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Lessons Learned After 101 Cases of Single-Site Magnetic-Assisted Cholecystectomy in Children

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ABSTRACT

Background / Purpose: The aim of this report is to present our experience with a magnetic-assisted single-site cholecystectomy technique ("magnachole") in pediatric patients.
Methods: We performed a retrospective chart review of all patients who underwent magnachole between 2009 and 2019. We evaluated patients' demographics, diagnosis, operative time, complications, conversion rate and length of stay. Additionally, simple lineal regression analysis was conducted to determine if the surgeon's experience, the patient's age at surgery, the patient's gender or the patient's body weight affected operative time.
Results: A total of 101 patients were operated during the analyzed period. The mean age at surgery was 12.6 (range 4 to 19) years, and the mean body weight was 53.7 (range 13.5 to 123) kg. The most frequent indication (91%) was symptomatic cholelithiasis. Mean operative time was 85 (range 45 to 240) min. The mean operative time decreased by 22.7 min ($p < 0.001$, 95% [CI] 10.35 to 35.13) when we compared the first 51 cases to the last 50 cases. Simple lineal regression showed a reduction of 2.6 min in operative time per year. Age at surgery, gender, and weight did not influence operative time. There were no intraoperative complications. Only 1 case required an additional port to complete the operation. There were no conversions to open cholecystectomy. Median length of stay was 26 h (range 10 to 168).
Conclusion: The magnachole technique is safe and effective, and has become our preferred surgical approach for children who need a cholecystectomy. As expected, the operative time decreased as surgeons gain experience with the technique. The technique is feasible regardless of the patient's body habitus.
Type of study: Treatment study.
Level of evidence: Level IV.

A variety of refinements to standardized minimally invasive techniques were developed during the first decade of the current century. Natural orifice surgery, needlescopic surgery, single port / single site, and other procedures pushed the limits of how minimally invasively surgery can be [1–5]. These techniques were initially received with skepticism and concerns about safety [6,7].

In order to minimize the number of ports, a technique based on the manipulation of organs by magnetic force was published in 2007, and applied to single-site laparoscopy in children in 2011 [8,9]. In the last 10 years we have done more than 180 single-site umbilical incision magnetic-assisted laparoscopic procedures in children. Particularly for cholecystectomy, we have refined the technique and overcome the learning curve. We have termed the procedure "magnachole" for a quick reference. We present our series and the lessons learned along the way.

1. Materials and methods

We conducted a retrospective chart review of all children who underwent magnachole between 2009 and 2019 at our institution. All patients who required a cholecystectomy at our center were managed with the magnachole technique, except for those under 4 years. Patients with incomplete medical records were excluded from the analysis. We evaluated the following parameters: demographics, diagnosis, operative time, intraoperative complications, need for conversion, postoperative complications and length of stay. The operative time of the first 51 cases was compared to the operative time of the last 50 cases using Student's t-test. Simple linear regression analysis was conducted to determine the influence of surgeon's experience, patient age, gender and

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body weight on the operative time. A p value <0.05 was deemed statistically significant.

1.1. Technique

The magnachole technique requires several specially designed instruments (Fig. 1). The scope has a 0° view, a diameter of 11 mm and a 6 mm working channel (Karl Storz, Tuttlingen, Germany). All other instruments are 5 mm in diameter, 45 cm in length, and should be of nonmagnetic material. A curved grasper is a key part of the instrument set. The magnetic device consists of a spring-loaded alligator grasper attached to an 11-mm neodymium magnet that is deployed in the abdominal cavity at the desired location, which couples with a powerful external magnet (Imanlap®, Buenos Aires, Argentina) mounted on an articulated self-retaining arm. Through a transumbilical incision, a 13 mm trocar is placed for the scope with the working channel. A nonarticulated curved grasper is introduced without a trocar through the same umbilical skin incision, through the fascia, 1 cm laterally to the 13 mm trocar (Fig. 2). The alligator grasper attached to the 11-mm magnet is introduced into the abdomen. The alligator grasps the gallbladder fundus and its 11-mm magnet couples with the external magnet attached to the articulated arm in a cephalad direction. The curved grasper is used to expose the triangle of Calot (Figs. 3 and 4). The remaining steps are similar to those of a standard laparoscopic cholecystectomy.

If deemed appropriate, a cholangiogram can be done with no limitations. The C-arm needs to be oriented in a way that avoids overlapping of the biliary tree and the magnet. This is easily doable by rotating and/or tilting the C-arm as needed (Fig. 5).

2. Results

A total of 101 patients were operated during the analyzed period. Demographics and diagnoses are summarized in Table 1. The overall mean operative time was 85 (45 to 240, median: 75) min. The mean operative time of the first 51 cases was 97 (60 to 240) min, whereas the mean operative time of the last 50 cases was 74 (45 to 130) min. This was statistically significant with a p value <0.01 (95% confidence interval 10.35 to 35.13). Simple lineal regression analysis showed a reduction of 2.6 min in operative time per year ($p = 0.016$) during the 10-year study period. Age at surgery, gender and weight did not influence

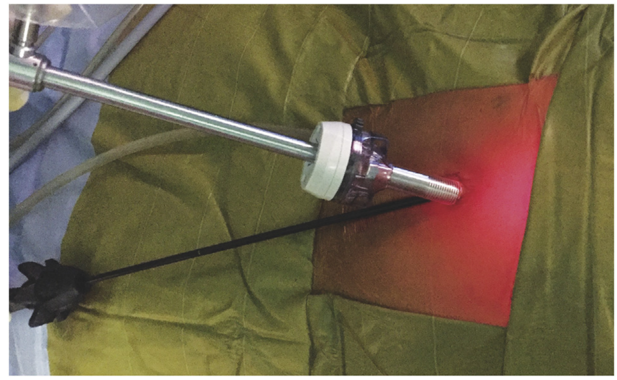

Fig. 2. The 0° 11 mm scope with working channel is introduced through a 13 mm umbilical trocar. Note the nonarticulated curved grasper introduced directly aside to the scope without a trocar.

operative time (Fig. 6). Regarding the variable weight, the heaviest patient operated in this series weighed 123 kg and the magnets resulted strong enough to lift the gallbladder fundus.

There were no intraoperative complications. In 2 cases we deployed 2 magnets (one patient underwent a concomitant splenectomy and the other an ovarian cyst excision). In 2 cases additional ports were required to complete the operation (one patient had portal cavernomatosis and the other patient underwent a concomitant Nissen fundoplication and gastrostomy). There were no conversions to open surgery. Postoperative complications included emesis in 4 cases and extended analgesia in 3. The median length of stay was 26 (range 10 to 168) h.

3. Discussion

Many literature reports have suggested that, compared to conventional laparoscopy, single-site transumbilical surgery carries several disadvantages such as lack of maneuverability, stability, reach and torque, constant collision of multiple instruments within a small surface, visual disorientation, and the need for a new learning curve [6–10]. These disadvantages raised concerns about the safety of all single-site transumbilical procedures, particularly in children. As a consequence, technology evolved in search for smaller and more ergonomic instruments that would allow the procedures to be done safely and efficiently in children [11,12]. Evidence began to accumulate, particularly in the case of single-site transumbilical appendectomy and cholecystectomy

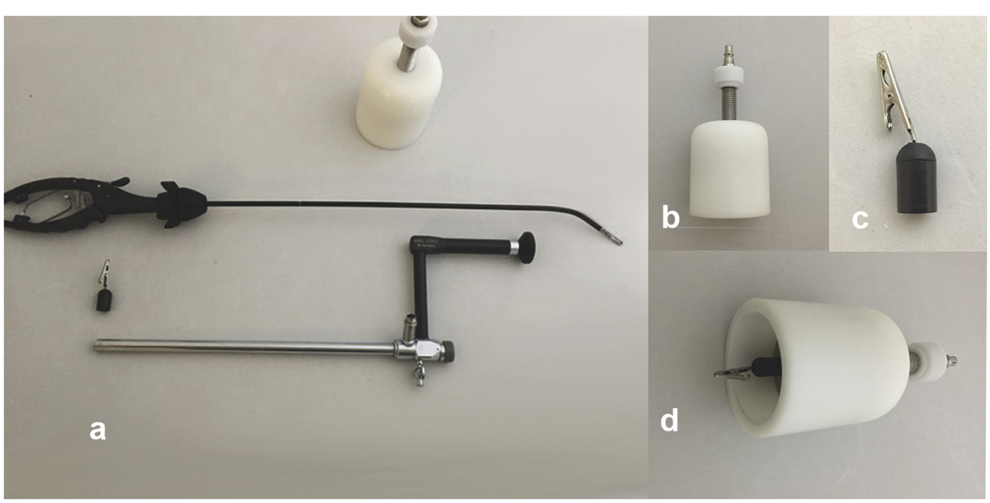

Fig. 1. (a) Complete set of special instruments used in Magnachole. A 5 mm × 45 cm Storz non articulated curved grasper (Karl Storz, Tuttlingen, Germany); a spring-loaded alligator grasper attached to an 11 mm neodymium magnet (Imanlap, Buenos Aires, Argentina); 0° 11 mm scope with a 6 mm working channel (Karl Storz, Tuttlingen, Germany) and an external magnet (Imanlap, Buenos Aires, Argentina). (b) External magnet with a screw-like mechanism to bring closer or move away the magnet from the abdominal wall, thus regulating the magnetic force it exerts. (c) Internal neodymium 11 mm magnet attached to an alligator clamp. (d) Interaction between both magnets and their size relation.

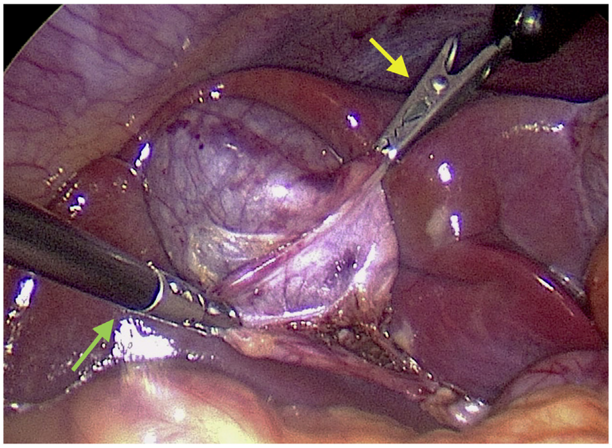

Fig. 3. The Calot triangle is exposed by cephalad traction of the fundus by means of the magnetic alligator grasper (yellow arrow). The cystic duct is retracted right and downwards with the nonarticulated curved grasper (green arrow). Dissection and clipping are done through the scope's working channel.

[13–15]. Difficulties persist, however, and single-site transumbilical procedures are still not widely performed in the pediatric population. Among other difficulties, the frequent need to add extra ports or transcutaneous retracting sutures is the main reason why the single-site transumbilical technique is not appealing to most pediatric surgeons [13,16,17].

In 2012 we reported our initial experience with the magnachole technique in 26 patients [18]. After 101 cases, we believe that this technique helps overcome many of the limitations of the single-site transumbilical cholecystectomy by allowing adequate traction avoiding the

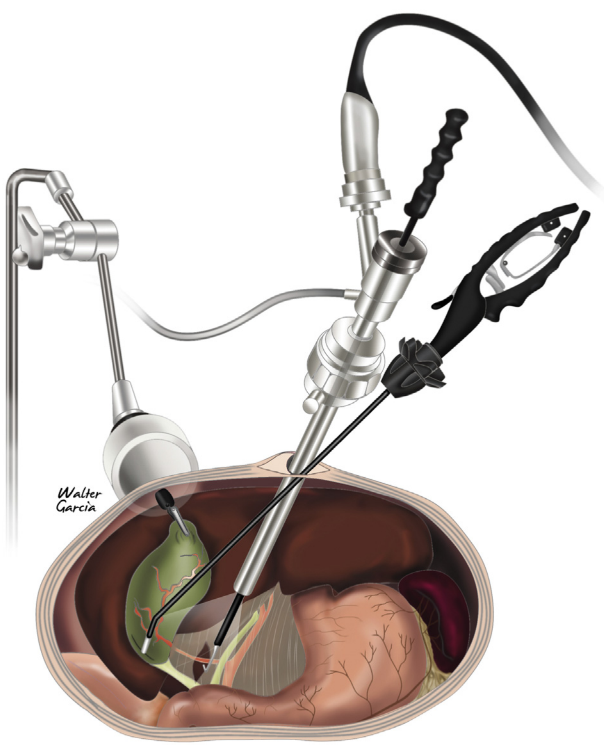

Fig. 4. This figures summarizes the main aspects of the magnachole technique: once all the instruments are introduced in the abdominal cavity, the coupled inner and outer magnet will be exerting cephalad traction on the gallbladder fundus, the curved grasper will pull the neck of the gallbladder laterally exposing the triangle of Calot and through the working channel of the 0° scope, a 45 mm instrument will perform all the usual steps of a laparoscopic cholecystectomy.

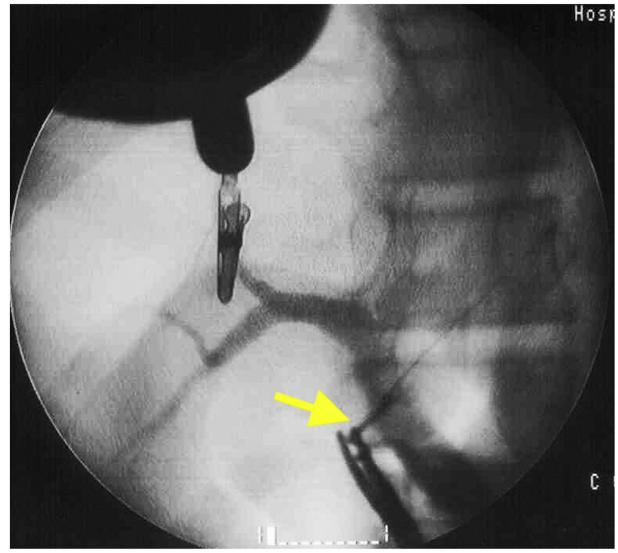

Fig. 5. The coupled inner and external magnets are located so that they can pull the gallbladder fundus without obstructing the cholangiogram. The yellow arrow is marking a grasper holding a 3 French catheter introduced in the cystic duct while the radiopaque contrast is introduced.

need for additional ports. In terms of safety, we had no intraoperative complications, and we confirmed that the area of the abdominal wall through which the magnetic force goes does not get any damage at all. Operative time or the incidence of complications was influenced neither by the patient's age nor by the patient's weight, although we only applied the technique in patients older than 4 years. Operative time decreased by 2.6 min per year, showing that there is a learning curve associated to this technique.

We compared our magnachole outcomes with those reported by Zeidan et al. in a large series of 325 pediatric patients who underwent a standard 4-port laparoscopic cholecystectomy from 1990 to 2010, and found that the length of stay, the operative time and the incidence of complications were equivalent between both techniques [19]. Additionally, we compared the mean operative time of the second half of our cohort ($n = 50$) to the operative time reported by St. Peter et al. in a retrospective review of 224 patients operated with the standard 4-port technique and there was no relevant difference: 74 (45 to 130) versus 77 (30–285) min, respectively. This finding supports that the magnachole technique is equivalent to the 4-port standard technique in terms of operative time once the learning curve is completed [20]. A comparison between Zeidan's, St. Peter's and our series is presented in Table 2.

Regarding postoperative umbilical pain, anecdotally we have not noticed any differences with patients undergoing conventional laparoscopy. However, we have not performed a formal review of this issue.

We learned several lessons along the way, which made us improve the technique. The first lesson was that two sets of magnets, while they may appear useful, were not suitable because it invariably resulted in inappropriate magnetic interaction between the sets. We solved this

Table 1
Demographics of the 101 patients are listed, including age, gender, bodyweight (kilograms), and diagnoses.

Number of patients	101	
Mean age (years)	12.6 (4 to 19)	
Gender	72 females / 29 males	
Mean weight (kg)	53.7 (13.5 to 123)	
Diagnosis	Symptomatic cholelithiasis	$n = 92$
	Cholecystitis	$n = 5$
	Choledocholithiasis	$n = 2$
	Gallbladder polyp	$n = 1$
	Recurrent abdominal pain	$n = 1$

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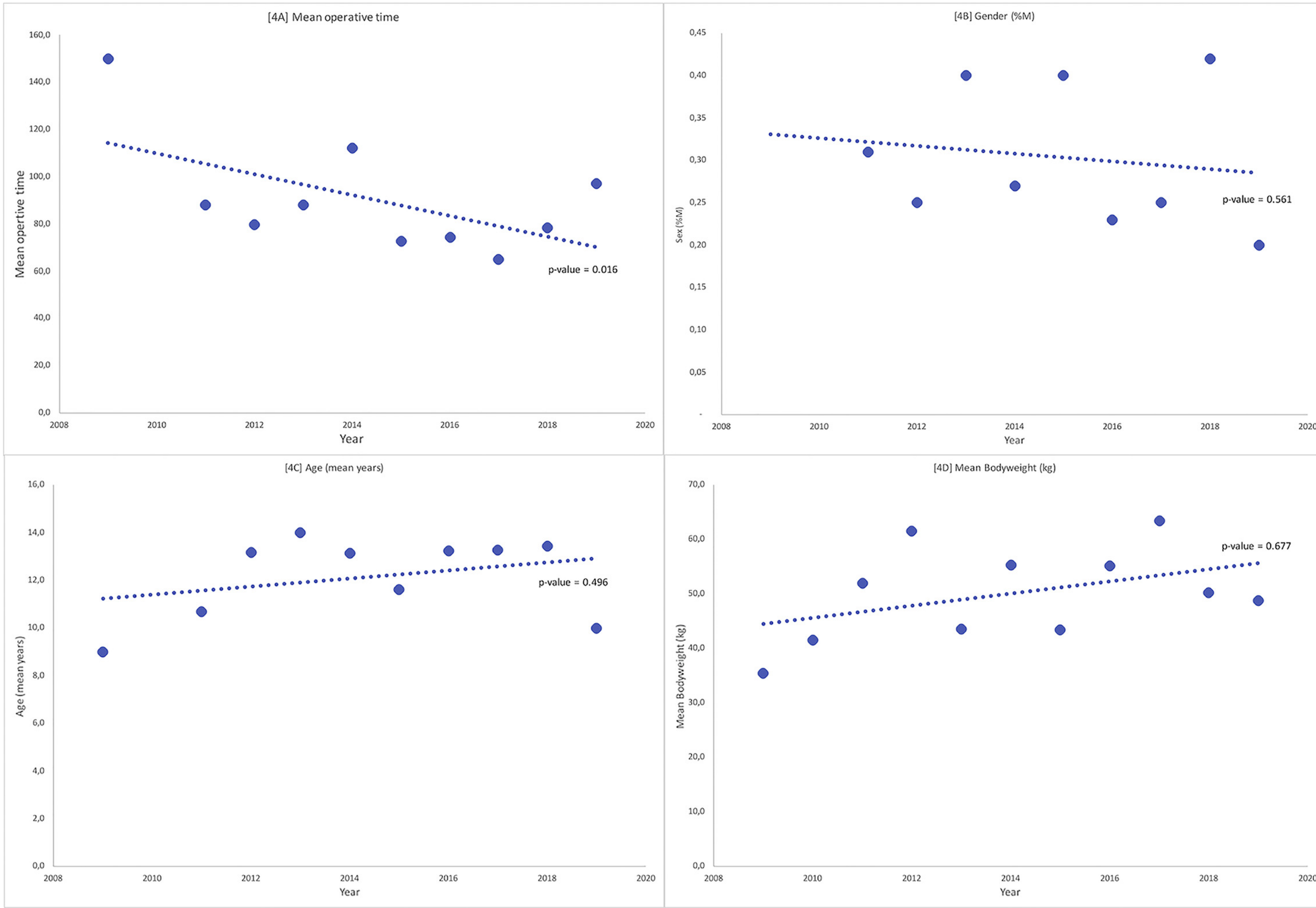

Fig. 6. Simple lineal regression analysis of year of surgery and operative time in minutes [A], gender [B], age [C] and bodyweight in kilograms [D]. Operative time is the only variable with statistical significance with a p = 0.016.

Table 2
Comparison between our series and two series of pediatric 4 port laparoscopic cholecystectomies. Variables analyzed were number of patients, age, type of cholecystectomy, length of stay (LOS), operative time, intraoperative and postoperative complications.

	Toselli et al. (2019)	Zeidan et al. (2014)	St. Peter et al. (2008)
Number of patients	101	202	224
Age (years)	14 (median)	13.5 (median)	12.9 (mean)
Type of cholecystectomy	Magnetic Assisted Single incision	4 port laparoscopy	4 port laparoscopy
LOS (days)	1	1	Not reported
Operative time (min)	85	117.5	77
Intraoperative complications (%)	0%	0%	0%
Postoperative complications (%)	6.9%	4.5%	1.3%

problem by using one set of magnets for the gallbladder fundus and a curved grasper through the umbilicus for the gallbladder infundibulum. A second lesson learned was that placing two trocars through the umbilical incision (which was our initial technique) resulted in constant collision and limited mobility. We solved that by inserting the curved grasper through a fascial incision without a trocar. Finally, although we have not reached a clinically limiting weight for our magnets in our series, if the liver is very heavy or large and the abdominal wall too thick, there are two ways to avoid adding ports: the external magnet can be switched for a stronger one and the inner magnet can be used to expose the triangle of Calot and the curved grasper to pull the fundus (Fig. 7).

A potential drawback of this procedure is the need for special instruments: the scope with the working channel, the magnetic device, and laparoscopic instruments that are longer than the typical instruments used in pediatric laparoscopy. The cost of these instruments, however, does not exceed the cost of standard laparoscopic instruments. Availability of the magnetic instruments used in this study (Imanlap®, Buenos Aires, Argentina) has increased and is currently being used by both pediatric and adult surgeons in several countries in Latin America (Mexico, Colombia, Bolivia, among others) and in Europe (Spain and France). In Europe a special CE market permission was issued, a mandatory certification of safety required for a product to be marketed in the European Union.

The limitations of our report are its retrospective nature and the lack of a concomitant group of demographically-equivalent 4-port laparoscopic cholecystectomies. We have compared our technique with published reports of 4-port laparoscopic cholecystectomies, but we understand that in order to properly compare techniques, the same team of surgeons should perform both, in a random manner. This fact limits the extent of our conclusions. However, we believe the magnachole technique is a valid alternative to the standard laparoscopic cholecystectomy.

4. Conclusion

The magnetic-assisted single-site cholecystectomy (magnachole) is a safe, ergonomic and effective technique. As expected, there is a learning curve associated with the procedure, but it is only reflected in the operative time and not in the incidence of complications, the need for conversion, or the hospital stay. Once the learning curve is overcome, all outcomes are similar to the outcomes of the standard laparoscopic cholecystectomy.

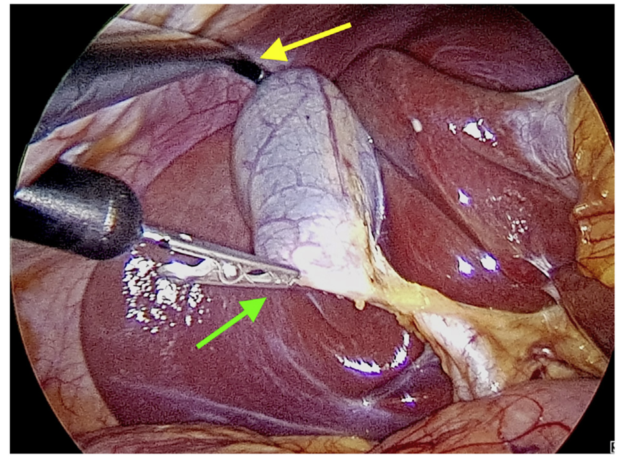

Fig. 7. If the abdominal wall is very thick or the liver is very heavy or large, the curved grasper can be switched and used to pull the fundus of the gallbladder and the inner magnet can be used to expose the triangle of Calot. Note the yellow arrow pointing at the curved grasper pulling the fundus and the green arrow exposing the triangle of Calot.

Acknowledgments

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