Robotic Assisted Aorto-femoral Bypass Grafting: Lessons Learned from our Initial Experience

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Objective. The da Vinci™ Surgical System (Intuitive Surgical Inc., Sunnyvale, CA) is a computer-enhanced telemanipulator that may help to overcome some limitations of traditional laparoscopic instruments. This prospective study was performed to assess the safety and feasibility of robotically assisted aorto-femoral bypass grafting (AF).

Methods. Five patients undergoing elective AF were enrolled in this study. In three patients, a laparotomy of 6 cm was first performed, the aorta being exposed using an Omnitrac® retractor. In two patients, aortic dissection was performed with laparoscopy, with the patient in a modified right lateral decubitus position. In all patients, the proximal anastomosis was attempted with the da Vinci™ system by a remote surgeon. The role of the assistant at the patient’s side was limited to exposure, haemostasis and maintaining traction on the running sutures performed by the robot. Six weeks after the operation, all patients underwent a duplex scan of the graft.

Results. Mean operative time was 188 min. Robotically assisted aortic anastomoses were successfully completed in four out of five patients. In these four patients, adequate blood flow was observed within the graft with no need for conversion for haemostasis. In the fifth patient, despite an adequate laparoscopic aortic dissection, the anastomosis was impossible to perform due to external conflicts between the robotic arms. A conversion using conventional suture was successfully performed. No robot-related complications were noted. Six weeks after the operation, the duplex scans demonstrated a graft patency of 100%.

Conclusion. Robotically assisted anastomoses are possible by their unique ability to combine conventional laparoscopic surgery with stereoscopic 3D magnification and ultra-precise suturing techniques due to the flexibility of the robotic-wristed instruments using different motion scaling of surgeon hand movements. In addition, prior training in laparoscopic aortic surgery is not necessary for surgeons to obtain the level required for suturing. Further clinical trials are needed to explore the clinical potential and value of robotically assisted AF.

Key Words: Laparoscopic; Robot; Vascular.

Introduction

Vascular surgical technology has progressively evolved in the direction of minimally invasive procedures for the treatment of aorto-iliac occlusive diseases. According to the TransAtlantic Inter-Society Consensus (TASC[CP1]), endovascular surgery is the treatment of choice for Type A focal lesions and the most currently utilized for type B and C lesions, although evidence of superiority over conventional surgery is still lacking.1 Aorto-femoral grafting is considered to be the gold standard for treatment of diffuse aorto-iliac lesions (type D).2 For this procedure, a 5-year patency of 90% in case of claudication, of 87.5% in case of critical ischemia has been described with combined morbidity/mortality greater than 10%.3 To reduce the surgical trauma, laparoscopic aortic surgery was proposed by Dion in 1993.4 Since then there have been an increasing number of reports describing different techniques of laparoscopic aortic surgery ranging from laparoscopically assisted procedures with minilaparotomy5–7 or with hand port8,9 to totally laparoscopic.10,11

However, the surgeon has to face a large number of technique-related challenges when performing an aorto-prosthetic anastomosis, which is exceedingly difficult to accomplish with the currently available endoscopic instruments and requires a huge amount of training.

The da Vinci™ Surgical System (Intuitive Surgical Inc., Sunnyvale, CA) is a computer-enhanced telemanipulator that may help to overcome some of the limitations of traditional laparoscopic instruments.
This prospective study was performed to assess the safety and feasibility of robotically assisted aortic-femoral bypass grafting (AF).

**Material, Patients and Methods**

Five patients with Type D lesions undergoing elective AF were enrolled in this study. Two patients were hepatitis C positive. Under general anaesthesia the first three patients underwent a 6 cm-midline laparotomy, the aorta being exposed using an Omnitract® retractor. In the final two patients, aortic dissection was performed laparoscopically with the patient in a right lateral decubitus position (see Coggia et al.12). Carbon dioxide pneumoperitoneum was established through a small incision performed on the anterior axillary line at 10 cm below the costal margin. A 10 mm trocar was introduced at this site to allow the introduction of a 30-degree viewing endoscope. Two other trocars were inserted on the anterior axillary line 5 cm above and below the endoscope in order to allow the insertion of grasping forceps and laparoscopic scissors. Two or three other ports were inserted on the linea alba and used for another pair of grasping forceps and the suction device (Fig. 1). The site of aortic cross clamping was dissected as well as the inferior mesenteric artery. The femoral arteries were dissected according to the conventional manner. The conventional prosthesis was inserted through a port. After systemic heparinization, the infrarenal aorta was percutaneously cross-clamped with two laparoscopic clamps (Xomed-MicroFrance, Saint-Aubain le Monial, France).

The da Vinci™ Surgical System (Fig. 2) has already been described and used extensively in minimally invasive procedures across a broad range of disciplines including general surgery,13 gynaecology,14 urology15 and cardiac surgery.16–18 A full range of instruments is provided to support the surgeon while operating. EndoWrist™ technology has a total of seven degrees of freedom, two more at the tip than traditional laparoscopic instruments. Tip articulations mimic the up-and-down and side-to-side flexibility of the human wrist. These articulations extend the surgeon’s minimally invasive surgery capabilities to a new level. Each instrument has a specific surgical mission such as clamping, suturing and tissue manipulation. Quick-release levers speed up instrument changes during surgical procedures.

The proximal anastomoses (four end-to-side and one end-to-end) were attempted with the help of the da Vinci™ (robot) System by a remote surgeon using 4–0 Prolene suture (n = 1) and that was further replaced with CV 4 Gore-Tex sutures (n = 4). Two large needle drivers with EndoWrist™ technology were used, both attached to the robotics arms (Fig. 3). A 20 cm long double-armed suture was fixed at the prosthesis heel with a U-stitch before inserting it through a trocar. The first running suture was started posteriorly then ran to the right side of the arteriotomy. A second suture ran from the left side. Once the anastomosis was completed, both sutures were tied anteriorly. Each limb of the graft was tunnelled into the femoral regions using vascular clamps. The distal femoral anastomoses were performed conventionally. Six weeks after the operation, all patients underwent a duplex scan of the graft.

**Results**

Robotically assisted aortic anastomoses were successfully completed in four out of five patients (three under minilaparotomy, one under total laparoscopy). In these four patients, adequate blood flow was observed within the graft with no need of revision for hemostasis. The mean operative time was 188 minutes, with a mean clamping time of 75 min ± 28 and mean procedural blood loss of 540 ml. One end-to-end and three end-to-side aortic anastomoses were performed. In the three patients with the minilaparotomy, the anastomoses were performed comfortably. In the fourth patient, the entire operation was performed laparoscopically, though a small laparotomy was performed at the end because of a concern of

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**Fig. 1.** Port placement diagram. R, da Vinci™ right arm; C, da Vinci™ Camera; L, da Vinci™ left arm. 1, 2 and 3: laparoscopic ports. P, proximal aortic clamp; D, distal aortic clamp.
moderate bleeding. None of the patients experienced any wound-related complications. Postoperative hospital stay averaged $8 + \frac{1}{2}.4$ days. In the fifth patient, it was impossible to perform the anastomosis due to external conflicts between robotic arms, despite an adequate laparoscopic aortic dissection. A conversion to open laparotomy using conventional techniques was successfully performed. An aortobifemoral bypass was completed. No robot-related complications were noted. However, the patient’s postoperative course was altered by our initial laparoscopic attempt and the long clamping time.

**Fig. 2.** General view of the da Vinci™ surgical system with the surgeon console and the surgical cart. Left insert, magnified 3D display of the operative field; right insert, EndoWrist™ technology gives a total of seven degrees of freedom at the tip of instruments mimicking the up-down and side-to-side flexibility of the human wrist.

**Fig. 3.** View of the surgical cart with the da Vinci™ right and left arms and camera in action with the help of the assistant surgeon.
time (125 min) and developed an ischemic colitis of the left colon. Six weeks after the operation, the duplex scans demonstrated a graft patency of 100%. At a mean follow-up of eight months, all bypasses were patent.

Discussion

Laparoscopic surgery is an emerging method in the field of aortic surgery. The supposed advantages of this approach (the reduction of patient pain and trauma, faster recovery times and lower healthcare costs) remain to be proven by controlled studies. In addition, it is a challenging procedure that falls victim to a difficult learning curve particularly for performing anastomoses. Contrary to GE surgeons, only some European vascular surgeons have minimal laparoscopic skills, thus explaining the time consuming procedures.

On the other hand, robotic surgery transfers well to the laparoscopic surgeon’s natural dexterity and precision. In this study, we described the first cases performed in vascular surgery. We have noticed that robotic surgery helped by the da Vinci System does not require a prior training in laparoscopic surgery to obtain the level required for suturing. Unlike standard laparoscopic surgery where the surgeon’s hand movements are counterintuitive, the da Vinci System provides natural hand–eye coordination, and as a result, removes a significant barrier to learning and performing minimal invasive surgery. In addition, as remote surgery, this technology has potential use in cases involving a high risk of patient-to-professional or professional-to-patient virus transmission.

Robotic, as compared to conventional laparoscopic surgery, has a prohibitive cost and has the same limitations: the absence of tactile feedback on which surgical skill and decision-making are strongly involved. For example, the absence of feedback can be deleterious when manipulating the Prolene sutures. This is the reason there was a move to Gore-Tex sutures, which are much less prone to breakage during grasping. Nevertheless, the robotic system may overcome the absence of touch by enhancing the precision of suturing using the stereoscopic magnification, the ultra flexibility of the robotic-wristed instruments and the stability of the system.

Another fundamental aspect of robotic surgery is its compatibility with space limitations. In one patient, it was found that an external conflict between robotic arms significantly altered the procedure. The cumbersome design of the da Vinci does not allow assistants to access both sides of the surgical table. In addition, the setting up takes 30 min while changing instruments takes 30 s. The instruments can be autoclavable but have only 10 uses. The instruments are attached to fixed arms and can be manipulated by the surgeon sitting at the console. Moving the table may require some complex manoeuvres such setting up the joint release buttons of all three arms. However, the ergonomic environment of the surgeon console should eliminate work-related injuries as it fully supports the body.

In conclusion, this preliminary experiment demonstrates that robotically assisted anastomoses are possible and can minimize some of the difficulties and limitations associated with laparoscopic aortobifemoral by-pass. Precision of surgical technique is a significant advantage. Several problems became evident, such as cumbersome devices, interferences between the robotic arms and poor tactile feedback. Reducing these drawbacks should expand the use of robotic surgery in vascular surgery. However, minimally invasive surgery has now entered a new era by the introduction of the robotic surgery systems, which will offer all the benefits of endoscopic surgery to the patient, while surgeons regain the dexterity they experience in open surgery.

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