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Robot-assisted Laparoscopic Aortobifemoral Bypass for Aortoiliac Occlusive Disease: Early Clinical Experience

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Background. *Robotic technology may facilitate laparoscopic aortic reconstruction. We present our early clinical experience with laparoscopic aortobifemoral bypass, aided by two different robotic surgical systems.*
Methods. *Between February 2002 and April 2004, we performed eight robot-assisted laparoscopic aorto-bifemoral bypasses for aortoiliac occlusive disease. All patients were male; median age was 55 years (range: 36–64). Dissection was performed laparoscopically and the robotic system was used to construct the aortic anastomosis.*
Results. *A robot-assisted anastomosis was successfully performed in seven patients. Median operative time was 405 min (range: 260–589), with a median clamp-time of 111 min (range: 85–205). Median blood loss was 900 ml (range: 200–5800). Median anastomosis time was 74 min (range 40–110). In two patients conversion was necessary, one due to bleeding of an earlier clipped lumbar artery after completion of the anastomosis, the other because of difficulties with the laparoscopic exposure of the aorta. On post-operative day 3 one patient died unexpectedly as a result of a massive myocardial infarction. Median hospital stay was 7.5 days (range: 3–57).*
Conclusion. *Our initial experience with robotic assisted laparoscopic surgery (RALS) shows it is a feasible technique for aortoiliac bypass surgery. However, laparoscopic aortoiliac surgery demands considerable experience and operative times need to be reduced before this technique can be widely implemented.*

Keywords: Robot-assisted; Laparoscopy; Aorto-iliac surgery.

Introduction

Laparoscopic vascular surgery for aortoiliac disease has evolved from hand-assisted laparoscopic to total laparoscopic procedures.[1–8] Although impressive series of totally laparoscopic procedures have been reported, it is still not widely accepted and considered a demanding procedure.[6–8] Laparoscopic dissection and exposure of the aorta can be complicated by loss of visualization due to leakage of carbon dioxide or the intrusion of bowel into the operative field. In addition, making a totally laparoscopic vascular anastomosis requires experience and technical skill. Robotic systems have been shown to facilitate advanced laparoscopic techniques, such as suturing, knot-tying and performance of vascular anastomosis.[9] We report our early experience with two different robotic systems for totally laparoscopic aorto-bifemoral bypass.

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Methods

In a period of 26 months (between February 2002 and April 2004) eight patients underwent robot-assisted aorta-bifemoral bypasses after informed consent. The number of patients is low due to the limited availability of the robotic systems and reducing indication for this procedure. In the reported study period, a robotic system was not available for several months. The first (Zeus-Aesop) system was on a limited loan and only recently our hospital acquired a da Vinci system. During the whole period we performed 18 procedures for occlusive aortoiliac disease: eight robot-assisted aortobifemoral bypasses, two conventional open aortobifemoral bypasses (severe ischemic rest pain, could not be postponed), two endarteriectomies (limited disease), four revascularization procedures for aortoiliac and renal or

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visceral occlusive disease, one acute type B dissection with mesenteric, renal and lower extremity ischemia and one aortobifemoral bypass as replacement of an infected prosthesis. All patients were conventionally operated on via a transperitoneal route. Because our experience with manually laparoscopic vascular anastomoses was insufficient, the infrarenal aortobifemoral bypasses in patients with severe ischemic rest pain were conventionally operated in the period of absence of a robotic system. Suprarenal, mesenteric revascularization and redo surgery were not deemed suitable for laparoscopic surgery with our current experience. The first five patients were operated with a Zeus-Aesop Surgical Robotic System® (Computer Motion, California, USA) and the latter three patients were operated with a da Vinci Surgical system® (Intuitive Surgical Inc, California, USA).

All operations were performed by the same surgical team (vascular surgeon (WW) and laparoscopic surgeon (MAC)), whereas the first two procedures were accompanied by a vascular surgeon with extensive robotic experience (CG).[10] A system engineer was present to assist all procedures.

Median age was 55 years (range 36–64). Operative indications were intermittent claudication ($n=7$) or ischemic rest pain ($n=1$). Mean ankle-arm index (AAI) was 0.51 ± 0.20 in rest; 0.30 ± 0.15 following exercise. Pre-operative work-up consisted of an arteriogram ($n=7$) or MRA ($n=1$). Five patients had unilateral occlusion of the common iliac artery (CIA) in combination with occlusion of the external iliac artery (EIA) with contralateral stenosis in the iliac arteries. Two patients had occlusion of the CIA with extensive stenotic lesions in the ipsilateral EIA and stenotic lesions in the distal aorta and contralateral iliac arteries. One patient had a distal aortic occlusion in combination with occlusion of the iliac arteries on both sides. Because of the length and severity of the occlusive and stenotic lesions surgical treatment was preferred to endovascular revascularization.

Surgical technique

All operations were performed under general anesthesia and dissection of the aorta was performed laparoscopically, subsequently the robotic system was introduced and the aortic anastomosis was performed. Patient positioning varied with robotic system. The robotic arms of the Zeus® are connected to the operating table rails and the patients were placed in a supine position with the left flank slightly tilted as described earlier.[10] The arms of the da Vinci® are mounted on a mobile surgical cart, which is positioned next to the operating table. Patients were placed in a right lateral decubitus position with rotation of the pelvis for access to the femoral arteries. The da Vinci® unit was placed at the right (ventral) side of the patient, with the robotic arms positioned over the patient (Fig. 1).

In the first two patients conventional laparoscopic dissection of the aorta was performed using the apron technique with suspension of the apron to the anterior abdominal wall as described by Dion *et al.*[11] These patients have been described in a case report earlier.[10] In the remaining six patients retroperitoneal dissection was performed with a dissection balloon (Origin Medsystems Inc., Menlo Park, California, USA) under intraperitoneal laparoscopic visual control to establish the creation of a pneumoretroperitoneum.[12] Femoral arteries were dissected manually by standard groin incisions.

All patients were given systemic heparin before clamping of the aorta. A PTFE (WL Gore and Associates, Flagstaff, Arizona, USA) prosthesis was stained orange with rifampicine to prevent light reflections. A PTFE graft was used because of the relative stiffness of this material. This enabled us to bend the edges of the prosthesis to facilitate eversion of the anastomosis. CV-4 polytetrafluororethylene (PTFE) (WL Gore and Associates, Flagstaff, Arizona, USA) sutures were used. Extra-corporally two sutures were cut to the appropriate length and tied, thereby creating a custom made double-armored suture. A U-stitch was placed in the heel of the prosthesis, where after the prosthesis with sutures in place was introduced through one of the trocars and an end-to-side anastomosis was made with a running suture technique. A zero degree endoscope was used for the dissection and a 30-degree endoscope for the vascular anastomosis. Six 10 mm trocars were introduced in the right hemi-abdomen to allow dissection and provide visibility of the aorta (Fig. 1).

Results

In all patients, the aortobifemoral bypass was successfully implanted; however, additional abdominal incisions were necessary in two patients. In one case (#6), after making the robot-assisted aortic anastomosis, bleeding from an earlier clipped lumbar artery resulted in a loss of visibility that coincided with severe declamping hypotension. An acute conversion was made by means of a 15 cm flank incision to control the bleeding. The robotic vascular anastomosis showed no leakage. The patient, however, required prolonged post-operative respiratory support and

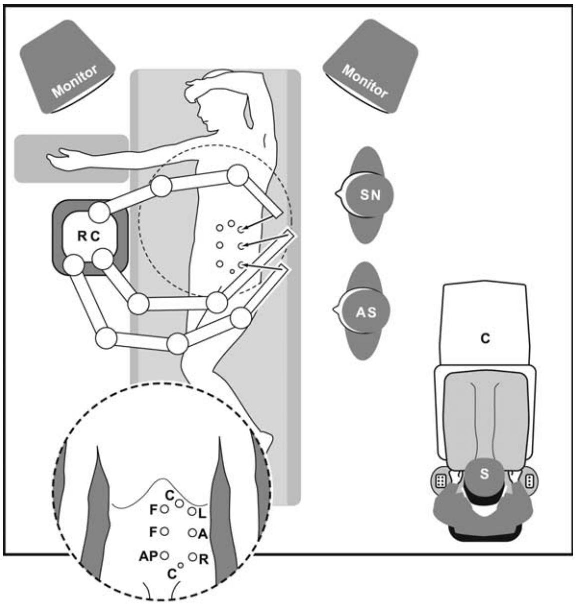

Fig. 1. Set-up of da Vinci with trocar positioning. Operating room set-up. RC, robotic cart; C, surgeon control console; AS, assistant surgeon; SN, scrub nurse; Inset: R, right robotic arm; L, left robotic arm; A, surgical endoscope positioner. Trocar positions in abdominal wall: C, Aortic clamp; F, fan retractor.

developed transient renal failure and severe critical illness polyneuropathy. At follow-up after 6 months he had made a near complete recovery.

The second conversion (case #8) was caused by tearing of the peritoneum, which resulted in continuous CO_2 leakage and bowel migrating into the retroperitoneal space, thereby obstructing the operative field and vision. A 15 cm flank incision was made for retraction and performance of a hand sewn end-to-side anastomosis.

On the 3rd post-operative day one patient died unexpectedly due to a massive myocardial infarction. At autopsy, pin-point stenoses of the left anterior descending coronary artery was found, that unfortunately had been missed during the pre-operative cardiac work-up.

All aortic anastomoses were dry and patent following removal of the aortic clamps.

Some technical problems with the robotic system (Zeus®) were encountered. Several times the instruments malfunctioned and once the voice-controlled Aesop® camera system did not respond, resulting in significant operative delay. A suture break occurred once (case #7), during performance of the robotic anastomosis, requiring the use of an additional suture.

Median operative time was 405 min (range: 260–589), with a median clamp-time of 111 min (range: 85–205). Median anastomosis time was 74 min (range: 40–110). Median blood loss was 900 ml (range: 200–5800). Median hospital stay was 7.5 days (range: 3–57). (Table 1). Median follow-up was 12 months (range: 3–30). Five patients remained free of intermittent claudication, one had a pain free walking distance of 300 m due to pre-existent infrainguinal occlusive disease, and one patient had a limited walking distance due to dyspnoea of cardiac origin. AAI's were normal (>1.0) in all but one patient (0.7). Duplex examination at 6 months intervals revealed all anastomosis to be patent without stenoses or false aneurysms.

Discussion

Laparoscopic surgery has developed rapidly since, its introduction. Even though operative times are longer the benefit of laparoscopic surgery (less pain and post-operative complications, reduced hospital stay, earlier return to work and better cosmetic appearance) are well recognized and laparoscopic surgery has become the standard for several procedures.[13] The enthusiasm for laparoscopic aortoiliac surgery is, however, low. Despite early positive reports it has not been widely embraced.[5–8,14] Two major problems are encountered: the maintenance of a stable operative field with clear vision and the performance of the vascular anastomosis.

For the laparoscopic dissection of the aorta three different techniques are used: a transperitoneal route, a retroperitoneal route and an apron technique.[11,14,15] With the transperitoneal approach, intrusion of bowel in the operative field is prevented by (extreme) patient positioning, in the latter two approaches, the peritoneum is used towards this goal. The first patients were operated on with the use of an apron peritoneal layer, which provided a stable operative field. However, it also proved to be a tedious and time consuming technique. The retroperitoneal approach with a dissection balloon can be performed quickly, but results in a relatively small retroperitoneal space which easily collapses with suction or CO_2 leakage. The retroperitoneal flap is thin and even a small hole in this layer results in CO_2 leakage or intrusion of bowel, with collapse of the working space or loss of visibility. For the transperitoneal route[15] the patient has to be extremely rotated, which interferes with the positioning of the da Vinci robotic arms.

Vascular anastomoses can be performed totally laparoscopically, which requires advanced laparoscopic skill and regular practice to maintain these skills. Robotic surgery facilitates laparoscopic suturing and knot-tying by robotic instruments with additional

Table 1

	Operating time (minutes)	Anastomosis time (minutes)	Clamp-time (minutes)	Blood loss (ml)	ICU stay (days)	Hospital stay (days)	Conversion	Follow-up (months)
1	290	74	104	200	1	4	No	30
2	260	60	90	200	1	6	No	30
3	380	65	125	700	1	8	No	16
4	420	85	175	1000	1	4	No	12
5	455	110	205	800	3	3	No	–
6	589	40	105	5800	16	57	Yes	6
7	390	60	117	1650	1	6	No	3
8	495	–	85	3000	1	10	Yes	3

degrees of freedom and 3D-vision, bypassing intensive practice. An additional advantage of a robotic system is the minimal dissection of the aorta and iliac vessels required. Robotic systems were used for the vascular anastomosis only. Both robotic systems have distinct advantages. The table mounted arms of the Zeus® are not obstructive and leave many options for patient positioning. The da Vinci® system on the other hand, is bulky and dominates the surgical field. Concerning technical performance of the robotic instruments, the da Vinci® offers more degrees of freedom and manipulation of its instruments is more intuitive.

When compared to total laparoscopic procedures,[5–7] reported operating times are longer (375, 227 and 290 vs. 405 min) especially considering the fact that in the series reported by Kolvenbach[6] and Coggia[7] two laparoscopic aortic anastomoses were made. However, both authors have a great amount of clinical experience with laparoscopic (assisted) vascular surgery and are supposed to have passed their learning curve. When compared to the earliest totally laparoscopic series for aortobifemoral bypasses by Dion[5] clamping time and anastomosis time are similar (121 and 66 min vs. 111 and 74 min). In the reported robot-assisted cases by Kolvenbach,[6] operating time and aortic cross clamping times were longer, but robot-assisted aortic anastomosis time was significantly shorter (52.7 vs. 40.8 min). The set-up time and mechanical problems with their robotic system was associated with longer operating time despite shorter anastomosis time. An improved robotic system might also shorten operating times. Difficulty performing aortic dissection is the main factor prolonging the operative time for this procedure. Another report by Desgranges[16] describing robot-assisted procedures also reports prolonged dissection time. Operating time was short (188 min) but in 3/5 patients a minilaparotomy was performed for exposure of the aorta. Aortic anastomotic time was not reported, but mean cross clamping time was 75 min. The robotic instruments have more degrees of freedom of movement and facilitate actions that cannot be made by conventional instruments and improve efficacy by reduction of actions to make endoscopic stitches and knots, however, at present the anastomotic time is prolonged.[9]

A robotic system is an expensive laparoscopic adjunctive instrument. Although, a cost analysis was not performed in our study, but robotic-assisted surgery can be assumed to be more expensive than open and conventional laparoscopic surgery. This should be taken in consideration before starting RALS. Robotic systems are still developing and improving. Technical improvements will reduce the complexity of robotic systems and probably shorten the learning curve for the vascular surgeon.

In conclusion, RALS for aortoiliac surgery can be of additional value in overcoming the long learning curve in laparoscopic suturing of vascular anastomoses. However, in this study the laparoscopic exposure of the infrarenal aorta was time consuming and not always predictable. Therefore, this procedure requires continued research before wide implementation can be expected.

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