Total laparoscopic infrarenal aortic aneurysm repair: Preliminary results

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Objectives: **We describe our initial experience of total laparoscopic abdominal aortic aneurysm (AAA) repair.**
Material and methods: **Between February 2002 and September 2003, we performed 30 total laparoscopic AAA repairs in 27 men and 3 women. Median age was 71.5 years (range, 46-85 years). Median aneurysm size was 51.5 mm (range, 30-79 mm). American Society of Anesthesiologists class of patients was II, III and IV in 10, 19, and 1 cases, respectively. We performed total laparoscopic endoaneurysmorrhaphy and aneurysm exclusion in 27 and 3 patients, respectively. We used the laparoscopic transperitoneal left retrocolic approach in 27 patients. We operated on 2 patients via a tranperitoneal left retrorenal approach and 1 patient via a retroperitoneoscopic approach.**
Results: **We implanted tube grafts and bifurcated grafts in 11 and 19 patients, respectively. Two minilaparotomies were performed. In 1 case, exposure via a retroperitoneal approach was difficult and, in another case, distal aorta was extremely calcified. Median operative time was 290 minutes (range, 160-420 minutes). Median aortic clamping time was 78 minutes (range, 35-230 minutes). Median blood loss was 1680 cc (range, 300-6900 cc). In our early experience, 2 patients died of myocardial infarction. Ten major nonlethal postoperative complications were observed in 8 patients: 4 transcient renal insufficiencies, 2 cases of lung atelectasis, 1 bowel obstruction, 1 spleen rupture, 1 external iliac artery dissection, and 1 iliac hematoma. Others patients had an excellent recovery with rapid return to general diet and ambulation. Median hospital stay was 9 days (range, 8-37 days). With a median follow-up of 12 months (range, 0.5-20 months), patients had a complete recovery and all grafts were patent.**
Conclusion: **These preliminary results show that total laparoscopic AAA repair is feasible and worthwhile for patients once the learning curve is overcome. However, prior training and experience in laparoscopic aortic surgery are needed to perform total laparoscopic AAA repair. Despite these encouraging results, a greater experience and further evaluation are required to ensure the real benefit of this technique compared with open AAA repair. (J Vasc Surg 2004;40:448-54.)**

Endoaneurysmorrhaphy with intraluminal graft placement described by Creech[1] is the gold standard for abdominal aortic aneurysm (AAA) repair. Mortality is less than 5%, but systemic morbidity remains substantial.[2] For several years, minimally invasive techniques have been developed in order to reduce the perioperative morbidity of AAA repair. In particular, endovascular prostheses have been increasingly used since 1995. However, despite satisfying short-term results, uncertainties remain concerning the durability of these implants and the possibility of progression of abdominal aortic aneurysm (AAA) to rupture.[3,4]

More recently, aortic surgery entered the field of laparoscopic surgery. The concept of laparoscopy is to perform the endoaneurysmorrhaphy described by Creech with the advantages of minimally invasive techniques, especially reducing surgical trauma. However, laparoscopic infrarenal aortic surgery is technically demanding. The main technical difficulties are the exposure of the abdominal aorta hampered by the small intestine, which blinds the operative field, and the performance of laparoscopic anastomoses.[5-8] We have described a transperitoneal laparoscopic approach, which allows a simple and reproducible exposure of the infrarenal abdominal aorta.[9] Taking advantages of our previous experience in laparoscopic surgery for aortoiliac occlusive disease (AIOD), we used this new total laparoscopic technique for AAA repair.

MATERIAL AND METHODS

Surgical technique. The patient is placed in a dorsal decubitus position with an inflatable pillow (Pelvic-Tilt; O.R. Comfort, LLC, Glen Ridge, New Jersey) placed behind his left flank, which gives a 50° to 60° rotation of the abdomen. A maximal right rotation of the operating table affords an abdominal slope of 70° to 80°. The operator faces the patient's abdomen, with the first assistant standing in front of him or her. The second assistant is placed on the right of the operating surgeon (Fig 1).

A pneumoperitoneum is insufflated up to 14 mm Hg through a Veress needle. A 45° endoscope (Storz-France SA, Paris, France) is positioned on the left anterior axillary line, 3 cm below the costal margin. Two 10-mm trocars are placed at the supraumbilical and left paramedian level to insert the operator instruments. A 10-mm trocar is placed under the xyphoid. At the beginning of the procedure, an

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Competition of interest: none.

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0741-5214/$30.00

doi:10.1016/j.jvs.2004.06.037

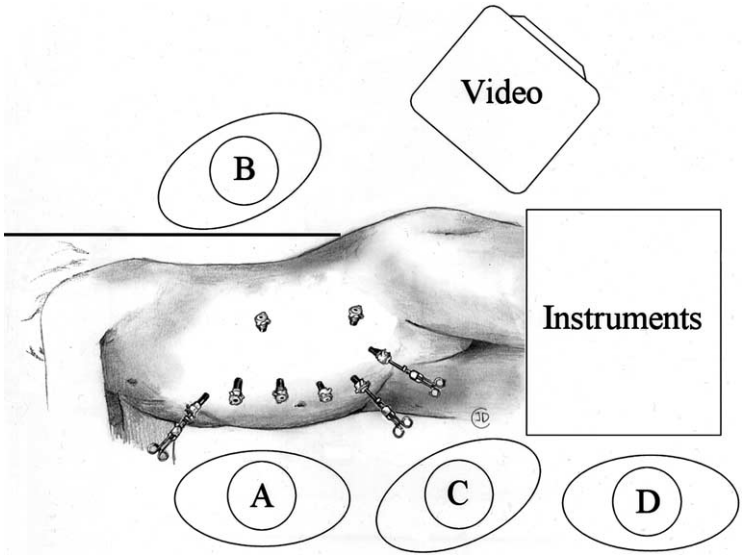

Fig 1. Basic operating room setup. *A*, Operating surgeon. *B*, Assistant for laparoscope. *C*, Assistant for instrumentation. *D*, Nurse.

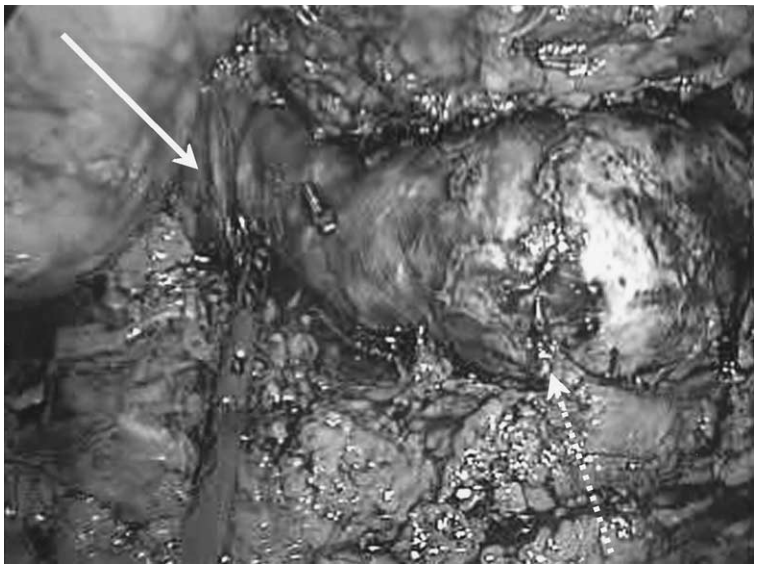

Fig 2. Operative picture showing the laparoscopic exposure of an abdominal aortic aneurysm. *Arrow*, left renal vein; *dotted arrow*, inferior mesenteric artery.

endoretractor (Endoretract II; USSC, Autosuture Company, Elancourt, France) is introduced through this port to maintain the left mesocolon. Another 10-mm trocar is positioned 6 cm below the navel to introduce 1 iliac clamp. A 10-mm trocar is placed in the left lower abdomen to insert assistant instrumentation. A peritoneal incision is made in the left paracolic gutter up to the splenic flexure. By elevating and medially displacing the left colon, the avascular plane of the Toldt fascia is entered and developed caudally to the aorta bifurcation, and cranially to reach the left renal vein. Due to the right lateral decubitus, small bowel and left mesocolon drop to the right part of the abdomen. This allows exposure of the infrarenal aorta until the common iliac arteries (Fig 2). This type of aortic approach is used in standard cases. In thin patients or patients with previous left colonic or kidney surgery, dissection in line of the Toldt fascia is difficult or not possible and we prefer to use a transperitoneal left retrorenal approach. The left retroperitoneal dissection is conducted by elevating and medially displacing the left colon, the left kidney and the spleen, providing right medial viscera rotation. In case of severe chronic obstructive pulmonary dis-

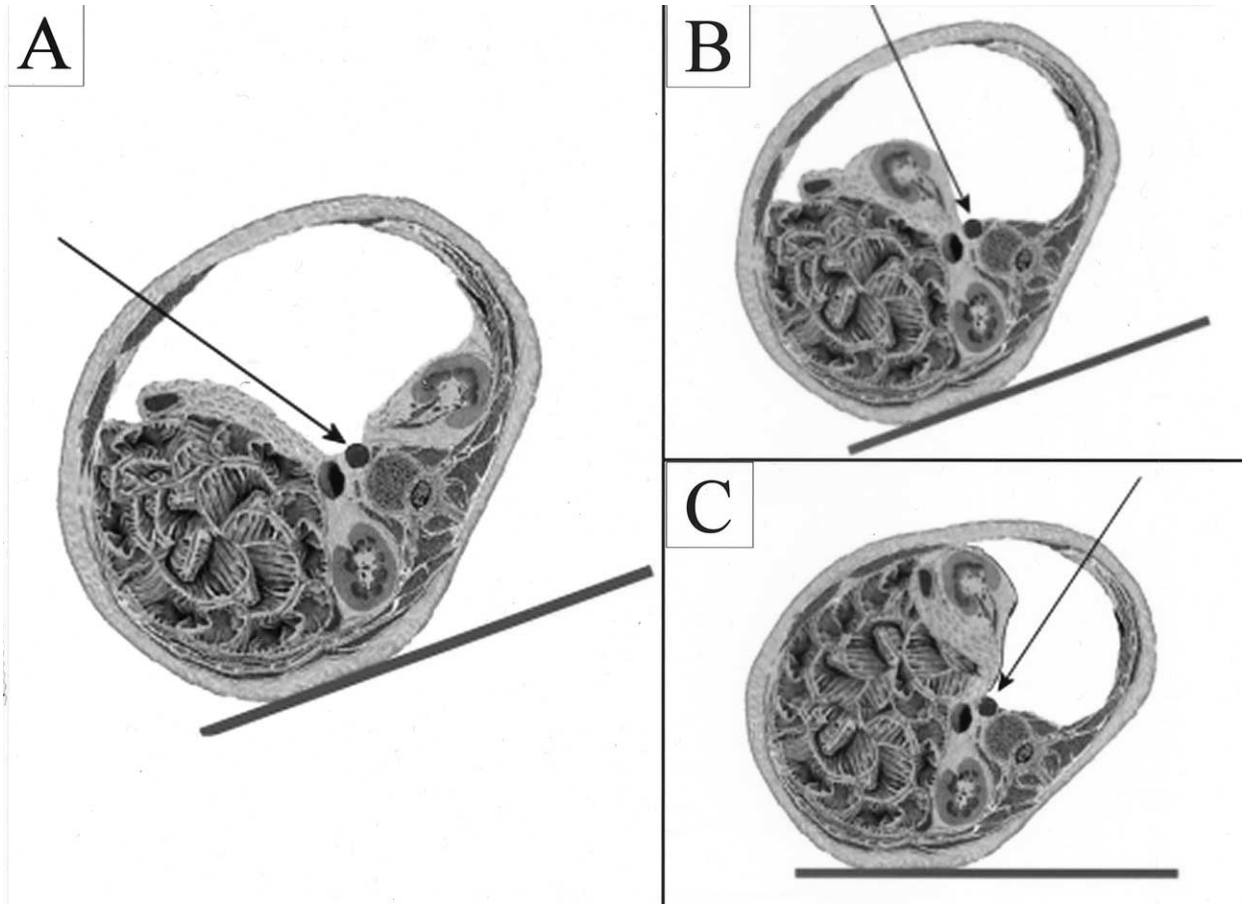

Fig 3. Transverse sections showing the different videoscopic approaches of the abdominal aorta. **A,** Transperitoneal left retrocolic approach. **B,** Transperitoneal left retrorenal approach. **C,** Retroperitoneoscopic approach. *Arrows* show orientation of the surgical instruments.

ease or in presence of a hostile abdomen, we prefer to use a left retroperitoneoscopic approach (Fig 3).

After achieving the dissection, the pillow is deflated and the operating table is rotated on the left, which allows a conventional approach to the femoral or external iliac arteries if needed. The patient is then taken back to a right lateral decubitus position.

Before clamping, a bolus of heparin is administrated. Sutures are prepared for anastomoses and control of lumbar arteries. Multiple 3/0 or 4/0 polypropylene (Prolene; Ethicon, Johnson-Johnson Intl, Brussels, Belgium) sutures are knotted on Teflon pledgets.[6]

The proximal laparoscopic clamp (Storz-France SA, Paris, France) is positioned through the sub-xyphoid 10-mm trocar. A stitch is placed into the left part of the aneurysmal sac and pulled out through the right abdominal wall. It will be used to open the aneurysmal sac after the aortotomy. Right iliac clamping is performed through an infraumbilical trocar. Left iliac clamping is performed through another trocar introduced in the left iliac fossa or with laparoscopic detachable clamp (Storz-France SA, Paris, France). A bulldog clamp occludes the inferior mesenteric artery (IMA). Aortic and right iliac laparoscopic clamps stabilize the left mesocolon into position and allow a stable exposure during the performance of laparoscopic endoaneurysmorrhaphy and anastomoses (Fig 4).

A longitudinal aortotomy is performed on the left side (Fig 5). Traction on the stitch, which was previously placed into the aortic wall, allows opening the aneurysmal sac. Mural thrombus is removed with a container. Different techniques are used to control the lumbar arteries: (1) external control with hemoclips (Ligaclip ERCA; Ethicon Endosurgery, Johnson-Johnson Company Intl, Brussels, Belgium) after proximal aortic clamping, before or after opening of the aneurysmal sac; (2) internal control into the aneurysmal sac with staples (EMS; Ethicon Endosurgery, Johnson-Johnson Company Intl, Brussels, Belgium) and/or with free 3/0 polypropylene stitches. As in the Creech's technique, the posterior wall of the proximal aneurysmal neck is incised. For a tube graft, the distal aorta is dissected circumferentially. It is important to have a control of the interaorticocaval space before section of the aorta. For laparoscopic iliac implantations, complete transverse section of the common iliac arteries is performed. A

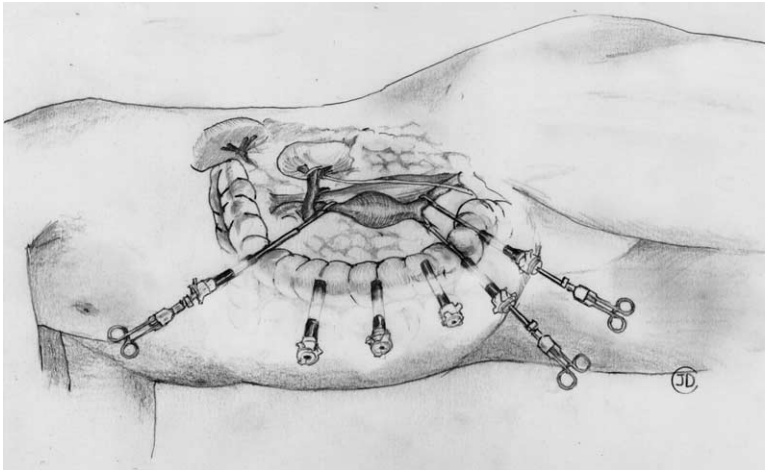

Fig 4. Drawing of the laparoscopic abdominal aortic aneurysm exposure via a transperitoneal left retrocolic approach: aortic and iliac laparoscopic clamps stabilize the left mesocolon and allow a stable exposure.

conventional woven Dacron graft (Gelweave; Vascutek-Terumo, Inchinnan, Scotland) is used. It is introduced into the abdomen through 1 of the trocars. If necessary, the right iliac limb is tunneled with the use of an aortic clamp introduced from the groin or the iliac fossa and conducted over the right common iliac artery under laparoscopic control. Anastomoses are performed with hemicircumferential running sutures previously knotted on Teflon pledgets (Figs 6 and 7). At the end of each anastomosis, both ends of the thread are tied together intracorporally.

At the end of the procedure, we perform a videoscopic inspection of the left colon to assess its viability. Back bleeding from the IMA and peroperative Doppler ultrasound (Ultrasonic Doppler Flow Detector, model 811b; Parks Medical Electronics Inc, Aloha, Ore) are used to assess the adequacy of collateral blood flow to the left mesocolon. If reimplantation of the IMA is needed, it can be perform laparoscopically or via a minilaparotomy. On closure, a suction drain is positioned near the prosthesis. There is no need to reattach the edge of the mesocolon because it falls back into place once the patient is taken back to a dorsal decubitus position. The small bowel lies over it and maintains it in place. Aortic wall covers the graft when the mesocolon falls into place. However, it could be easily sutured with single or running stitches. Abdominal fascia of trocar holes is closed with adsorbable sutures.

Clinical experience. Between November 2000 and September 2003, we performed 168 total laparoscopic reconstructions for aortoiliac disease. All patients gave their informed consent before the procedures. We operated on 129 of them in our institution and 39 in other centers. Ninety-five of the 129 patients were operated on for extensive AIOD. Two others patients underwent total laparoscopic redo aortic reconstructions for aortobifemoral bypass graft occlusion.

Our present study includes 30 patients who were operated on for AAA in our institution by 1 surgeon (MC)

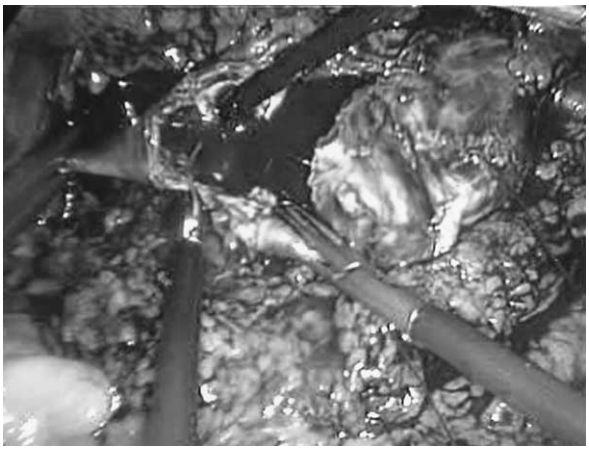

Fig 5. Operative picture showing aortotomy and section of the proximal neck.

between February 2002 and September 2003. We did not include in this series 15 patients we operated on in others centers and 2 patients who underwent total laparoscopic redo aortic procedures for para-anastomotic pseudoaneurysms. During the same time period, 18 others patients underwent elective open AAA repair and 2 patients, who were unfit for surgery, underwent endovascular repair.

Our study includes 27 men and 3 women (Table I). The patients ranged in age from 46 to 85 years, with a median age of 71.5 years. Preoperatively, patients underwent angiography and computed tomography (CT) angiogram. Angiography was used to assess the permeability of visceral, inferior mesenteric, iliac, and lumbar arteries. CT angiography was used for the morphologic study. The median aneurysm size was 51.5 mm (range, 30-79 mm). Patients with aneurysms less than 50 mm in diameter were

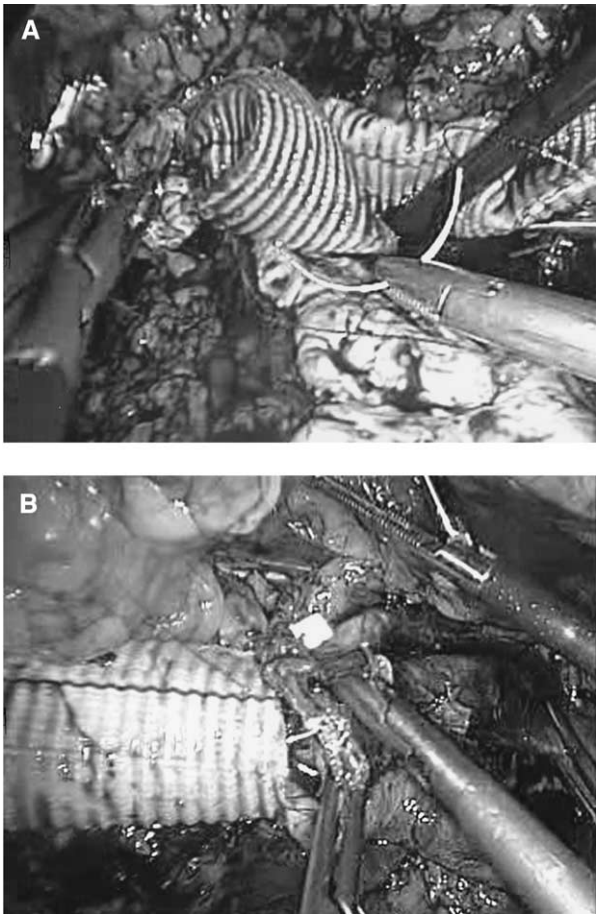

Fig 6. Operative picture showing proximal (**A**) and distal (**B**) anastomoses of a total laparoscopic tube graft.

operated on for severe associated AIOD in 4 cases and painful aneurysm in 1 case (Table II).

Patients were classified in accordance with American Society of Anesthesiologists (ASA) classification. In addition, all patients underwent stress echocardiography; pulmonary, hepatic, and renal function tests; and esogastric endoscopy. Coronarography was performed for patients with abnormal stress echocardiography. Patients classified as ASA V and patients with significantly abnormal cardiac, hepatic, and renal tests were excluded for laparoscopic procedures. Severe chronic pulmonary disease was not a contraindication for laparoscopic AAA repair. Patients were classified as ASA class II, III and IV in 10, 19 and 1 cases, respectively. Other preoperative data are summarized in Table I.

RESULTS

We implanted tube, aortobilial, and aortobifemoral bypass grafts in 11, 15 and 4 patients, respectively. The laparoscopic transperitoneal left retrocolic approach was used in 27 patients. Two thin patients were operated on via a transperitoneal left retrorenal approach. One patient was

Fig 7. Operative picture at the end of a total laparoscopic abdominal aortic aneurysm repair showing a laparoscopically implanted tube graft.

operated on via a left retroperitoneal approach because of a hostile abdomen. We performed 1 laparoscopic reimplantation of the IMA because vascular flow to the left colon was compromised after IMA clamping.

An intraoperative decision was made to perform a short laparotomy because of technical difficulties that occurred in 2 cases. For the patient operated on via a retroperitoneal approach, exposure was hampered by difficulties with the adequate retraction of the viscera as a result of an accidental tearing of the peritoneal sac and a 10-cm flank incision was needed. Another patient had a very calcified aorta and over-sewing of the distal aorta was difficult, requiring a 6-cm laparotomy in the left iliac fossa

Median operative time was 290 minutes (range, 160-420 minutes). We define clamping time as the time elapsed between aortic clamping and unclamping of the first iliac or femoral artery. In this series, the median clamping time was 78 minutes (range, 35-230 minutes). Median blood loss was 1680 cc (range, 300-6900 cc). The median body temperature at the end of the operation was 36.6°C (range, 35.2-38.5°C).

In our early experience, 2 patients died of myocardial infarction during the postoperative period. These were the third and eleventh patients of our series. The first patient was ASA IV and had severe nontreatable coronary lesions. The second patient had been operated on for a 6-cm infrarenal AAA. He had a past history of coronaropathy, with severe lesions of the right coronary artery. Medical treatment with blockers was instituted. He presented a hepatic shock with coagulopathy during the laparoscopic AAA repair, which was related to a right ventricular myocardial infarction. He was reoperated on 3 hours after the initial laparoscopic procedure for a postoperative hemoperitoneum without any cause of bleeding and died after the procedure. Ten major nonlethal postoperative complications were observed in 8 patients. Seven of these complications were observed in the first third of this series. There

Table I. Preoperative data

Preoperative data	*N = 30*
Age	71.5 (range, 46-85)
BMI	27.9 (range, 19.3-39.7)
Hypertension	15 (50%)
Tobacco use	22 (73%)
Hyperlipidemia	7 (23%)
Diabetes	5 (16,6%)
Ischemic heart disease	9 (30%)
COPD	6 (20%)

BMI, Body mass index; *COPD,* chronic obstructive pulmonary disease.

Table II. AAA characteristics

Preoperative data	*N = 30*
Diameter (mm)	51.5 (range, 30-79)
Proximal neck length (mm)	18 (range, 0-52)
Aortoaortic aneurysm	24 (80%)
Aortoiliac aneurysm	6 (20%)
Associated AIOD	4 (13,3%)
Associated renal and/or visceral occlusive lesions	3 (10%)

AAA, Abdominal aortic aneurysm; *AIOD,* aortoiliac occlusive disease.

were 4 transcient renal insufficiencies, which resolved without dialysis, and 2 cases of lung atelectasis. One patient was reoperated on at day 13 for a small bowel incarceration in a 10-mm trocar hole. Three other reinterventions were performed, related to a spleen rupture at day 5, a right external iliac artery dissection after a conventional anastomosis of the prosthetic limb, and a hematoma in the left iliac fossa after a conventional approach.

Apart from these complications, most patients had a fast recovery with minimal wound discomfort. The median time elapsed between operation and removal of the nasogastric tube was 1 day, and the nasogastric tube is now removed at the end of procedure. The median duration of ileus was 2 days. A general diet was reintroduced after a median duration of 3 days, and most patients were ambulatory by day 3 with minimal complaint of pain. Median hospital stay was 9 days (range, 8-37 days).

With a mean follow-up of 12 months (range, 0.5-20 months), complete recovery was observed in 28 patients, and all grafts were patent. One patient presented a left limb claudication 3 months after an aortobiiliac bypass. CT-angiogram study showed an external iliac artery dissection but the left prosthetic limb remained patent. For this patient, the left common iliac anastomosis was performed laparoscopically but without hemodynamic anomalies on postoperative duplex study. A cross-over femorofemoral bypass was performed and the postoperative course was uneventful. No other hemodynamic or morphologic anomalies were observed on follow-up duplex and CT-angiogram studies.

DISCUSSION

Laparoscopic treatment of infrarenal aortic aneurysms has been recently reported.[10-18] It appears to be a reproducible technique for dissection. Previously described techniques of laparoscopic AAA repair have been performed either in an assisted fashion[10, 12-15, 17, 18] or with aneurysm exclusion.[11,14] However, exclusion is not a definitive repair because of the persistent flow in the aneurysmal sac in about 4% to 7%, with a possible progression to rupture.[19] Only 1 case of laparoscopic AAA repair was performed according to the criterion standard endoaneurysmorrhaphy.[16]

This short series demonstrates that total laparoscopic AAA repair is feasible with acceptable short-term outcomes. Our transperitoneal laparoscopic approach allows a stable aortic exposure during the performance of endoaneurysmorrhaphy and anastomoses. The operative field remains free from intrusion of intra-abdominal organs, which are dropped in the right part of the abdomen. If suprarenal clamping is necessary, dissection can be continued above the renal arteries with the use of a partial mediovisceral rotation. Use of a 45° angled laparoscope allows a circumferential view of vascular structures during dissection and anastomoses. With the left lateral view, control of the posterior wall of the aorta is possible. If the dissection in line of the Toldt fascia is not possible without tearing the mesocolon, we prefer to use a transperitoneal left retrorenal approach. By comparison with a left retroperitoneoscopic approach, the transperitoneal left retrorenal approach allows a larger working space, both externally for the placement of trocars and internally with the dome-shaped cavity due to the pneumoperitoneum.[20,21] Our technique of anastomosis uses sutures blocked over pledgets, which avoid the need of intracorporeal knots at the beginning of the running sutures. This technical point is important to avoid a direct trauma to the suture material when performing the starting knots of the running sutures. Compared with a single running suture, the separate use of 2 short sutures allows avoidance of the obstruction of the operative field.

Operative and clamping times in our series were longer than usually observed during open AAA repair. However, after a step learning curve, these times were significantly reduced, and we must underline that, after our initial experience, many longer times corresponded to the training of our fellows or other surgeons. Median blood loss is comparable with figures reported for conventional aortic surgery. Back bleeding from the lumbar arteries is the main difficulty during laparoscopic AAA repair because vigorous suction is necessary with collapse of the abdominal cavity and immediate loss of visualization. Extreme blood losses were in fact observed in patients having very calcified aortas. An interesting observation was the limited decrease of body temperature at the end of the operation. This parameter is important in vascular surgery considering that hypothermia is associated with coagulopathy, morbid myocardial events, and prolonged recovery and hospitalization.

Operative mortality figures for elective open AAA repair are less than 5%, with substantial systemic morbidity.[2] Many of these complications relate to the abdominal incisions, bowel manipulation, blood loss, and coagulopathy. In our series, the mortality rate was 6,6%, but we must underline that there were no deaths once we completed our learning curve. Moreover, 1

of these deaths was related to a myocardial infarction in a patient with nontreatable coronary lesions. We think it was a mistake in patient selection before AAA repair. In our experience, high surgical risks are the same for open and laparoscopic AAA repairs, except for morbid obesity and severe chronic obstructive pulmonary disease, which are not contraindications for laparoscopy. Unlike open surgery, total laparoscopic AAA repair avoids the need for large abdominal incisions and bowel manipulation. It provides minimal complaint of pain and theoretically could provide faster recovery, shorter postoperative ileus duration, and rapid return to general diet and ambulation. Moreover, we can expect a reduced incidence of abdominal wall hernia, which remains between 20% and 30% after open AAA repair.[22,23] Median length of hospital stay was still long in our series, but several patients were kept in the hospital although they did not need medical care.

Patient selection before laparoscopic AAA repair is mandatory. Inflammatory and ruptured AAAs are contraindications for total laparoscopic repair. Associated severe and diffuse occlusive lesions of the visceral arteries are also contraindications if not treatable with endoluminal techniques. However, isolated occlusive lesions of the superior mesenteric artery can be treated by means of laparoscopic bypass. We did 3 total superior mesenteric artery laparoscopic bypasses during laparoscopic AIOD reconstructions and think it would be possible during AAA repair. Occlusive lesions of the renal arteries could also be treated with laparoscopic bypass. Our laparoscopic approach is adequate for laparoscopic bypass to the left renal artery, but we did not do it during aortic reconstructions. For associated lesions of the right renal artery, a minilaparotomy would be preferable.

On the basis of the results obtained in this short series, we think that total laparoscopic AAA repair is feasible and worthwhile for patients. Despite these encouraging results, a greater experience and further evaluation are required to ensure the real benefit of this technique compared with open AAA repair. We strongly want to underline the importance of training in videoscopic sutures to obtain the required level of expertise for laparoscopic anastomoses. Prior experience with laparoscopic AIOD reconstructions is essential before performing total laparoscopic AAA repair. The learning curve is also important, and we observed changes in laparoscopic surgical skills after 15 laparoscopic AAA repairs. However, we think that about 50 procedures are necessary to obtain a good level of expertise. Another important requirement is the development of laparoscopic instruments designed for vascular surgery, especially needle holders with strength jaws and efficient suction devices. Under these conditions, laparoscopy will enter the field of minimally invasive techniques for AAA repair. The main advantage of laparoscopy compared with endovascular procedures is the performance of the criterion standard endoaneurysmorrhaphy, and we can expect the excellent long-term results of conventional AAA repair.

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Submitted Feb 1, 2004; accepted Jun 21, 2004.