilament sutures. The monofilament thread was then pulled out through a 19-G percutaneous needle ligature carrier insertion device (LAPA-HER-CLOSURE; Hakko, Co., LTD., Tokyo Japan) to provide adequate visibility of the inferior space of the liver. A small piece of gauze (TROX™, Type D; Oosaki Medical, Nagoya, Japan) for use in laparoscopic operations was placed between the liver and thread to prevent any liver injury due to compression by the thread. This method did not cause any additional



a) Group A, Snake retractor method,
b) Group B, Crural suture method with gauze,
c) Group C, Needle grasper method using 2.4 mm forceps without a trocar

Fig. 1 A representative operative image of our liver retraction methods. **a** Snake retractor method. **b** Crural suture method with gauze. **c** Needle grasper method using 2.4-mm forceps without a trocar

scarring, as it was able to be performed with a needle puncture alone. The time required to complete liver retraction was measured from the insertion of the needle and thread into the abdominal cavity until the liver had been lifted into its correct position.

Needle grasper method

A 2.4-mm needle grasper (clutch type, Mini Lap® System; Teleflex, Morrisville, NC, USA) was used to retract the liver as shown in Fig. 1c. This needle forceps gripped the diaphragm and lifted the left lobe without the insertion of a trocar. The skin puncture of this 2.4-mm needle grasper did not leave any significant operative scar. With this procedure, we must be careful not to damage the intra-abdominal organs when inserting the needle grasper at the middle-upper abdomen, as the tips of this needle grasper are very sharp. Once the needle grasper had gripped the diaphragm appropriately, the operative procedures were able to be performed without an assistant surgeon having to lift up the liver. The time required to perform liver retraction was measured from the puncture of the skin until the liver had been lifted into its correct position.

Results

Background characteristics of patients

The background characteristics of patients are shown in Table 1. There were no significant differences in the characteristics of patients among the three groups. All patients were diagnosed with gastroesophageal reflex disease based on clinical symptoms, upper gastrointestinal examinations and 24-h esophageal pH monitoring. Anti-reflux surgery and liver retraction technique were performed in 43 patients. Laparoscopic fundoplication (Nissen procedure) was performed for all patients as anti-reflux surgery. The period when we performed the methods and the number of patients who underwent the given liver retraction techniques were as follows: snake retractor method (from 2005 to 2014): $n=18$, crural suture method (from 2015 to 2017): $n=13$, and needle grasper method (2018), $n=12$. All three liver retraction methods provided a satisfactory view of the working field.

Operative results and clinical data

The operative results and postoperative clinical data are shown in Table 2. The operative times were shorter in groups B and C than in A (A vs. B, $p=0.05$, A vs. C, $p=0.03$, B vs. C, $p=0.99$). The liver retraction time was significantly shorter in group C than in A or B (A vs. C, $p=0.02$, B vs. C, $p<0.01$). Regarding the blood loss, there was no significant difference among the three groups. Postoperative blood test data (peak value) are also shown in Table 2. There was no significant difference in the postoperative liver enzyme levels among the three groups. The peak value of CRP in group B was significantly lower than for the other two groups (A vs. B, $p<0.01$, B vs. C, $p=0.03$). Regarding the number of patients with pancreatic enzyme elevation, there was no significant difference among the three groups. No serious complications associated with liver retraction were recognized in any groups, and there was no significant difference among groups regarding the postoperative hospital stay.

Postoperative transitional changes in liver enzyme and CRP levels

The postoperative transitional changes in the liver enzyme and CRP levels are shown in Fig. 2. The postoperative AST and ALT levels increased temporarily but improved within a week in all groups (Fig. 2a, b). In Group B, the postoperative elevation in the AST and ALT levels was slight, but there was no significant difference among the three groups. The postoperative CRP levels increased temporarily but improved within a week in all groups, but the CRP elevation in group B was lower than that in the other two groups, although not to a significant degree (Fig. 2c).

Table 1 Patients' background and characteristics

Methods	Snake retractor	Crural suture	Needle grasper	*p* value		
Group	Group A	Group B	Group C	A:B	A:C	B:C
Age (years)	19.7 ± 13.6	10.0 ± 9.4	24.4 ± 16.7	0.05	0.78	0.07
Sex (M:F)	15 (83.3%): 3 (16.7%)	10 (76.9%): 3 (23.1%)	10 (83.3%): 2 (16.7%)	0.87	0.99	0.92
Height (cm)	130.6 ± 21.8	114.6 ± 25.4	137.9 ± 27.9	0.13	0.16	0.07
Weight (kg)	24.3 ± 12.5	18.0 ± 5.3	26.4 ± 9.9	0.17	0.58	0.05
BMI (kg/m^2)	13.7 ± 3.8	13.9 ± 2.8	13.6 ± 2.5	0.94	0.99	0.96

BMI body mass index, *NA* not available

Table 2 Operative results and postoperative complications

Methods	Snake retractor	Crural suture	Needle grasper	*p* value		
Group	Group A	Group B	Group C	A:B	A:C	B:C
Operative results						
Operative time (minute)	318 ± 102	238 ± 89	228 ± 63	0.05	0.03	0.99
Liver retracting preparation time (minute)	11.7 ± 4.9	14.6 ± 10.7	4.1 ± 4.9	0.99	0.02	< 0.01
Blood loss (ml)	41.6 ± 85	18.5 ± 42	25.6 ± 47	0.84	0.99	0.92
Postoperative blood serum laboratory data						
AST (U/l)	108.7 ± 94.8	65.6 ± 31.6	112.3 ± 85.5	0.22	0.97	0.36
ALT (U/l)	97.5 ± 75.4	56.1 ± 28.9	86.7 ± 69.4	0.6	0.8	0.32
CRP (mg/dl)	9.4 ± 6.4	3.8 ± 2.5	10.0 ± 6.7	< 0.01	0.9	0.03
Overall complication	0.6 ± 0.6	0.4 ± 0.5	0.8 ± 0.6	0.47	0.31	0.08
Patients' number of liver enzyme elevation	7 (36.8%)	4 (30.7%)	5 (41.7%)	0.7	0.96	0.59
Patients' number of pancreatic enzyme elevation	2 (10.5%)	2 (15.3%)	2 (16.7%)	0.91	0.88	0.99
Postoperative hospital stay (days)	13.6 ± 5.1	17.7 ± 9.3	13.0 ± 3.3	0.52	0.97	0.51

AST aspartate aminotransferase, *ALT* alanine aminotransferase, *CRP* C-reactive protein

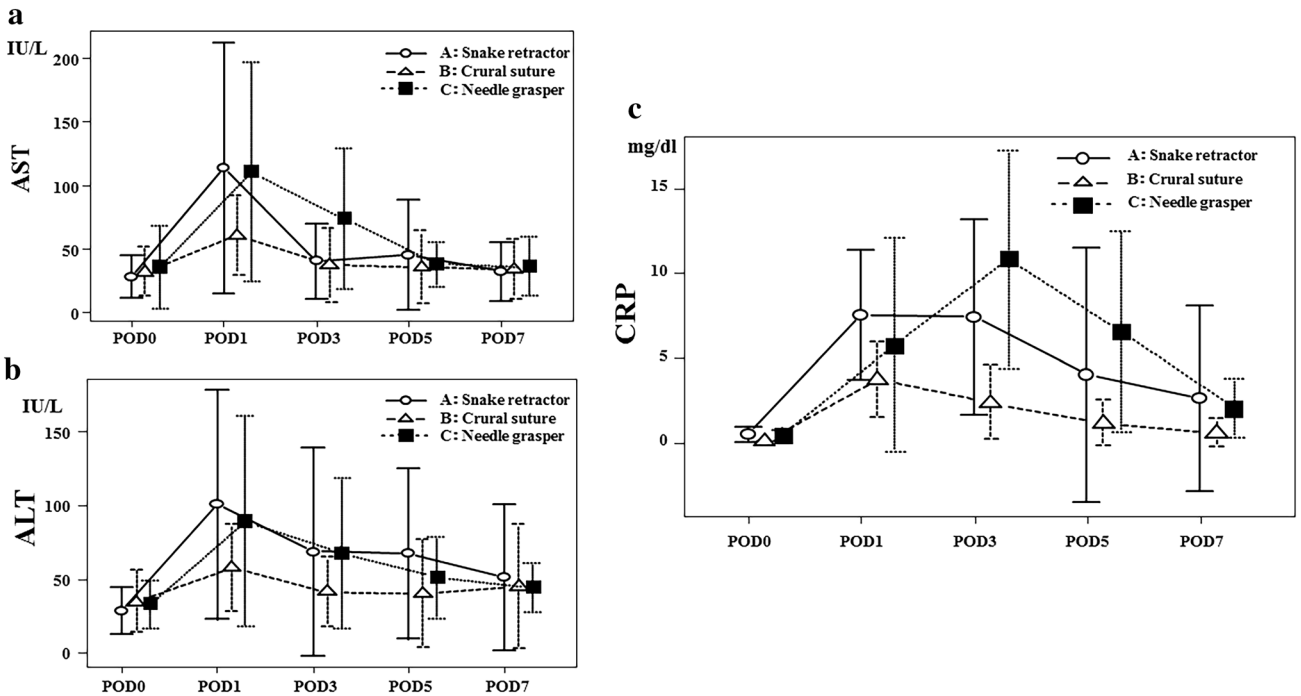


Fig. 2 Postoperative transitional change in the serum laboratory data. *AST* aspartate aminotransferase, *ALT* alanine aminotransferase, *CRP* C-reactive protein, *POD* postoperative day. **a** Postoperative change in the aspartate aminotransferase level. **b** Postoperative change in the alanine aminotransferase level. **c** Postoperative change in the C-reactive protein level

Discussion

In this study, we compared the operative results and postoperative complications among three different liver retraction methods in laparoscopic fundoplication for neurologically impaired patients based on our single institution's experience. The major findings of this study were as follows: (1) the time required for liver retraction using the needle grasper method was significantly shorter than that for the snake retractor method and crural suture method; (2) there was no significant difference in the postoperative transitional changes in the liver enzyme levels among the three groups; (3) the serum liver enzyme levels increased temporarily but improved within a week in all groups; (4) the CRP levels for the crural suture method

were significantly lower than those for the snake retractor method and needle grasper method; (5) no serious complications associated with liver retraction were recognized in any group.

Liver retraction is an essential procedure and technique for laparoscopic gastric surgery including fundoplication. Several methods for performing retraction have been developed, each with its advantages and disadvantages. The most important factors associated with liver retraction methods are obtaining a good operative field of view, achieving a comfortable working space, and inducing as little liver damage as possible. A previous report found that the AST levels peaked at 12 to 24 h after liver injury [10]. In the present study, the AST levels peaked at a similar point. The AST levels eventually returned to normal within a week in all groups. The increased liver enzyme levels related to liver retraction were reversible and did not induce any major clinical complications.

The snake retractor method requires a slightly longer time to change the shape of the device to an appropriate one. In addition, regulating the power of retraction with this device tends to be difficult. This procedure also takes several steps until the liver is successfully lifted into its correct position. These steps might also be associated with the relatively long liver retraction time. In addition, the outside portion of the snake retractor device sometimes interferes with the operator's ability to manipulate the forceps, depending on the patient's body size and trocar layout. This limitation associated with the operator's manipulation can make the operative procedures difficult to perform and lead to a longer operative time. An assistant surgeon must, therefore, change the position and fixation angle of the snake retractor from time to time during the operation to obtain a better surgical field during the operation; however, this procedure can sometimes lead to excessive liver retraction, and repeated retraction is associated with a risk of liver damage. In addition, the use of rigid liver retractors has been reported to cause ischemia of the liver and increase the liver enzyme levels [11]. From a cosmetic point of view, this procedure is inferior to the other two procedures, as it requires an additional 5-mm incision.

The crural suture method gives the operator a good visualization of the gastroesophageal junction without using any specific devices. However, it requires passing a needle through a narrow space under the left lobe of the liver at the beginning of the operation. Passing the needle through the crura is also relatively difficult, with the technique requiring substantial skill. The left lobe of the liver is suspended gently into a V shape by two threads with gauze. The use of gauze helps prevent any damage to the suspended liver [12]. As a result, this method requires a relatively long liver retraction time. However, a stable operative field of view and a good working space are obtained after an appropriate crural suture is performed. The crural suture method is similar to the Penrose drain method described by Shinohara et al. [6]. Those authors compared liver retraction using the Penrose drain and the Nathanson liver retractor, demonstrating that the serum liver enzyme levels with the Penrose drain method were significantly lower than those with the Nathanson liver retractor method. That report also concluded that the transient liver enzyme levels were influenced by the type of liver retractor used [6]. The Nathanson retractor method was one of the most popular methods for a time, but it caused complications, such as hepatic hematoma, liver necrosis, liver failure, atrophy, and other injuries [6]. The crural suture method was found to be superior to the other two procedures regarding the degree of liver damage. Notably, liver ischemia can lead to an elevated CRP level [13]. Our results showed that the liver enzyme and CRP levels with the crural suture method were lower than those in the other two groups. Taken together, these findings indicated that the crural suture method was the safest of the three liver retraction methods [14].

The needle grasper method is very simple and does not require any high degree of skill. Group C had a shorter operative and liver retraction time than the other groups; however, this method showed higher postoperative serum liver enzyme levels than the other groups. Once the 2.4-mm forceps gripped the diaphragm and obtained an optimal surgical space, it was not necessary to change the position of the forceps, as the grasper was fixed by the diaphragm and abdominal wall. This fixation eliminated the need for an assistant surgeon to retract the liver.

While this method did require an additional puncture, a 2.4-mm incision might not make a significant difference cosmetically. The needle grasper method was useful and able to be performed without requiring any specific training, although this procedure was associated with a temporary increase in the liver enzyme levels.

The present study is associated with several limitations. First, this study included several operators who had various levels of laparoscopic surgical skill. Second, the patients enrolled in this study were neurologically impaired, but the severity of such impairment was not evaluated or considered. Finally, the number of patients was small, and the results were obtained from a small number of patients.

Conclusion

The crural suture method reduced the degree of liver damage and was truly a minimally invasive and favorable method, but it requires a high level of skill and expertise. The needle grasper method was technically the easiest liver retraction method to perform. Both the snake retractor and needle grasper methods sometimes interfere with the operator's ability to manipulate the forceps outside the body. It is

important to select the most appropriate method based on the operator's skill and patient's body size.

Acknowledgements We thank Mr. Brian Quinn for his comments and help with the manuscript. This study was supported by a Grant-in-Aid for Scientific Research from the Japan Society for the Promotion of Science (JSPS: 19K10485, 19K09150, 19K09078, 19K03084, 19K18061, 19K17304, 19K18032, 18K08578, 18K16262 17K10555, 17K11514, 17K10183, 17K11515, 16K10466, 16K10094, 16K10095, 16K10434, 16H07090).

Funding No competing financial interests exist.

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