Review Article on Thoracic Surgery

Magnetic anchoring guidance system in video-assisted thoracic surgery

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Abstract: The magnetic anchoring guidance system (MAGS) is one of the most promising technological innovations in minimally invasive surgery and consists in two magnetic elements matched through the abdominal or thoracic wall. The internal magnet can be inserted into the abdominal or chest cavity through a small single incision and then moved into position by manipulating the external component. In addition to a video camera system, the inner magnetic platform can house remotely controlled surgical tools thus reducing instruments fencing, a serious inconvenience of the uniportal access. The latest prototypes are equipped with self-light-emitting diode (LED) illumination and a wireless antenna for signal transmission and device controlling, which allows bypassing the obstacle of wires crossing the field of view (FOV). Despite being originally designed for laparoscopic surgery, the MAGS seems to suit optimally the characteristics of the chest wall and might meet the specific demands of video-assisted thoracic surgery (VATS) surgery in terms of ergonomics, visualization and surgical performance; moreover, it involves less risks for the patients and an improved aesthetic outcome.

Keywords: Lung cancer; video-assisted thoracic surgery (VATS); video camera systems

Received: 25 December 2016; Accepted: 28 December 2016; Published: 13 February 2017.
doi: 10.21037/jovs.2017.01.13
View this article at: http://dx.doi.org/10.21037/jovs.2017.01.13

Introduction

The constant advancement and widespread application of laparoscopic surgery, video-assisted thoracic surgery (VATS) and natural orifice transluminal endoscopic surgery (NOTES) techniques pushed to conceive and develop new strategies capable of enhancing visibility and avoiding instruments collision, which represent the main limitations of minimally invasive surgery, in particular in single keyhole surgery such as uniportal VATS. The magnetic anchoring guidance system (MAGS) was developed for this aim, although it was originally designed for abdominal surgery; its introduction allowed performing laparoscopic surgery using a small single incision thus reducing risks of bleeding, herniation and internal organ damage and providing better cosmetic results. The reported outcomes drew the attention of experts and practitioners to adopting MAGS to overcome the main technical challenges of VATS, such us the development of specialised instruments and video camera systems permitting to perform effortlessly surgical procedures through a uniportal access of small size. Additionally, the characteristics of the rigidity of the chest wall might fit for MAGS better than the abdominal environment. Nonetheless, the first step in this direction has yet to be taken.

Technical characteristics and initial experience in minimally invasive surgery

MAGS magnets are made of neodymium-ironboron (NeFeB), an earth magnet highly resistant to demagnetization. Prototypes tested in a study by Best *et al.* included an external component weighing 134–547 g whose magnetic force was able to lift up to 39 g (weight of the heaviest internal component) at a maximum distance of 3.64 cm (the threshold for drop-off). Nonetheless, the measured coupling force referred to a static rather than dynamic coupling force, not taking into account the frictional forces generated *in vivo* by the tools inserted into the abdomen (1).

The first prototypes of MAGS platforms tested on porcine models consisted of two magnetic components: the internal component was inserted into the insufflated abdomen through a 15 mm diameter trocar and then moved into position by manipulating the external magnets. The trocar was removed and replaced by a thinner trocar wrapped in fiber-opticcables which delivered illumination since the MAGS internal platform was unprovided with its light source. The miniature camera was regulated by way of the external magnets and using a digital editing system to achieve real-time digital zoom and right rotation. Furthermore, a magnetically anchored robotic arm was also inserted into the abdominal cavity: Due to its design, the robotic arm mimicked the motions of a cauterizer operated by the surgeon right hand, under control of an external joystick (2).

MAGS application *in vivo* performances started with laparoendoscopic single site (LESS) nephrectomy in human patients, where instruments [such as light-emitting diode (LED) light source, camera, grasper, retractor and cautery dissector] were attached to a housing magnet or ferromagnetic target. The way of external wires provided the power supply and the signal transmission. After positioning the internal component using magnetic guidance, the external MAGS component could be replaced by a metal stem introduced percutaneously. MAGS also demonstrated good results in NOTES transvaginal cholecystectomy and LESS appendectomy in porcine models (3).

Concerning the eventuality of prolonged magnetic coupling causing tissue damage, a histologic assessment in porcine models was performed after 2–4 hours of magnetic coupling across the abdominal wall (mean 2.1 cm thick, considerably inferior to mean abdominal wall thickness in adult human beings). Except for a few petechiae, no tissue damage was observed (4).

In a comparison between single-site suturing using MAGS LESS or conventional LESS method performed by a group of surgeons with different level of experience in LESS surgery, MAGS LESS suturing was universally favored in terms of reduction of workload (assessed in mental demand, physical demand, temporal demand, performance, effort, frustration levels) and enhanced ergonomics, visualization and needle handling (5). Further evaluation of the image quality and its impact on the surgical performance using wired or wireless video cameras comes from a randomized comparison on *ex vivo* and *in vivo* NOTES performances using a laparoscope, a flexible endoscope and two prototype deployable cameras, a MAGS camera and a PillCam, provided with a magnetic baseplate for guidance and anchoring. The MAGS camera was wired for signal and power transmission and incorporated a charge-coupled device (CCD) detector able to capture images at 30 frames/s (fps), while the Pill Cam used wireless signal transmission at 2–7 fps and was powered by wire. The horizontal field of view (FOV) was measured using a standardised image and two objects moving from within the FOV toward the edge of the field, and the object-camera tip-object angle was measured with a protractor. Image resolution tests were performed at three clinically relevant distances: 5 mm, 5 and 10 cm. Surgical performance regarding knot-tying exercise was evaluated in a boxing trainer designed to simulate laparoscopic surgery in the abdomen; two experienced laparoscopic surgeons performed five consecutive iterations with each of the 4 camera systems chosen in randomised order. Finally, the suturing performance was evaluated *in vivo* in a live porcine laparoscopic Nissen model. Regarding image resolution, the laparoscope and the MAGS camera resulted considerably superior and their resolution scores were very similar at 5 cm and 10 cm distances. In suturing the endoscope and the MAGS camera proved slightly inferior to the laparoscope. Concerning the Pill Cam, it was assessed as being very quick thanks to its small size and wireless signal transmission, but it had to be held very close to the target to optimise the visualisation, and the slow frame rate was incompatible with real-time viewing. Therefore, this study pointed out the extraordinary imaging quality of MAGS camera as well as the requirement of further optimisation for the purpose of theatric-abdominal surgery (6).

Mags perspective in VATS

Ironically, in the context of the technological advancements in VATS, MAGS seems to be more suitable for thoracic environment (7). Because of the rigidity of the chest

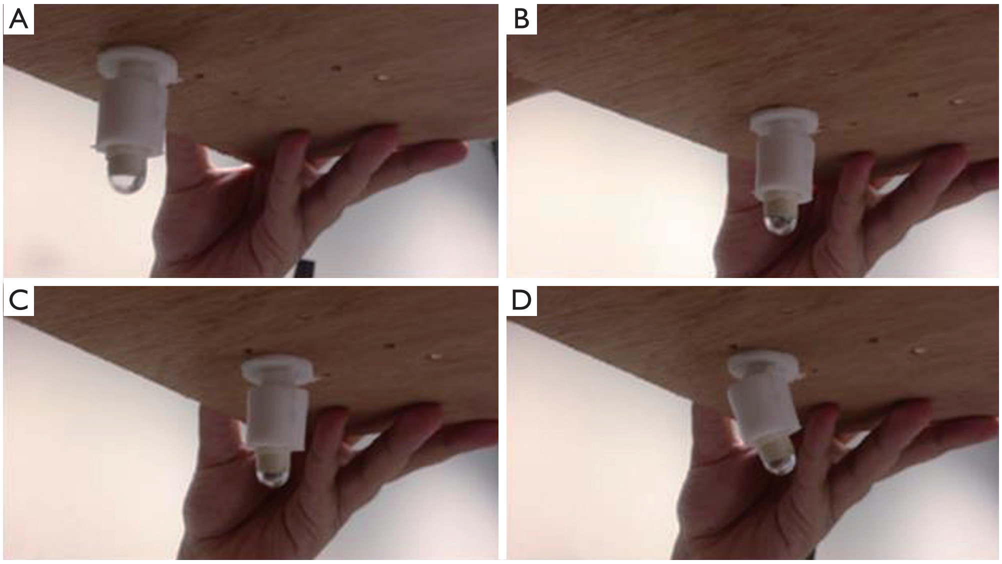

Figure 1 Wireless steerable endoscope (WSE) prototype. The WSE is held against gravity by a magnet under a wooden plank mimicking attachment to the internal wall of a body cavity (A). The WSE can (B) slide; (C) axially rotate; (D) providing multiple viewing directions [Reprinted with permission (8)].

which provides more stability for magnetic anchorage and less coupling force fluctuation due to tissue thickness in comparison with the abdominal wall. Indeed, others have explored the possibility of a wireless remote video camera placed on a surgical instrument, but it was quickly dismissed due to the presence of movement artefact in the images. The main obstacle is represented by the ribs and thoracic cage making access and specimen retrieval challenging. Nonetheless, the magnets placed on the outer surface of the chest wall allow holding and controlling a remote camera attached to the internal component of the MAGS, resulting in a large viewing angle and less instrument fencing (*Figure 1*). The development of self-LED illumination and a wireless antenna for signal transmission that means no wires cluttering the operating space, potentially permit to insert multiple cameras into the chest cavity to provide a panoramic view of the operating field (9).

Future developments, along with high-definition 3D imaging, may be the cable less thoracoscope, designed with a self-LED illumination system, and the remote wireless steerable endoscope (WSE) replacing the conventional thoracoscopy. Allegedly, the WSE would be introduced into the chest through the uniportal access and magnetically anchored to the inner thoracic wall, thus eliminating the occupancy by the thoracoscope and potentially allowing a smaller incision. Via wireless guidance system the prototype can be quickly moved into position and oriented achieving multiple angles, while the video images are real-time transmitted to the monitor (8).

Comments

The MASG made its appearance on the stage of minimally invasive surgery in the past decade responding to the demand of new technological devices suited for specific surgical procedures. MAGS seemed to meet the requirement of a work platform that could be easily inserted into the abdominal cavity through a small incision and that could house surgical instruments and camera systems. Furthermore, wireless signal transmission and devices controlling were developed to prevent the operating field from being cluttered by wires and improve the visualisation, thus influencing the surgical performance outcome and the ergonomic aspect of it positively both in *ex vivo* and *in vivo* field testing. From an imaging standpoint, a randomized comparison of different camera systems in NOTES surgical procedures pointed out that there is no evidence of substantial difference in effectiveness between conventional laparoscopy (considered the gold standard for optical characteristics in abdominal surgery) and MAGS camera, albeit the latter still requires further optimization for the purpose of intra-abdominal surgery. On the other hand, the interest in taking advantages of magnetic anchoring systems in the field of VATS has not been supported by a concrete effort so far, despite the encouraging perspectives of introducing MAGS cameras and WSE into the chest cavity through a small-sized single access, minimizing the interference among instruments, enhancing the extension of the FOV and the imaging resolution.

Conclusions

It is desirable to obtain a practical feasibility upon the effectiveness of magnetic anchoring systems that promise to pave the way to further surgical enhancements, namely higher quality VATS performances and irrefutable advantages for the patients.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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doi: 10.21037/jovs.2017.01.13
Cite this article as: Giaccone A, Solli P, Bertolaccini L. Magnetic anchoring guidance system in video-assisted thoracic surgery. J Vis Surg 2017;3:17.

