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NEW TECHNOLOGY

# Retraction and triangulation with neodymium magnetic forceps for single-port laparoscopic cholecystectomy

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**Abstract**

*Introduction* There have been attempts to minimize the invasiveness of laparoscopic cholecystectomy by reducing the size and/or the number of the operating ports and instruments. These attempts create technical challenges related principally to retraction and triangulation necessary to expose the surgical field for a safe surgery. A new technique based on retraction and triangulation with magnetic instruments for single port laparoscopic surgery is presented.

*Methods* Between March 2007 and December 2008, 40 laparoscopic cholecystectomies were performed with single-port laparoscopic surgery with the assistance of magnetic forceps (IMANLAP$^{TM}$ project). The surgical technique is described, and the intraoperative and postoperative course of the patients is assessed.

*Results* There were no intraoperative complications, no need to convert to open surgery, and no need to add a second port. Depending on the patient's anatomy, a 1-mm needle was added in some cases. There were no interactions observed between the magnetic devices and the anesthetic monitoring and the rest of the devices of the operation room.

*Conclusions* This new procedure is feasible and safe. The main goal is control of the magnetic field, allowing enough controlled strength for retraction and sufficient triangulation for adequate exposure of the surgical field. This allows for the use of a single port through which an optic device with a working channel can perform the operation with safety. Finally, the procedure can be performed in a manner similar to the traditional laparoscopic cholecystectomy, and it also appears to be simple to learn.

**Keywords** Magnetic retraction · Magnetic triangulation · Single port · Laparoscopy · Cholecystectomy

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Laparoscopic cholecystectomy has become the procedure of choice for the treatment of symptomatic stones and polyps in the gallbladder, and the advantages of minimally invasive surgery have been widely accepted [1–3]. In recent years, attempts have been made to minimize the invasiveness, by reducing the size and/or the number of the operating ports and instruments, and even more, the use of a natural orifice as the access port (Natural Orifice Transluminal Endoscopic Surgery—NOTES) [4–21].

Decreasing the number of access ports, the necessary fixation of ports to a certain site of the abdominal wall, and/or the use of smaller instruments, creates technical challenges, related principally to retraction and triangulation necessary to expose the surgical field for a safe surgery.

With the concept of safety in mind, between 2005 and 2007, we developed a technique based on the use of magnetic instruments for retraction and triangulation. One of us (GD) reported the first experience with single-port cholecystectomy using retraction and triangulation with magnetic forceps managed from the outside of the abdominal wall (IMANLAP project) in one patient in 2007 [13]. The first 40 consecutive cases are presented in this article.

The main objective of this project was to obtain firm retraction and enough triangulation for a safe surgery, without the need for additional incisions, using magnetic graspers. The second objective was to develop a technique easily reproduced by laparoscopic surgeons.

## Patients and methods

Between March 2007 and December 2008, 40 laparoscopic cholecystectomies were performed with single-port laparoscopic surgery, with the assistance of magnetic forceps (IMANLAP project). Informed consents were taken from the patients.

The mean age of the patients was 48 (range, 27–68) years, and 31 were women. The mean body mass index (BMI) was 28 (range, 21–37). Five patients were diagnosed with gallbladder polyps, 9 patients had multiple stones, and 26 had one stone in the gallbladder.

Patients with previous upper abdominal open surgery, BMI > 40, acute cholecystitis, patients with a pacemaker, and pregnancy were excluded from this study.

### Description of the IMANLAP technique

Under general anesthesia, the patient is placed in a reverse Trendelenburg's position slightly rotated to the left, with the surgeon between the legs (French position). A single umbilical access for a port of 11–12 mm is created (open Hasson technique), and a pneumoperitoneum of 12–14 mmHg is developed. An 11-mm laparoscope, 0° direction of view, 45° ocular angle, with a 6-mm working channel is used (Fig. 1). Through the working channel, a set of instruments of 5 mm in diameter and longer than 42 cm (Fig. 2) are passed. Two magnet forceps (TD-magnet; Tandem-Dominguez) are passed under visual control through the access port.

Each TD-magnet device (10–11 mm in diameter) is made by a surgical steel tube with neodymium magnets inside of it, attached with a flexible band to an alligator-type grasper (Fig. 3a). These TD-magnet instruments are handled by specially designed forceps (Thomas-forceps; Fig. 4) made by austenitic surgical steel that is not affected by the magnet field.

The Thomas-forceps is passed through the working channel and allows the positioning of the alligators of each grasper in the place of the gallbladder chosen by the surgeon (fundus or Hartmann's pouch) and to change the position when necessary.

The first TD-magnet grasping the gallbladder fundus is "called" by an external magnet in an upward direction toward the right axilla, lifting the liver cephalad and exposing the gallbladder (Fig. 5). A second TD-magnet grasps the Hartmann's pouch and is "called" by a second

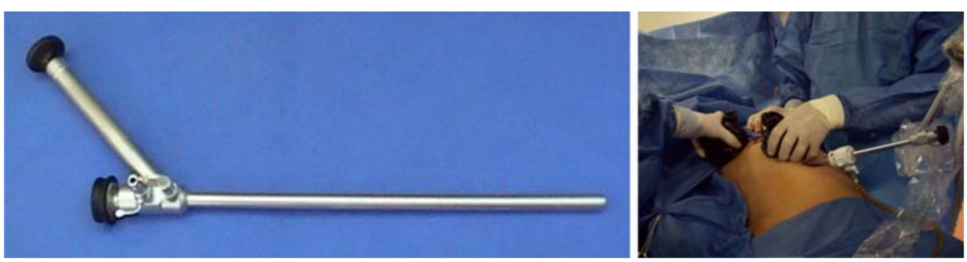


**Fig. 1** Laparoscope of 11 mm, 0° direction of view, 45° ocular angle, with a 6-mm working channel

**Fig. 2** Laparoscope admits a long (longer than 42 cm) set of instruments of 5 mm of weight that pass trough the working channel

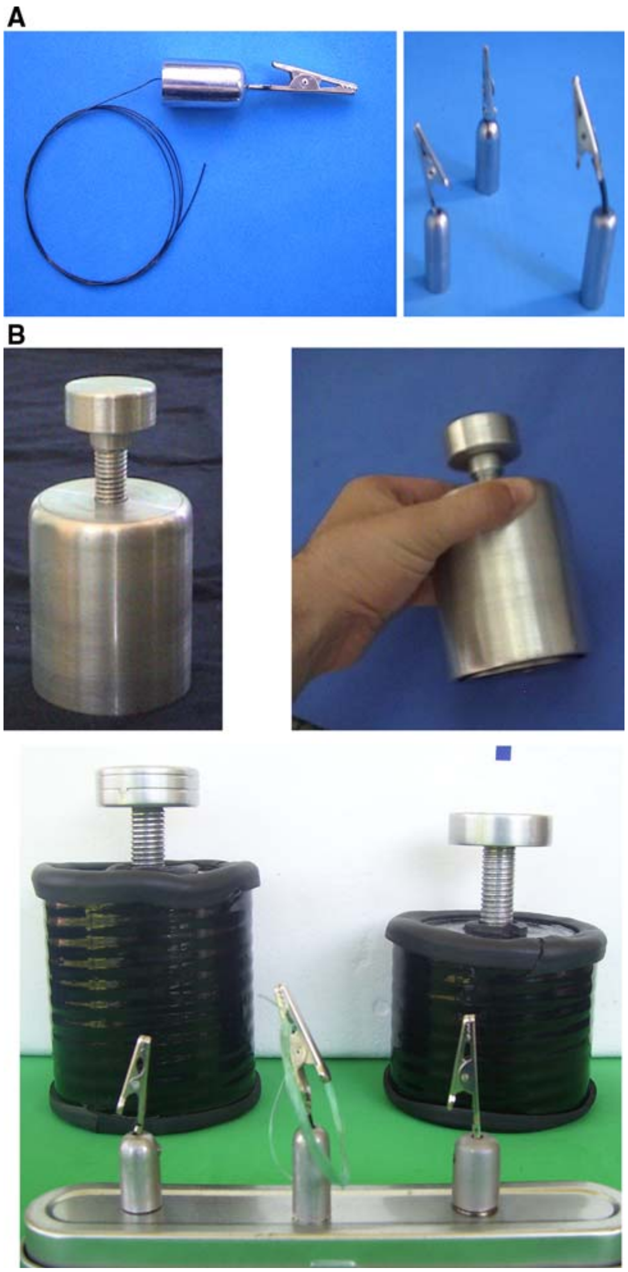


**Fig. 3** **A** Tandem-Dominguez (TD-magnet). **B** Different models of external magnets and TD-magnets

**Fig. 5** TD is positioned in the gallbladder fundus

external magnet toward the right lower quadrant or to the opposite (epigastrium), which then yields the desired dynamic triangulation for best exposure of the Calot's triangle (Fig. 6).

These magnet-retracting systems (TD-magnets and external magnets) exert dynamic force on the gallbladder, or any other selected organ, beyond the abdominal wall under a remote-controlled system (external magnets; Fig. 3b). This external system allows controlled movements of the TD-magnet forceps inside the peritoneal cavity for retraction and triangulation (Fig. 7).

Depending on the patient anatomy, a 1-mm needle (no magnetic steel) can be inserted through the abdominal wall to delicately separate the liver or to help in the Calot dissection (Fig. 8).

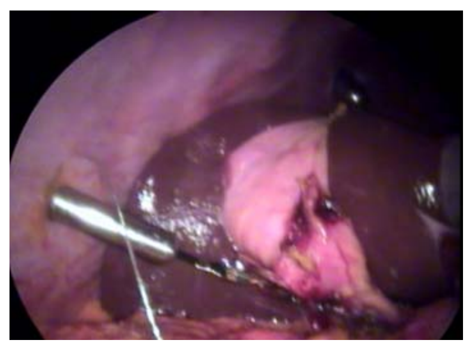
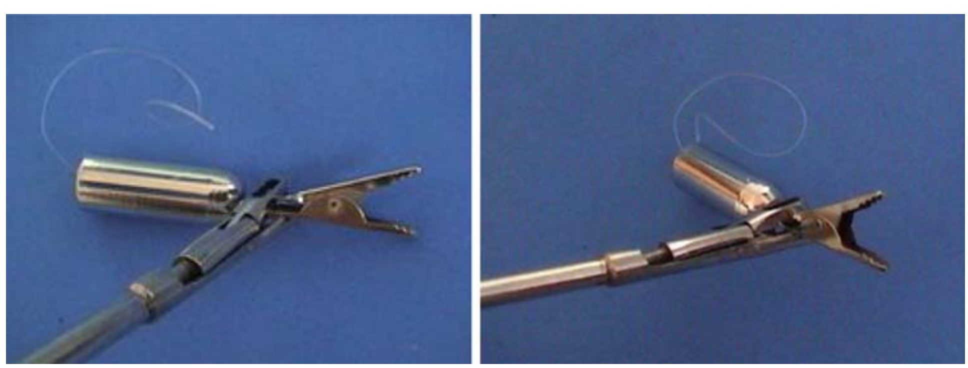


**Fig. 6** Exposition of the gallbladder with two TD

**Fig. 4** Thomas forceps



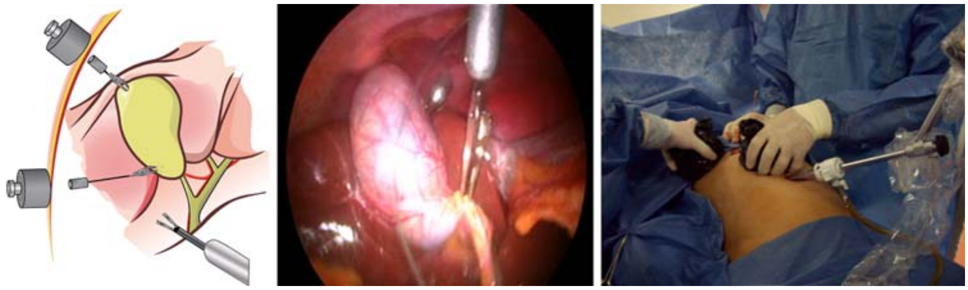


**Fig. 7** Graphic of the magnetic system

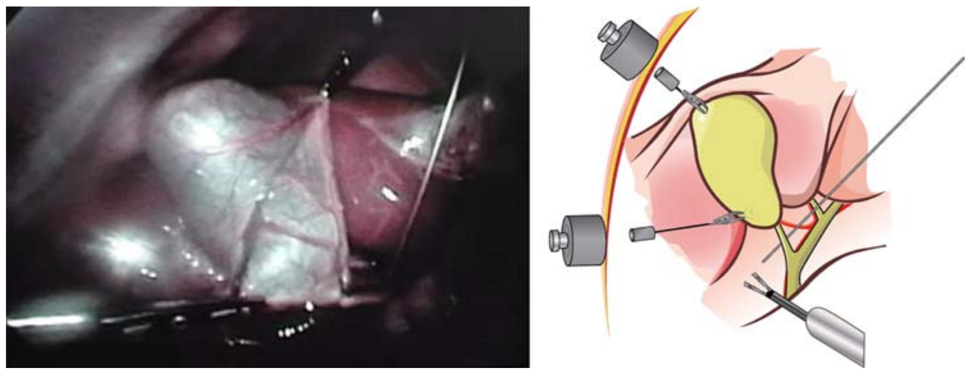


**Fig. 8** 1-mm diameter needle

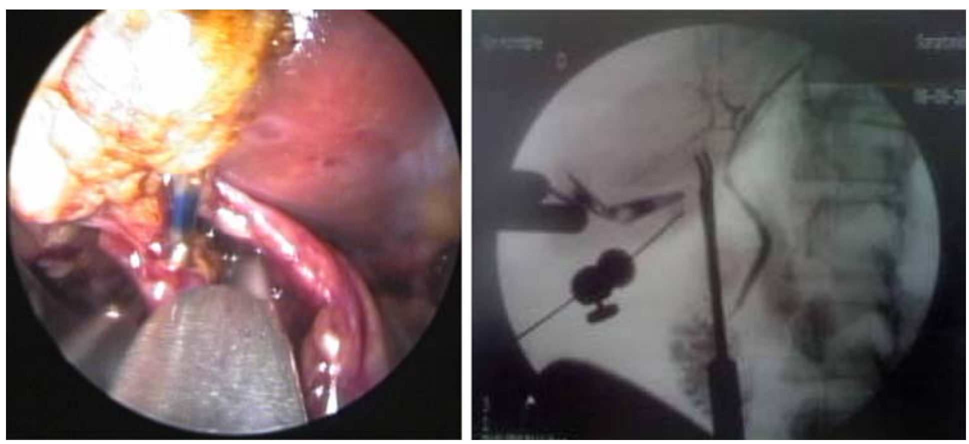


**Fig. 9** Intraoperative cholangiography. TD-magnets can be seen in the X-ray image

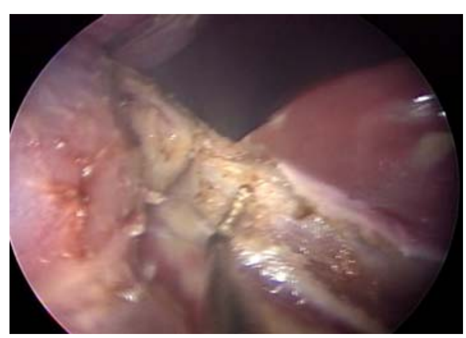


**Fig. 10** Cholecystectomy is completed in the habitual way of traditional laparoscopic cholecystectomy; in the picture, the dissection is made with a hook

Once the surgical field is exposed, each 5-mm diameter instrument (dissection forceps, scissors, hook, harmonic scalpel, clips, suction probe, needle handle, etc.) can be passed through the working channel of the laparoscope to complete the cystic duct and vessels dissection, ligation and section, cholangiography (Fig. 9), and gallbladder dissection in the usual way that the traditional laparoscopic cholecystectomy is performed (Fig. 10).

Since the initial communication, the authors have made improvements in the TD-magnet, covering the magnets by martensitic surgical steel and adding a leash, which allows an easy separation if they get entangled with each other. In addition, the authors have regulated the strength of the magnetic external field, allowing graduated magnetic strength so that retraction can be performed as needed (abdominal wall thickness, intra-abdominal adhesions, etc.). This also facilitates the maneuverability of the device inside the abdomen. The Thomas-forceps was made with austenitic surgical steel, which is not affected by the magnetic field.

## Results

All of the operations were uneventful and were completed by a mini-invasive route, with no need to convert to open surgery and with no need to add a second port. In 17 cases the operation was completed exclusively with magnetic retraction, and in 23 cases the use of a 1-mm needle was added.

The mean time to complete the operation was 93 (range, 55–130 minutes). In nine patients, an intraoperative cholangiography was performed and was normal in all cases. There were two minor intraoperative complications. In two cases, a small disruption of the gallbladder wall occurred and was solved with an alligator grasp without magnets that closed the hole, and the operations continued as usual.

In two of the first cases, the TD-magnet fell in the abdominal cavity, and it was necessary to look for it with radioscopy. The new TD-magnet has a leash that passes through the working port.

There were no anesthetic complications related to the magnet devices, such as changes in the pulse rate or the electrocardiogram monitoring. One patient had a metallic prosthesis in the dorsolumbar backspin, and there was no interference with the magnet devices. There was no interference detected between the magnets and other devices in the operating room.

One patient developed an infection at the site of the umbilical trocar insertion and received oral antibiotics for 1 week. No patient required opioid analgesia in the postoperative course, and all of the patients were discharged within 24 hours of the operation (Fig. 11).

The first author was the principal surgeon in all the cases. Eighteen different surgeons participated in these surgeries, managing the external magnets and the 1-mm needle. In all cases, the assistants handled the magnet devices easily.

**Fig. 11** Cosmetic results

## Discussion

The revolution caused by the introduction of laparoscopic surgery made substantial differences in patient's recovery compared with traditional surgery. The development of a wide variety of instruments and the use of multiple ports of access allowed the surgeons to achieve a good and safe exposure of the surgical field with laparoscopic surgery. The disadvantage of laparoscopic surgery compared with open surgery was the loss of the tridimensional vision, which was rapidly compensated by great image quality, enormous magnification of the vision field, and quality of lighting, in addition to great training in this new kind of exposure. As a consequence, an adequately trained laparoscopic surgeon can offer his patients the same safety standards of the open surgery era, and laparoscopic cholecystectomy with four access ports is the procedure of first choice for symptomatic gallbladder stones and polyps [1–3]. This great advance not only happens in centers with high technological complexity, its utility has expanded to a high percentage of surgical centers around the world.

During the last few years, an enormous technological investment took place to reduce even more the number and/or size of wounds needed to accomplish the procedure. On the one hand, we saw the development of small-diameter instruments (needlescopic), and on the other hand, the decrease of the number of ports (three, two, or single port) [4–18]. There also is another new and different concept of less invasive surgery, which seeks "to hide" the port of access to the peritoneal cavity, called N.O.T.E.S. (Natural Orifice Transluminal Endoscopic Surgery) [21], where the surgical aggression can be equivalent to single-port laparoscopic surgery (one peritoneal access port) but is more technically challenging, still experimental, and has more risks for postoperative complications (stomach or colon closure can fail, and the vagina, which is more secure, has limited indications—only female patients) and limited claimed benefit of cosmetics [22].

Prevention of involuntary injuries must be the first challenge to be solved when a new technology is tested. At this point, it turns out to be fundamental the retraction, triangulation, and suitable vision in every step of the procedure.

To accomplish this, with a single incision at the umbilicus and without the need for complex instruments, we developed the current technique. With it, a suitable surgical field can be achieved, with appropriate separation of the structures at the triangle of Calot, and appropriate cephalad and lateral retraction of the gallbladder. Retraction and triangulation play a basic role in surgical procedures safety, and in the traditional laparoscopic surgery concept; every retracting forceps requires one access port.

Our study demonstrates a new way to expose the surgical field, with no need for extra access ports, replaced by the use of magnetic devices for retraction and triangulation (IMANLAP project: “iman” means magnet in Spanish).

The possibility of retraction and triangulation from different angles, as if there were multiple access ports with opposite directions, is the principal achievement of this new technique with magnetic forceps and retractors. In addition, the magnetic forceps can be moved from the upper abdomen to the pelvis with no need for a new incision, therefore, the necessity of retraction and triangulation is not limited by an access port fixed to the abdominal wall.

The concept is to take advantage of the retraction force that results by the approximation of two magnets. One large extracorporeal magnet maneuvers a small magnet located intraperitoneally. The authors initially fixed an alligator grasper to the internal small magnet, but afterwards the addition of a flexible band between the alligator and the magnet allowed softer movements of the Tandem-Dominguez (TD-magnet) in terms of retraction.

Other authors have reported the use of magnets for less invasive gallbladder surgery. A magnetic anchoring and guidance system (MAGS) for endoscopic surgery has been developed by J. A. Cadeddu and D. Scott et al. from Southwestern Texas University [23, 24]. They used their method on four cases of experimental transvaginal NOTES cholecystectomy in pigs.

Also Kume et al. from Akita University in Japan has presented a swine operation with a magnetic retraction system [25]. Their nice discussion exposed some of the challenges of using magnets devices, which we have solved with our systems. The first one is not to get the magnet fixed to the abdominal wall but to leave open the possibility of movement of the magnet devices to change the exposure of the organ handled by the magnetic system (retraction and triangulation). We developed a system that controlled the strength of the magnetic field between the intraperitoneal and the extracorporeal magnets, which solved the problem.

The control of the magnetic field strength allowed us to locate a second pair of magnets to mobilize the Hartmann pouch of the gallbladder apart of the fundus by producing lateral and downward retraction. The new design of the TD-magnet makes it easier to handle two of them inside the peritoneal cavity and makes it more difficult for the devices to become coupled; however, if it happened, the new design makes them easy to separate. We also have designed the Thomas-forceps with austenitic surgical steel that is not affected by the magnet field, allowing easy position and reposition of the grasper of the TD-magnet.

There are some limitations in this work. First, we operated on selected patients and excluded those with large bile ducts or a history of jaundice or acute cholecystitis. We recently operated on two patients with acute cholecystitis, applying this technique, and were successful in both patients. We also have used this magnetic system for retraction and triangulation for patients operated on with NOTES and MANOS (Minilaparoscopy-Assisted Natural Orifice Surgery) [26, 27]. We have used successfully the TD-magnet system for single-port laparoscopy for other surgeries, such as groin hernia repair, appendicitis, and gynecologic procedures.

Although this is a relatively small series, it is the largest published to date in patients. We did not notice alterations in any physiological parameters resulting from the interaction of the devices with the patient and the rest of the devices used in the operating room.

## Conclusions

This relatively small experience with retraction and triangulation with forceps controlled by magnetic fields, used on patients for “super minimally invasive surgery,” appears to show feasibility and safety. The main goal of this technique is control of the magnetic field, providing enough strength for retraction and sufficient triangulation for adequate exposure of the surgical field. This allows for the use of a single port through which an optic device with a working channel can safely perform the operation. Furthermore, this technique allows the performance of a cholecystectomy in a manner similar to traditional laparoscopy, and it is easy to learn for experienced laparoscopists.

**Conflict of Interest** The Magnetic system and the Thomas-forceps are under patent-licensing arrangements. Patent pending No. 11/834.746.

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