Sutureless thoracic aorta to femoral artery bypass with robotic videoendoscopic approach: a fast track procedure

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Abstract

This study was undertaken to determine the feasibility of robotic videoendoscopic thoracic aorta to femoral artery bypass. In six pigs, three ports were inserted in the fourth, eighth and tenth left intercostal spaces. Lung retraction was obtained by insufflating CO₂. The ZEUS robotic surgical system and the AESOP system were used to perform aortic dissection and to position the camera via voice control. A length of 5 cm of descending thoracic aorta was exposed. A 4 mm polytetrafluoroethylene (PTFE) graft was used as conduit. The proximal anastomosis was constructed using a prototype of sutureless aortic connector. Left femoral artery was exposed and an endograsp was passed to create a retroperitoneal tunnel. The prosthesis was then anastomosed to the left femoral artery. CO₂ insufflating pressure was 9 ± 1 mmHg. The operation was completed in three animals while the other three died. In two animals, the death was due to aortic injury during aortic exposure and in one complications of anesthesia. Total operative time was 48 ± 15 min. Robotic videoendoscopic descending thoracic aorta to femoral artery bypass is a technically feasible operation in a pig model. The use of the sutureless device to perform the proximal anastomosis dramatically reduces the technical demand of this procedure.

Keywords: Occlusive aortic disease; Sutureless anastomosis; Robotic surgery; Endoscopy

1. Introduction

The surgical approach to occlusive aorto-iliac disease requires transabdominal or retroperitoneal exposure of the abdominal aorta. These procedures have established efficacy and are associated with low mortality and morbidity in well-selected patients [1]. Recent reports describe the performance of ‘laparoscopic aorto-iliac’ or ‘aorto-femoral’ bypass, but the enthusiasm for these procedures has been limited by a number of technical difficulties. Both the transabdominal and the retroperitoneal approaches to laparoscopic vascular surgery present technical difficulties with bowel retraction, or by maintaining pneumoperitoneum while suctioning the operative field. Moreover, laparoscopic procedures are contraindicated in patients with multiple, previous abdominal operations [2–5]. Many of these technical limitations may be avoided if the aorto-femoral bypass originates from the descending thoracic aorta as demonstrated in two studies reported by Hill [6] and Noel [7]. The thoracoscopic approach to the aorta has the advantages of easy aortic dissection, excellent graft inflow and improved aortic exposure without need for insufflations [7]. The thoracoscopic approach presents some technical limitations, indeed. The need of aortic cross- or side clamp, the fact that constructing a vascular anastomosis with endoscopic technique is a technically highly demanding procedure and the duration of this procedure are all factors reducing the diffusion of this surgical technique. The introduction of robotic technology and the use of sutureless anastomotic device could solve those problems and this experimental study has been designed to verify this hypothesis.

2. Methods

Six pigs underwent acute study on general anesthesia and mechanical ventilation through single lumen endotracheal tube. With the animals in ventral decubitus, two 5 mm dissecting ports were inserted in the fourth and tenth left
intercostal spaces 2 cm posterior the scapula angle line. The 10 mm camera port was placed in the eighth left intercostal space on the scapula angle line (Fig. 1). Lung retraction was obtained insufflating CO2 in the left chest with measurement of the insufflation pressure. The ZEUS robotic surgical system and the AESOP system (Computer Motion Inc., Goleta, California) were used to perform aortic dissection and to position the camera via voice control. The posterior parietal pleura was opened, hemiazygos vein divided and a length of 5 cm of descending thoracic aorta were exposed with regard to seventh and eighth vertebral body (Fig. 2). A 4 mm polytetrafluoroethylene (PTFE) graft was used as conduit. The proximal side-to-end anastomosis was constructed using a sutureless anastomotic device inserted through the camera port incision. We used a design iteration of the CorLink device (Cardiovation, Ethicon Inc.), an automated aortic connector [8]. The synthetic graft was mounted onto a nickel–titanium connector coupled with an aortic punch. The aortic punch made the aortotomy and sealed it while the pre-mounted graft was inserted in the descending thoracic aorta. The anastomosis was done in a few seconds, without clamping the aorta. Inflow was generically assessed removing the clamp on the conduit. A 5 cm incision was done in the left groin to expose the femoral artery and an endograsp was passed behind the left kidney, into the posterior thoracic attachments of the diaphragm to create a retroperitoneal tunnel. The prosthesis was then end-to-side anastomosed to the left femoral artery with a running 5-0 polypropylene suture. An intravascular ultrasound (IVUS) was performed to evaluate the proximal anastomosis by inserting a probe Sonicath UltraTM 3.2 through the left femoral artery (Fig. 3). Values were expressed as mean ± standard deviation.

3. Results

CO2 insufflating mean pressure was 9 ± 1 mmHg. Mean total operative duration was 48 ± 15 min. The operation was successfully completed in 3/6 animals. Three animals died before the end of the surgical procedure (mortality = 50%). In two animals, the death was due to aortic injury during aortic exposure and in one, complications of anesthesia. There were no bleeding complications associated with the construction of the sutureless anastomosis.

4. Discussion

Other authors have already reported the advantages of the thoracoscopic approach to the aorta as an alternative way to solve the occlusive aorto-iliac disease [6,7]. In this study, we have introduced two new concepts that could potentially improve the surgical technique: the use of robotic instrumentation and voice-controlled camera guidance to prepare the descending thoracic aorta and the use of a sutureless device to construct a vascular anastomosis.

One of the main problems of the endoscopic procedures resides in the limitation of vertical, horizontal, rotational and grasping movements. Many studies in the domain of minimal invasive cardiac surgery have demonstrated that computer-assisted systems like ‘ZEUS’ [9] and ‘Da Vinci’ [10] can duplicate the degrees of freedom obtained with the use of a standard endoscopic instruments controlled by the surgeon’s hands. In addition, natural tremor is completely filtered and the instrument movements are scaled for a better surgeon ergonomics. As all new surgical procedures, this technique requires a learning curve. We lost two animals (33%) due to aortic injury during the aortic preparation before learning how to safely handle the instruments. On completion of the learning curve, robotic control of endoscopic instruments really improves the surgical dexterity.

The second limiting factor of the videoendoscopic thoracic aorta to femoral artery bypass is the proximal

Fig. 1. Animal in ventral position. Ports are inserted in the fourth, eighth and tenth intercostals spaces. Note the robot’s arms position with respect to the animal: the camera arm is on the right animal side while both the instrument arms are on the left in order to reduce the risk of arms conflict.
anastomosis construction. The construction of a vascular anastomosis using endoscopic technique is highly technically demanding and limited to a few skilled surgeons. The difficulty results in long operative duration and occasionally significant blood loss as reported by several authors: Noel had a mean anastomotic duration of 57 min and mean operative duration of 310 min; Hill reported a mean anastomotic duration of 80 min and a mean operative duration of 280 min. Moreover, this technique requires aortic cross-clamp which could cause paraplegia, renal failure, mesenteric ischemia and the possibility of distal emboli [8].

Sutureless anastomosis is an old concept. Payr and other authors have described several non-suture techniques to construct a vascular anastomosis since 1900 [11]. Those techniques have not reached clinical success mostly because of technical and engineering limitations. In the last 5 years, the use of metal alloys with thermal memory, coupled with new construction technologies, led to the development of sutureless devices mostly used in cardiac surgery [12–14]. The ideal anastomotic device has to provide minimal graft manipulation, optimal intima-to-intima apposition, minimal amount of prosthetic material in the vessel lumen, optimal anastomotic angle and, above all, evidence of long-term effectiveness. In this study, we used a prototype of an automated anastomotic device. The synthetic graft is mounted onto a nickel–titanium connector coupled with the aortic punch. The anastomosis is performed in a few seconds, without clamping the aorta. We believe that this way of constructing the aortic anastomosis has several advantages: it reduces the technical demand and the individual surgical dexterity as determinant factor for anastomosis outcome; it avoids aortic cross-clamp and it makes the procedure quicker than standard endoscopic techniques. Even if the duration of a surgical procedure is not of primary importance, a mean operative time of 48 min to treat the abdominal aorta occlusive disease could represent an important step forward in the development of a fast track vascular procedure.

However, this is a preliminary study and we are still far from the clinical application of this technique. There are at least two limitations: there is still no evidence of long-term effectiveness of the sutureless anastomosis device and the reproducibility in patients of this surgical technique has to be proved. Moreover, a femoro-femoral cross-over graft, necessary to provide a complete revascularization of the lower limbs, has to be added and the costs of all new

**Fig. 2.** A length of 5 cm of descending thoracic aorta were exposed using robotic assisted videoendoscopic technique.

**Fig. 3.** IVUS of the descending thoracic aorta at the sutureless anastomosis level. Metallic struts and the prosthetic conduit appear on the left side.
technologies, we used to achieve these results, could affect the wide acceptance of this fast track procedure.

5. Conclusions

Robotic videoendoscopic descending thoracic aorta to femoral artery bypass is a technically feasible operation in a pig model. Robotic control of endoscopic instruments can enhance the surgical dexterity and allow quick and excellent exposure of the entire descending thoracic aorta. The use of the sutureless device, to perform the proximal anastomosis, allows avoidance of aortic clamp, to reduce the technical demand and the duration of this procedure. Cost and absence of long-term effectiveness of sutureless anastomotic device could be the limiting factors for its clinical application.

References