Magnetic Anchoring and Guidance Systems (MAGS)

Current state of MAGS technology and its future role in Minimally Invasive Surgery

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Due to recent advances in technology, even traditional laparoscopy is becoming less invasive and the concept of what constitutes minimally invasive surgery continues to be redefined. Most recently, laparoendoscopic single site surgery (LESS) and natural orifice surgery (NOTES) have increased in popularity with the idea that cosmesis and trocar morbidity can be improved with smaller or even absent abdominal incisions.

However, these increasingly minimally invasive approaches can be fraught with difficulties. The technical demands due to loss of triangulation, increased instrument couplings, and nascent camera angles have limited these operations from becoming mainstream. Furthermore, because of the shared extracorporeal working space, the surgeon and camera operator often experience a loss of ergonomic functionality.

For these reasons, LESS/NOTES are often considered difficult (i.e. frustrating) procedures even in the hands of the most experienced surgeons. Several adaptations have been made to alleviate these problems. Articulating instruments that bow out were introduced to create the triangulation that is seen with conventional laparoscopy. While this solved the problem of instrument triangulation, a new set of problems resulted. Surgeons had to adapt to a crossed working environment where the right hand controlled the instrument on the left side of the display while the left hand was required to operate the camera due to the deviation from the standard laparoscopic instruments. Flexible cameras and the da Vinci platform both helped to remedy some of these problems, but each have their own limitations. While flexible cameras reduce the number of external collisions, decreases in optical clarity as well as unfamiliar working angles are experienced.

The da Vinci platform has decreased the learning curve needed to perform LESS for two reasons. First, triangulation is improved with the robotic instruments as these incorporate the “bowing out” concept. Second, the surgeon’s hands are uncrossed at the console so that the right hand controls the instrument on the right side of the display. However, the robotic arms still cross inside the patient, and new operative techniques must be mastered to avoid internal collisions. Importantly, the problem of external instrument collisions also remains.

Magnetic anchoring

One technology that has proven to circumvent many of the problems with LESS is magnetic anchoring and guidance systems (MAGS). This technology works something like the classic ship in a bottle where a small incision is made in the abdominal wall (or orifice in case of NOTES) through which surgical instruments are inserted, expanded and deployed. Theoretically, these devices do not occupy space outside the body, but are accessible to the surgeon for use. To be effective, these instruments must be

steered and anchored to the abdominal wall in a non-traumatic manner while having adjustable working angles and locations.

MAGS accomplishes this with the use of external hand magnets that couple to the internal devices. This allows one or more laparoscopic instruments to be removed from the working port (and therefore external space) and returns the surgeon to a more comfortable ergonomic environment. A further adaptation of MAGS is the restoration of loss working angles. With this technology, the surgeon does not have to look down the barrel of the laparoscopic instruments and the blind spots experienced with conventional LESS are avoided.

Although MAGS technology has eliminated several problems associated with LESS/NOTES, several issues specific to this technology have arisen. The first involves anchoring the instruments to the abdominal wall. Magnetic forces diminish logarithmically with increasing distance, and the weight of the internal device-magnet complex creates a restoring magnetic force. To anchor the internal devices required identifying magnets that were both strong enough to couple across the abdominal wall, while at the same time small enough to not hinder intracorporeal operating space.

Therefore, two pieces of equipment had to be optimised: the external magnet and the internal device-magnet complex. Neodymium-iron-boron (NdFeB) magnets were selected for their strength, with magnets strong enough to couple at physiologic distances. Further, these magnets have been shown to not cause skin or abdominal wall damage through four hours of coupling in a pig model.1 A schematic representation is shown depicting both the external magnet and internal device-magnet complex. An external view of the hand-held magnets is also shown in a pig model (Figure 1).

Another concern is the obese patient and how MAGS could perform across large coupling distances. Our group has shown that at a range of 8 cm, the magnets are strong enough to maintain their coupling strength, which includes the abdominal wall thickness of all but the most obese patients. However, some limitations remain. Any additional forces to the magnets can also cause decoupling and may be a detriment to the study of the many magnets with retraction or dissection instruments.

Intraperitoneal camera

Perhaps the most promising initial application of the MAGS concept is the intraperitoneal camera. Early in the development of MAGS, LESS camera images rivaling the current 5 mm digital laparoscopes were produced. This has been noted to be a hindrance in their acceptance by surgeons. MAGS, however, may be able to reconcile this difference. For example, we now accept a single camera as the standard for laparoscopic surgery. With this technology, multiple cameras could be deployed into the abdomen allowing the surgeon to switch between the two, giving multiple viewing perspectives and possibly eliminating the camera operator.

MAGS also has the ability to be integrated with the key tenets of laparoscopic surgery to be maintained during LESS, namely triangulation. Theoretically, this should support surgeon comfort and reduce workload. Our group recently compared MAGS-assisted LESS to conventional LESS looking at several outcome measures. Our group recently compared MAGS-assisted LESS to conventional LESS looking at several outcome measures.

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Arguments for increased difficulty and ergonomic workload experienced by the surgeon. MAGS, however, may help to reconcile this difference. For example, we now accept a single camera as the standard for laparoscopic surgery. With this technology, multiple cameras could be deployed into the abdomen allowing the surgeon to switch between the two, giving multiple viewing perspectives and possibly eliminating the camera operator.

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References