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Robotic Surgery, the First 100 Cases: Where Do We Go from Here?

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ABSTRACT

Background: Since the robot-assisted cardiac surgery program at this center was initiated in September 1998 the results have been regularly critically evaluated. We report a retrospective review of the first 100 robotic procedures and their evolution.

Methods: Between September 1998 and May 2001, 146 patients underwent robot-assisted procedures. All procedures were performed using the Aesop robotically controlled camera or the Zeus robotic system. A harmonic scalpel was used for all internal thoracic artery (ITA) dissections whether the dissections were performed manually or with the Zeus robotic system.

Results: There were 123 closed-heart and 23 open-heart procedures, which included 8 atrial-septal defect repairs, 11 mitral valve repairs, 4 mitral valve replacements, 57 Aesop ITA takedowns, 68 Zeus ITA takedowns, and 13 totally endoscopic coronary artery bypass grafts. Graft patency in Aesop and Zeus ITA takedown groups was 96%. All the patients were New York Heart Association class I after their procedures.

Conclusion: With the development of surgical robots, it has been possible to perform endoscopic cardiac surgery for selected cases. Future directions will be demonstrated, including telementoring, telesurgery, and Zeus-assisted initiatives in cardiac surgery and other surgical disciplines.

INTRODUCTION

In recent years, advances in minimally invasive surgical technique have led to new approaches to coronary and open-heart surgery. Since the robot-assisted cardiac surgical program was initiated at this center in September 1998, the results have been continuously evaluated. We report a retrospective review of the results of the first 100 robotic procedures and their evolution.

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METHODS

Between September 1998 and May 2001, 146 patients underwent robot-assisted procedures at the London Health Sciences Centre. There were 15 mitral valve procedures, 8 atrial-septal defect (ASD) closures, and 123 single coronary artery bypass grafts (CABG) (Tables 1 and 2).

Surgical Procedure

Single-lung ventilation with a double-lumen endotracheal tube was applied in all the cases.

In all cases surgery was performed using the Aesop robotically controlled endoscopic camera or the Zeus robotic system. For mitral valve procedures and ASD closure, a small right thoracotomy was made in the left lateral position (Figure 1). A 5-mm scope attached to the Aesop arm was inserted into the chest cavity (Figure 2). Cardiopulmonary bypass was employed via ascending aortic and femoral venous cannulation; myocardial protection was done by antegrade (and occasionally retrograde) cardioplegia. For CABG, 3 ports (1 port for a scope, 2 for instruments, Figure 3) were inserted on the left or right chest wall. Until August 1999, the internal thoracic artery (ITA) was harvested manually using Aesop (Figure 4); after September 1999 it was harvested robotically. The method for harvesting ITA was already described in detail [Kiaii 2000]. The harmonic scalpel was used for all internal thoracic artery (ITA) dissections whether done manually or robotically. In CABG cases, coronary artery anastomosis using robotic arms (Figures 5 and 6) was performed if possible [Boyd 2000, Kodera 2001].

The data were gathered prospectively and analyzed retrospectively per the requirements for the institutional review board–sanctioned clinical trial and for quality control and safety procedures. Informed consent was obtained from all patients.

RESULTS

There were 123 closed-heart and 23 open-heart procedures. Open-heart procedures consisted of 8 ASD repairs,

Table 1. Open-Heart Group: Patient Profiles

	Age, Average (Range), y	Male/Female, n
Atrial-septal defect (n = 8)	47 (25-61)	2/6
Mitral valve repair (n = 13)	55 (21-71)	9/4
Mitral valve replacement (n = 3)	47 (44-51)	1/2

Table 2. Coronary Artery Bypass Graft Group: Patient Profiles

	Age, Average (Range), y	Male/Female, n
Aesop (n = 57)	57 (31-81)	44/13
Zeus (n = 68)	58 (31-78)	63/5

Figure 1. Right minithoracotomy atrial-septal defect repair using Aesop.

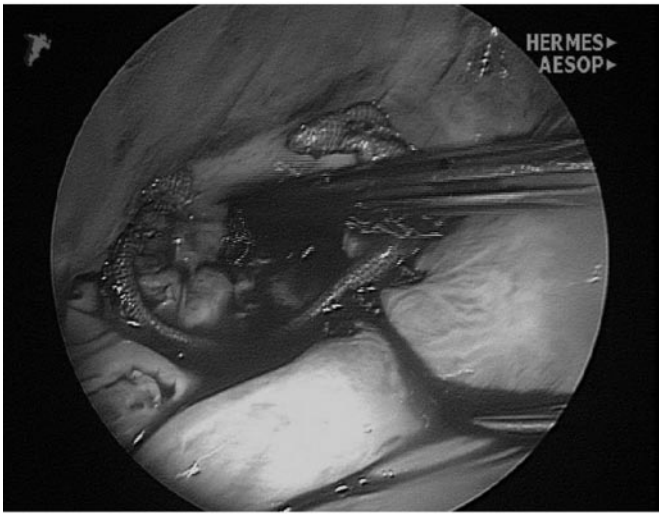

Figure 2. Right minithoracotomy mitral valve repair using Aesop.

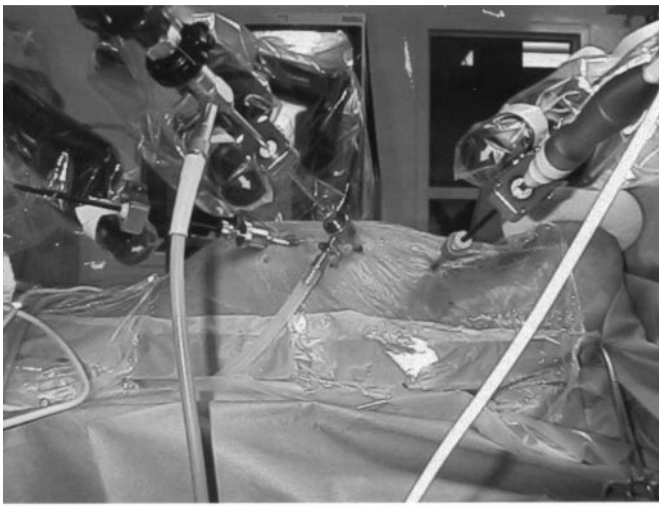

Figure 3. Zeus robotic internal thoracic artery takedown.

Figure 4. Aesop-assisted thoracoscopic internal thoracic artery takedown.

11 mitral valve repairs, and 4 mitral valve replacements. The average cardiopulmonary bypass times were 51 minutes in the ASD group, 188 minutes in the mitral valve repair group, and 199 minutes in the mitral valve replacement group. The average aortic cross-clamp times were 51 minutes in the ASD group, 113 minutes in the mitral valve repair group, and 109 minutes in the mitral valve replacement group. Average postoperative hospital stays were 4 days for ASD, 6.8 days for mitral valve repair, and 8 days for mitral valve replacement (Table 3).

Fifty-seven cases involved Aesop-assisted endoscopic ITA takedowns. Sixty-eight ITA dissections were done robotically with Zeus. The average ITA harvesting times were 57 minutes in the Aesop group and 64 minutes in the Zeus group (Table 4). In 13 patients the ITA takedown and the left anterior descending artery anastomosis were done totally endoscopically with Zeus.

Follow-up angiograms were obtained prior to discharge in 52 of 57 (91%) of the Aesop group and 55 of 68 (81%) of the

Figure 5. Zeus totally endoscopic coronary artery bypass.

Zeus group. Graft patency was 96% in each group. Average postoperative stay was 4.2 days in the Aesop group and 4.3 days in the Zeus group (Table 4).

There were no deaths in the series, neither in the coronary nor the open cases. There were 6 infections treated, 1 in the Aesop ITA takedown group, 4 in the Zeus group, and 1 in the mitral valve replacement group (Tables 5 and 6).

All patients were asymptomatic (New York Heart Association class I or Canadian Cardiovascular Society class I) and returned to their normal lives after their procedures.

ITA harvest times have improved from a maximum of 120 minutes to a mean of 57 minutes for Aesop endoscopic ITA

Figure 6. Zeus totally endoscopic coronary artery bypass.

Table 3. Open-Heart Group: Operative Results

	Pump Time, min	Cross-Clamp Time, min	Hospital Stay, d
Atrial-septal defect	51 ± 28 (29-118)	24 ± 14 (13-57)	4
Mitral valve repair	188 ± 26 (158-211)	113 ± 24 (81-150)	6.8 (4-20)
Mitral valve replacement	199 ± 72 (140-279)	109 ± 41 (73-153)	8 (5-12)

Table 4. CABG Group: Operative Results*

	ITA Harvest Time, min	Graft Flow (mL/min)	Graft Patency	Hospital Stay, d
Aesop	57 ± 23 (25-120)	37 ± 22 (13-126)	96% (50/52)	4.2 (2-13)
Zeus	64 ± 17 (35-110)	43 ± 25 (6-148)	96% (53/55)	4.3 (2-12)

*ITA indicates internal thoracic artery.

Table 5. Open-Heart Group: Postoperative Complications

	Atrial-Septal Defect Repair	Mitral Valve Repair	Mitral Valve Replacement
Mortality	0	0	0
Infection	0	0	1
Others			

Table 6. Coronary Artery Bypass Graft Group: Postoperative Complications

	Aesop	Zeus
Mortality	0	0
Perioperative myocardial infarction	0	4 (6%)
Atrial fibrillation	0	3 (4%)
Infection	1 (1.7%)	4 (6%)
Return to operating room	1 (1.7%)	2 (3%)

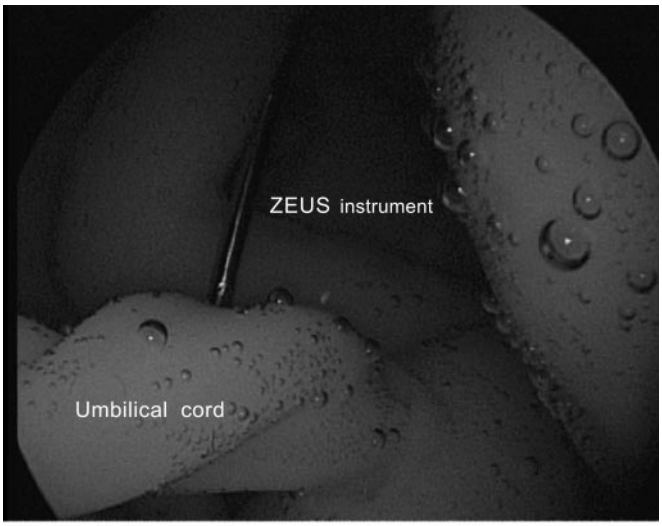

Figure 7. Model of fetus surgery.

Figure 8. Socrates telementoring demonstration.

Figure 9. Socrates mentor station.

and 66 minutes for Zeus ITA takedown. Improvements in stabilization and Zeus robotic arm microjoint technology play an important role in the excellent outcomes and the ongoing improvement in times associated with these procedures.

COMMENT

With the development of surgical robots, it has been possible to perform endoscopic cardiac surgery for selected cases [Autschbach 2000, Damiano 2000, Torraca 2001]. In this paper we report our initial experience with more than 100 robot-assisted procedures performed since 1998.

We have successfully performed ASD closures and mitral valve repair/replacement through a small thoracotomy using voice-activated camera control. However, totally endoscopic ASD closure or mitral valve procedures have not yet been done in our institute.

There are several objectives for the robot-assisted surgery. First, it allows surgeons to perform procedures through tiny incisions. It has already been proven that endoscopic assistance is possible and effective in laparoscopic surgery, but it is difficult to perform endoscopic cardiac surgery because of the difficulty in performing the precise and dexterous movements required for endoscopical sutures with hand-held instruments.

Second, it might be possible to perform a surgical procedure from a distant place using proper Internet or satellite networks. This technology also may allow surgeons to train each other in different places.

Our results have proven that the robot-assisted procedure is feasible; however, there are still some difficulties to overcome. The lack of haptic feedback, limited working space, and limited instrument movement due to fixed points and nonflexible instruments may result in difficulties in robotic assistance. In fact, it was possible to complete coronary anastomosis in only 15% of the CABG patients.

Prospects for future development are exciting. These include initiatives in fetus surgery (Figure 7), telementoring (Figures 8 and 9), telesurgery, and robotic active assistance in cardiac surgery and other surgical disciplines.

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