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Robotic Telescopic Assistance in Pediatric Laparoscopic Surgery

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ABSTRACT

With the advent of the twenty-first century, there is a rapid evolution in the application of robotic technology for operative procedures. Currently, this technology is available in two forms: robotic telescopic assistance using AESOP® (Computer Motion, Goleta, California); and robotic applications for procedural laparoscopy through either the da Vinci® (Intuitive Surgical, Sunnyvale, California) or ZEUS® (Computer Motion) systems.

At our hospital, AESOP has been utilized for robotic telescopic assistance for almost three years. There are a number of advantages with this system for certain operations including a steady visual field, a consistent telescope operating system, lack of human fatigue, and a reduction in the number of people actively participating in a small space.

This paper will describe the current operations in which AESOP is utilized at our institution, data indicating a decrease in the operative time for laparoscopic fundoplication using this system, and a discussion of the advantages of the use of this technology.

INTRODUCTION

ROBOTIC TECHNOLOGY HAS ONLY RECENTLY BEEN UTILIZED IN THE OPERATING THEATER. Until the past decade, surgical robots belonged to the realms of fantasy and science fiction. With improvements in microprocessor speed, software functionality, and engineering technology, "smarter" and more effective robotic devices have been created to assist surgeons in performing operative procedures.

In 1991, the Automated Endoscope System for Optimal Positioning [AESOP®] (Computer Motion, Goleta, California) was first developed as a robotic telescopic assistant for surgeons performing minimally invasive operations. In 1994, AESOP 1000 was the first robotic surgical assistant approved by the Food and Drug Administration (FDA). It was remotely controlled by ancillary surgical staff or by a surgeon using a foot pedal. In 1996, AESOP 2000 incorporated rudimentary voice recognition for the surgeon to control assisted maneuvers, but an element of difficulty remained in relaying the surgeon's commands to the telescopic field of vision. Currently, the more advanced third-generation robotic assistant (AESOP 3000) has increased maneuverability and is controllable through the surgeon's voice, utilizing advanced speech recognition technology (Fig. 1A). The seamless nature of the surgeon's control over the robot-assisted movements of the telescopic camera makes the current version of AESOP significantly superior to prior versions.

The AESOP 3000 has a robotic arm that is attached to the operating room (OR) table to control the op-

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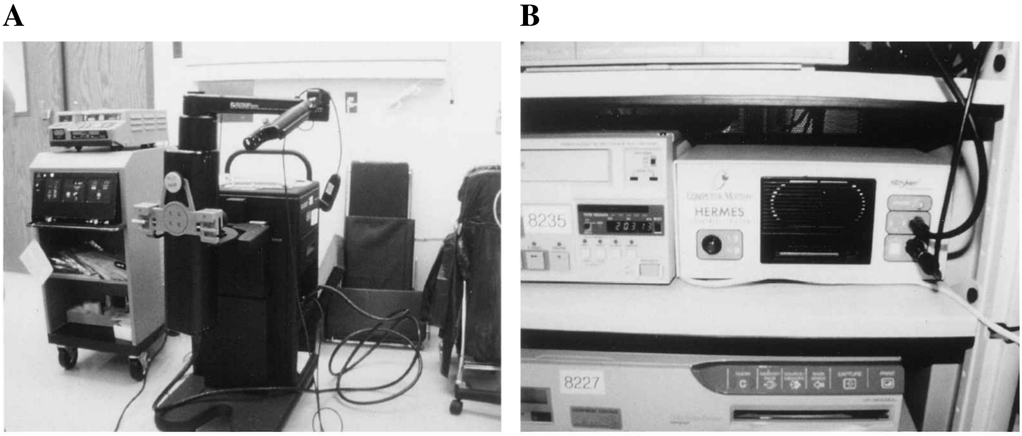

FIG. 1. **(A)** The AESOP® 3000, attached to its cart when not in use. **(B)** The Hermes® processor, which allows the surgeon to control AESOP through voice recognition.

erative telescope. The AESOP 3000 can be manipulated either by the surgeon manually or by the circulating nurse using a keypad or via voice activation through Hermes® (Computer Motion, Goleta, California), which is the sole method used at our hospital (Fig. 1B). Hermes is an OR networking system that allows the surgeon to operate AESOP through voice activation. It also allows the surgeon to capture pictures, operate a videocassette recorder, and change the speed of AESOP movement. Moreover, it can also be used to adjust the OR table, OR lights, and cautery settings.

Reported experiences with robotic telescopic assistance have been primarily limited to adult and animal studies in a variety of operations in general surgery, urology, gynecology, cardiac, and vascular surgery.[1,2] Although greater stability with less inadvertent movement of the visual field has been a reported benefit in these studies, this has not always translated into improved operative outcomes. However, these studies have had sample sizes too small to detect differences between the human and robotic approaches to camera control. Here we report our experience with robotic telescopic assistance in pediatric laparoscopy.

CHILDREN'S MERCY HOSPITAL EXPERIENCE

In early 2000, the AESOP 3000 was investigated and found to be much more facile than earlier versions, with technological advances allowing for efficient clinical application. Therefore, beginning in May 2000, the AESOP 3000 was employed for certain laparoscopic procedures. It became evident that, at least in our hospital setting, AESOP was advantageous for certain procedures but not helpful for others. A number of advantages of this technology became apparent. The use of AESOP allows a consistent and steady visual field throughout an operation, which is imperative for an efficient laparoscopic operation. Not only is there better and more stable visualization of the operative field, but there is also no sudden movement or loss of the visual field due to human fatigue. This is especially pertinent when performing a laparoscopic procedure in a small patient as there is simply not enough space available for more than two people (surgeon and assistant) around a small patient (Fig. 2). Moreover, it became apparent that there was much better utilization of the OR personnel. Prior to this, nurses were the ones who were being asked to hold the camera and there was a great deal of dissatisfaction on their part with this task. This holds even more true in many academic settings where a medical student, perhaps the least trained or experienced camera holder available, is often asked to perform this extremely important task. In other teaching programs, the teaching surgeon uses one hand to hold the camera and telescope and the other hand to assist the operating surgeon. With AESOP, the teaching surgeon has a free hand and can help the operating surgeon as needed, whether it be to change the orientation of the angled telescope, aid with the next operative move, or to help manipulate other instruments as needed.

FIG. 2. The operating surgeon (with headset and microphone) and teaching assistant perform a laparoscopic fundoplication in a 1-month-old patient using AESOP® as the robotic telescopic holder. There is not enough space around this small patient for another person to hold the camera.

As further experience was gained with AESOP, it became evident that certain cases were more suitable for its use than others. The ideal case for AESOP is a common operation that is performed similarly each time, is centered in one anatomic area, and that requires relatively little movement of the telescope/camera. Another aspect of the ideal case would be a duration greater than 1 hour. Using these characteristics, the ideal cases for use in our hospital are laparoscopic fundoplication, laparoscopic cholecystectomy, laparoscopic esophagomyotomy, and laparoscopic adrenalectomy. AESOP is not routinely used in operations such as laparoscopic pyloromyotomy or laparoscopic appendectomy which take approximately 20–25 and 40–45 minutes, respectively.

Although laparoscopic splenectomy is a relatively common operation centered in one anatomic area and usually lasts over 1 hour, it is our feeling that the camera and the telescope must be manipulated many times during the operation to insure a safe procedure. For this reason, we do not utilize AESOP for this operation. However, there are certainly other pediatric surgeons who may find AESOP advantageous for laparoscopic splenectomy. Similarly, for a laparoscopic pull-through procedure, the duration of laparoscopic mobilization of the colon is usually quite limited so AESOP is not usually employed in these settings. On the other hand, if a pediatric surgeon is in a non-teaching practice, AESOP may be very practical for all of the operations that have been mentioned.

In March 2002, we reviewed our experience with a single standardized operation and compared operative times with and without AESOP.[3] Prior to this, the senior surgeon (GWH) had performed over 200 laparoscopic fundoplications. In that review, 154 patients, age 3 weeks to 15 years, underwent successful laparoscopic Nissen fundoplication (LNF) by the senior author from November 1999 to March 2002. From November 1999 through April 2000, LNF procedures were performed with a nurse controlling the telescope. From May 2000 to March 2002, the AESOP 3000 robotic assistant was utilized for control of the laparoscope. The patients were divided into four chronological groups. Group A consisted of patients who underwent operations with a human surgical assistant prior to the use of AESOP 3000 (November 1999 to April 2000). Three other groups comprised patients who had operations utilizing robotic assistance with the telescope and camera: group B (May 2000 to December 2000); group C (January 2001 to May 2001); and group D (June 2001 to March 2002). These later groups reflect periods of time with respectively increased experience utilizing the AESOP 3000 voice-controlled telescopic assistant. The LNF operations were similar in all respects with the exception that a nurse held the telescope and camera in the group A patients.

In this experience, no intraoperative complications occurred, whether using the robotic or human assistant for control of the telescope. Furthermore, postoperative outcomes were similar. However, operative times were significantly decreased in AESOP groups C (93 minutes) and D (69 minutes) compared to group A (108 minutes). Therefore, after a period which was felt to be a learning curve for the AESOP 3000 (group B), shorter operative times were accomplished utilizing robotic telescopic assistance compared to a human assistant (Table 1).

Setup

The AESOP 3000 is comprised of a robotic arm which attaches to the operating table, a carrying cart for the robotic arm, a microphone headset worn by the surgeon, and a computer control center for voice-command recognition (Hermes). The robotic arm of the AESOP 3000 can be manipulated in various ways depending on the needs of the surgeon, the size of the patient, the type of operation, and the maneuverability required. The base of the robotic arm can be tilted from 90 degrees to 45 degrees in relation to the operating table. The robotic arm can be adjusted to various heights from the operating table as well. The joint of the robotic arm can be tilted up or down from +30 degrees to −30 degrees from the horizontal plane. Although there are recommended positions and orientations for different operations, we have found it is usually best to experiment to find the most desirable setup for a particular operation and patient size.

For a laparoscopic fundoplication, we position AESOP on the patient's left side on the rail of the table at the level of the shoulder. AESOP is then angled in full tilt (45 degrees) down toward the foot of the table and the arm is placed in the −1 position. This position is effective for most patients whether the patient is 1 month old or 10 years old (Fig. 3A). The operation is performed with a single cannula and the instruments are introduced through stab incisions in the abdominal wall (Fig. 3B). This same setup is used for a laparoscopic esophagomyotomy. With the patient in reverse Trendelenberg position, the operating surgeon usually operates above the AESOP arm, whereas the assistant's right hand will sometimes be below the arm and sometimes above it. For a laparoscopic cholecystectomy, which is usually performed in a child 8 years of age and older, we place AESOP on the patient's right side on the rail of the OR table at the level of the patient's right femoral head (Fig. 4A). AESOP is usually not tilted and the robotic arm is sometimes placed in the −1 position and sometimes in the 0 position, depending on the patient's size. With this orientation, the surgeon stands on the patient's left, working over AESOP. AESOP usually does not interfere with the surgeon's hands as the surgeon is using instruments placed in the epigastric region of the patient. With the assistant working through a right middle or right lower abdominal incision and holding the fundus of the gallbladder cephalad over the liver, the assistant's hand is sometimes under the arm of AESOP and sometimes over it (Fig. 4B).

Prior to first using AESOP, the surgeon must create a personal interface card which allows Hermes to

TABLE 1. COMPARISON OF OPERATING TIMES WITH AND WITHOUT ROBOTIC TELESCOPIC ASSISTANCE

Group	*No. patients*	*Mean operating time (min)*
A	10	108
B	34	110
C	39	93
D	71	69

A vs. B, $P = .058$; A vs. C, $P < .05$; A vs. D, $P < .05$. Reprinted with permission.[3]

A B

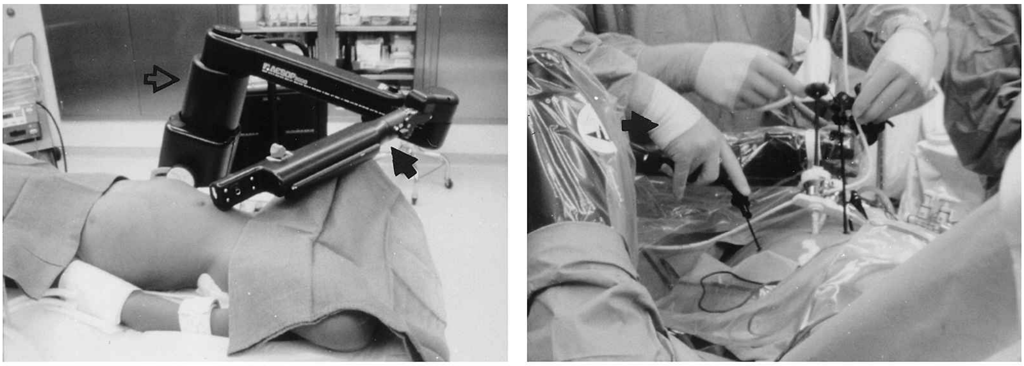

FIG. 3. **(A)** AESOP® positioned on the left side at the level of the patient's left shoulder for a laparoscopic fundoplication. AESOP is then angled in full tilt (open arrow) toward the foot of the table and the arm is placed in the -1 position (solid arrow). **(B)** The surgeon's two hands and the assistant's right hand (solid arrow) work over the AESOP arm. On occasion, it is more efficient for the assistant to have his or her right hand under the AESOP arm.

recognize the surgeon's voice commands. This involves a single 20–30 minute period of recording approximately 200 specific voice commands. The actual use of voice commands during surgery follows a simple menu-based structure that can be visualized on the video monitor. All aspects of telescopic movement, including memory of specific telescopic positions, can be handled through voice commands. Additional functions such as picture control (e.g., brightness), printer use, and other system attributes can also be controlled through voice commands.

DISCUSSION

One overwhelming advantage of the AESOP system recognized by many surgeons is its ability to provide a steady camera view of the surgical field compared to a human assistant.[1,3] AESOP enables the sur-

A B

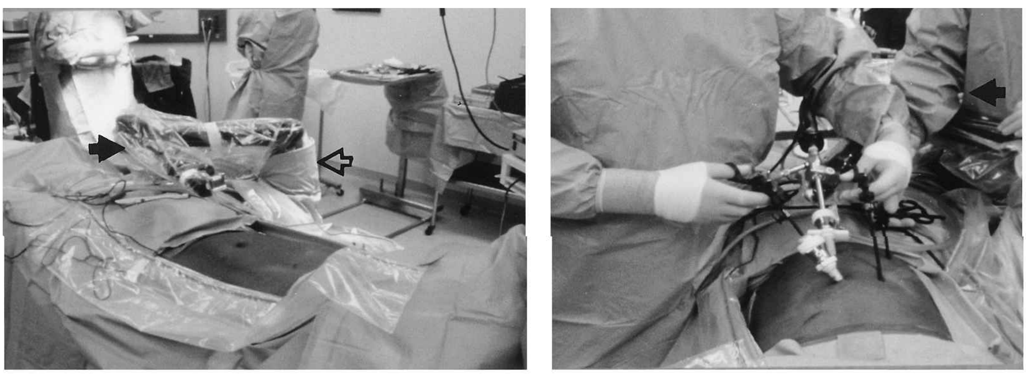

FIG. 4. **(A)** The AESOP® arm positioned on the patient's right side at the level of the patient's right femoral head for a 12-year-old undergoing a laparoscopic cholecystectomy. AESOP is not tilted (open arrow) and the robotic arm is at the 0 position in this patient (solid arrow). **(B)** The surgeon's hands over the AESOP arm. The assistant's right hand (open arm) is also positioned over the arm, but it is sometimes necessary for the assistant's hand to be under the robotic arm.

geon to have a motionless operative field of view devoid of the fine motor tremor inherent in human assistance. This stability of the operative field of view is particularly relevant to pediatric laparoscopy with its smaller operative spaces and telescopic magnification which makes the fine motor tremor of a human assistant more readily apparent. With such steady control of the camera, motion sickness and frustration on the part of the operating surgeon can be avoided.

AESOP is also able to perform fine, uniform movements of the telescope in an incremental or continuous fashion. The incorporation of voice recognition control allows AESOP to perform a task of the surgeon's preference without interrupting the operative movements.[4] Ideally, the surgeon's operative technique can be enhanced by limiting the flaws in human surgical assistance. These advantages will potentially lead to less technical error by the surgeon and, as such, fewer complications and shorter operative times.

Most laparoscopic procedures require an assistant to the surgeon. In this age of decreased OR staff availability due to national nursing shortages, assistance for the operating surgeon is no longer guaranteed. However, the robotic telescopic assistant is always available to the surgeon. This may be projected to allow for fewer delays in operative scheduling and less overall hospital expenditure for operative services.[5]

Disadvantages that have been found with AESOP include a learning time for seamless integration of the robotic assistant into the operation. In addition, there is a short time required to make the voice card for voice recognition. As with any new technology, there are high initial costs. However, these initial costs are offset by reduction in OR times and in personnel costs.

CONCLUSION

Due to rapid changes in technology, the revolution in changing from open to minimally invasive surgery continues to evolve. This evolution is now moving toward the use of robotic assistance in the operating room. AESOP is one form of this robotic assistance and ZEUS and daVinci are other forms. In our hospital, AESOP has led to much greater acceptance of the laparoscopic approach for fundoplication and cholecystectomy by the nursing staff, and they are ardent supporters of this robotic technology. This will likely enable a greater acceptance of either the ZEUS or da Vinci system in the near future. In addition to greater acceptance of the technology by the nursing staff, there has been a clear diminution in operating times, which is certainly desirable for any operative procedure.

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