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CASE REPORT

Robotic renal transplantation: first European case

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Summary

A kidney from a 56-year-old mother was transplanted to her 37-year-old daughter laparoscopically using the daVinci HDSi surgical system. The kidney was introduced into the abdomen through a 7-cm suprapubic incision used also for the uretero-vescical anastomosis. Vascular anastomoses were carried out through a total of three additional ports. Surgery lasted 154 min, including 51 min of warm ischemia of the graft. Urine production started immediately after graft reperfusion. Renal function remains optimal at the longest follow-up of 3 months. The technique employed in this case is discussed in comparison with the only other two contemporary experiences, both from the USA. Furthermore, possible advantages and disadvantages of robotics in kidney transplantation are discussed extensively. We conclude that the daVinci surgical system allows the performance of kidney transplantation under optimal operative conditions. Further experience is needed, but it is likely that solid organ transplantation will not remain immune to robotics.

Introduction

The technique for kidney transplantation (KT) has evolved little since 1950s [1]. Rosales *et al.* recently reported on a patient undergoing successful laparoscopic KT [2]. Although this case report shows that a kidney can be transplanted laparoscopically, it does not demonstrate that this operation can be reliably duplicated by the average transplant surgeon. Laparoscopy is indeed used infrequently in operations requiring multiple vascular anastomosis because of loss of hand–eye coordination, use of long instruments amplifying natural surgeon's tremor and carrying a fulcrum effect, and poor ergonomy causing surgeon's fatigue [3].

The daVinci™ surgical system (dVss) (Intuitive Surgical®, Sunnyvale, CA, USA) is a computer-assisted electromechanical device acting as a remote telepresence manipulator controlled by a surgeon [4]. The dVss provides the operating surgeon with 3D high-definition view including 10× to 15× magnification, fully restoring hand–eye coordination; it employs wristed instruments, with seven degrees of freedom, and it tracks surgeon's movements 1300 times/s, providing for tremor filtration and scaled motion. Furthermore, the surgeon simultaneously drives the binocular endoscope, achieving steady view, and toggles between three operative arms [5]. These features translate into significant operative advantage, especially when the operative field is deep and narrow, and when fine dissection and microsuturing are required [5]. The dVss is currently used in urology, for radical prostatectomy, pyeloplasty, and ureteral reimplantation [4], as well as in vascular surgery for coronary artery by-pass [6], repair of renal artery aneurysm [3], and repair of abdominal aorta [7]. Thus, it would seem that the dVss could facilitate the implementation of laparoscopy in KT.

We herein report what we believe to be the first European case of robotic KT, present the technique we have employed, and discuss the pros and cons of the use of this new technology in KT.

Case report

The recipient was a 37-year-old Caucasian woman on dialysis since 32 months because of lupus nephritis. She was 164 cm tall and weighed 59 kg. Her surgical history included hysterectomy, performed through a Pfannenstiel incision. On July 3, 2010 she received a left kidney from her mother, a 56-year-old woman. The graft had no vascular or urologic variations and was procured laparoscopically. It was perfused with cold Celsior solution and was transplanted after 58 min of cold storage.

Surgical technique

The patient was positioned supine, with the right flank slightly elevated, and was secured to the operating table using wide bandings (Fig. 1a). The table was then tilted 25° to the left, further elevating the right flank, and 15° in Trendelenburg's position. A 7-cm suprapubic incision was made along the previous Pfannenstiel incision where a hand access device was inserted (Lap Disc; Ethicon spa, Pomezia, Italy). Through a 12-mm port, placed within the lap disk, pneumoperitoneum was created at a pressure of 12 mmHg. Under laparoscopic view, an 11 mm port, to be used for the endoscope, was placed slightly to the left of the mid-line and some centimeters below the navel, and an 8 mm robotic port was placed along the right pararectal line some 5 cm below the costal margin. A final port (12 mm), to be used by the assistant surgeon at the table, was placed along the left pararectal line halfway between the Pfannenstiel incision and the camera port (Fig. 1b). The dVss, placed to the patient's right side, was docked into position (Fig. 1c) and a 0° endoscope was advanced through the 11 mm port. Two operating arms were used. The distal robotic arm operated through a port placed within the suprapubic lap disk.

The operation began by mobilizing the cecum until the common iliac vessels were exposed (Fig. 2a). Lymphatics were individually ligated and cut. Dissection was carried out using either bipolar Maryland forceps or micro bipolar forceps on the left robotic arm, and monopolar curved scissors on the right robotic arm (Fig. 3). Iliac vessels were then crossclamped using laparoscopic bulldogs and the kidney was pushed into the abdomen through the Pfannenstiel incision and dragged over the right psoas muscle using a Cadiere forceps. The left robotic arm was re-docked and armed with DeBackey forceps and the

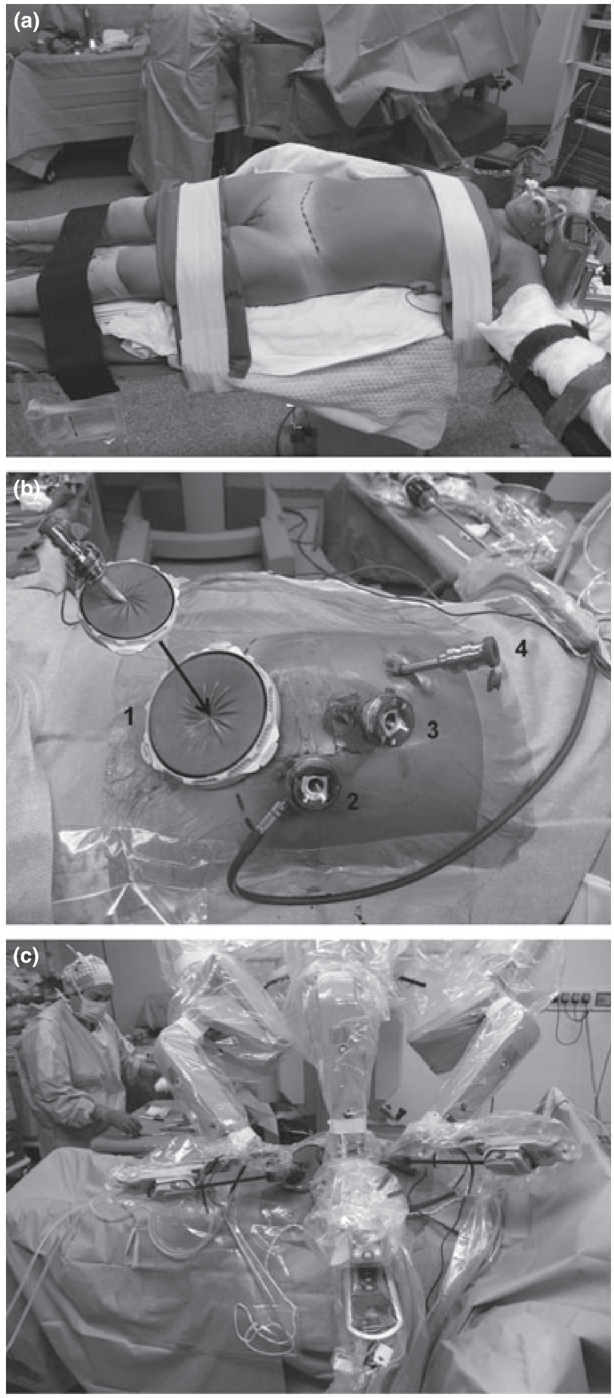

Figure 1 (a) Operative position. Dotted line marks the previous Pfannienstel incision. (b) Lap disk and operative ports in place. Port number 2 is used by the assistant surgeon at the table. Port number 3 is used for the optics. Port number 4 is used for the right robotic arm. While the daVinci^{TM} surgical system (dVss) is functioning a further port, used for the left robotic arm, is held in place by the Lap Disk (see superimposed image and arrow). (c) dVss docked in the operative position.

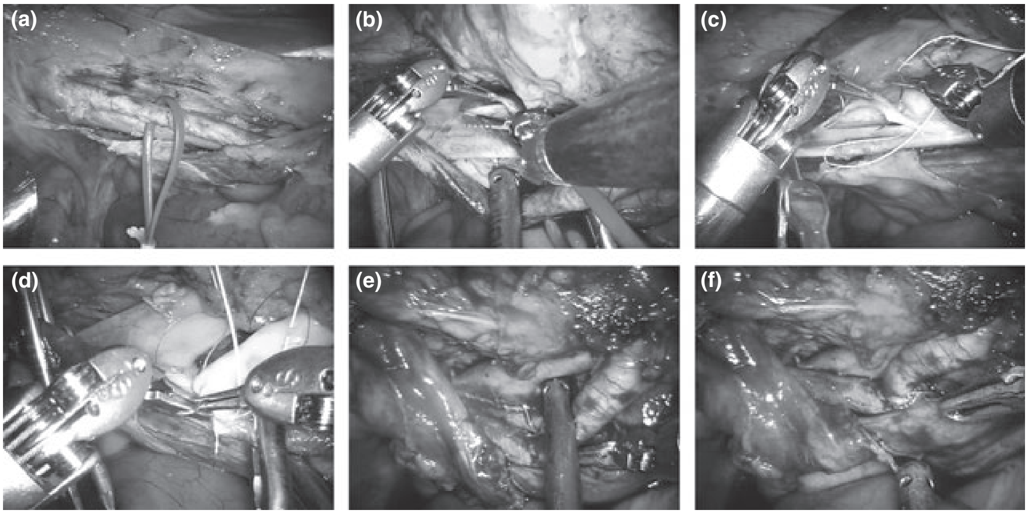

Figure 2 (a) Common iliac vessels exposed; (b) Venotomy being made using Potts scissors; (c) Venous being made using black diamond micro forceps and De Backey forceps; (d) Arterial being made using black diamond forceps and De Backey forceps; (e) Venous anastomosis after graft reperfusion; (f) Arterial anastomosis after graft reperfusion.

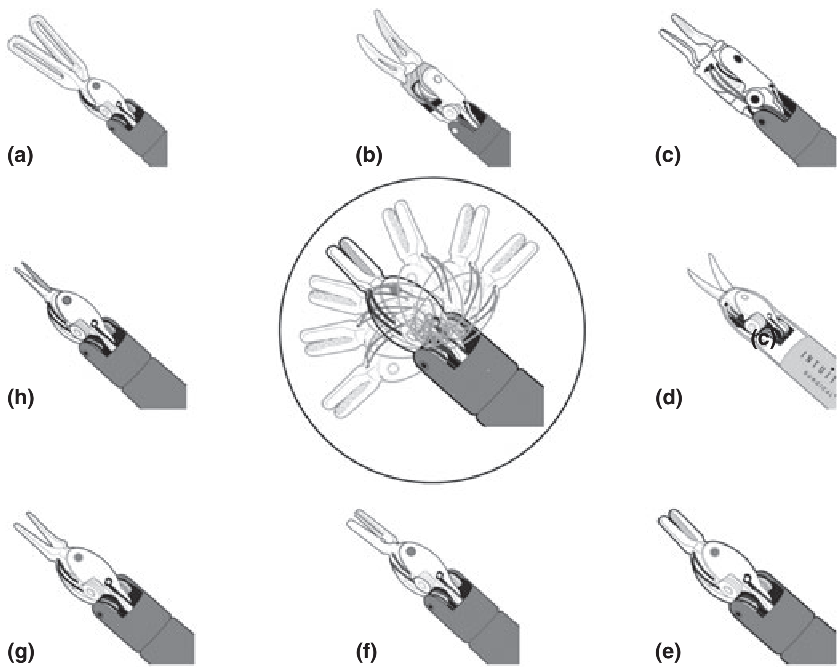

Figure 3 Drawing depicting the full set of robotic instruments used for kidney transplantation. The central drawing, within the circle, shows the range of motion of wristed robotic instruments. (a) Cadiere forceps, (b) fenestrated Maryland bipolar forceps, (c) micro bipolar forceps, (d) monopolar curved scissors, (e) large needle driver, (f) black diamond micro forceps, (g) De Backey forceps, (h) Potts scissors.

right-one with Potts scissors. After creating a venotomy (Fig. 2b), the renal vein was anastomosed end-to-side to the common iliac vein using two half running sutures of 6–0 expanded polytetrafluoroethylene (ePTFE) using black diamond micro forceps on the right robotic arm and DeBackey forceps on the left-one (Fig. 2c). The same steps were followed to create an end-to-side arterial anastomosis between the renal artery and the common iliac artery (Fig. 2d). After removal of laparoscopic bulldogs, kidney revascularization was prompt and homogeneous. No bleeding was noted, no additional stitches were placed (Fig. 2e and f), and urine production started immediately.

Warm ischemia time was 51 min. The uretero-vesical anastomosis was fashioned through the suprapubic incision using standard technique (Gregoir-Lich extravesical anastomosis). Before closure of the Pfannenstiel incision, the graft was covered by cecum and pelvic peritoneum thus making it a retroperitoneal graft. Total operative time was 154 min.

Postoperative course

Postoperative course was uneventful and the kidney functioned immediately. Serum creatinine reached 1.4 mg/dl (normal value 0.5–0.9) on postoperative day 10. The day after the transplant, the patient was mobilized and started on oral intake. Pain was described as minimal, and no analgesic was required beyond 48 h after surgery. The patient was discharged on postoperative day 10. At the longest follow-up of 3 months, she has not been readmitted and her renal function remains optimal (serum creatinine 1.4 mg/dl).

Discussion

Surgical robotics is a refinement of classic laparoscopy. The only current available system, the dVss, is not a classical robot, in the narrower sense of the word, but rather an electromechanical surgical actuator faithfully translating movements of surgeon's hands into wristed instrument actions [4]. As such, the dVss should enhance surgeon's ability to accomplish complex laparoscopic operations requiring fine dissection and microsuturing.

On the other hand, the greatest limitations of the dVss are high cost and lack of haptic feed-back. Other drawbacks are risk of technical failure, loss of direct contact between surgeon and patient, and poor adaptability to multiquadrant surgery [4].

The high cost of the dVss is a significant problem that has probably limited the diffusion of this new technology. However, like other computer-driven technologies, costs are expected to drop over time, especially when the patent of ''remote center-of-motion robot for surgery'' (US patent number: 5397323; Issue date: March 14, 1995) will expire (on October 30, 2012) and competitors of Intuitive Surgical will have a chance to propose alternative systems.

Lack of haptic feed-back is a further main drawback of current dVss. Theoretically, it could lead to an increased risk of inadvertent tissue injury but, to date, robotically performed operations have not been associated with higher clinical complication rates than their standard laparoscopic or open counterparts [4]. On the other hand, reduction in suture strength is known to occur following robotic needle driver manipulation [8,9]. While research on haptic sensors is ongoing [10–12], improved visual clues seem to act as a substitute for haptic feedback [12,13].

No device or technology is impervious to malfunction. The dVss is no exception to this rule. Current systems, however, are designed to minimize the deleterious effects of such failures on patients thanks to system redundancy features [4]. The dVss can incur into recoverable and nonrecoverable faults. Only in the latter instance, the robotic procedure has to be aborted and/or there may be a real hazard on patient safety. In a series of 725 radical prostatectomies, the mean rate of recoverable and nonrecoverable faults per procedure was 0.21 and 0.05, respectively. Interestingly, all nonrecoverable faults occurred before the beginning of the operation resulting in rescheduling of surgery [14].

Loss of direct contact between surgeon and patient requires adaptation and improved coordination with the assistant surgeon who, instead, maintains a direct contact with the patient. This process requires a learning curve. Paradoxically, this limitation of current dVss may also have positive implications. Lack of direct interaction between surgeon and patient could reduce the risk of disease transmission, especially in KT recipients in whom there is a high prevalence of hepatitis infection.

Overall, it would seem that the dVss could be used for KT under well-controlled, investigational conditions. The first use of the dVss for KT was reported by Hoznek *et al.* in 2002. Iliac vessels, however, were dissected through a standard oblique incision and the dVss was used only to complete the anastomoses [15].

The first fully laparoscopic KT using a dVss was reported by Giulianotti *et al.* (Chicago, IL, USA), early this year [16], although the first world case was performed by Geffner at the Saint Barnabas Medical Center (New Jersey, USA) in January 2009 (unpublished data). As of June 25, 2010, a total of 25 robotic KT had been performed in the USA, eight at the University of Illinois and 16 at Saint Barnabas Medical Center (5th International Conference: ''Living donor abdominal organ transplantation: state of the art.'' June 25–26, 2010; Florence, Italy); to our knowledge, the case described herein is the first performed in Europe.

The technique that we have presented differs substantially from that used in Chicago [16] and New Jersey.

At the University of Illinois, Giulianotti *et al.* decided to adopt a hand-assisted technique making the incision in the periumbelical area and placing the graft intraperitoneally [16].

Regarding the site of incision, a periumbelical incision is known to carry a higher risk of incisional hernia as compared with the bikini type incision we have adopted. Furthermore, a suprapubic incision allows direct performance of uretero-vescical anastomosis. Although this anastomosis can easily be constructed using the dVss, it requires repositioning of the robot [16] and prolongs the period during which the freshly revascularized graft is exposed to the detrimental effects of pneumoperitoneum [17]. Hand assistance, easier through a periumbelical incision, could facilitate some operative steps, such as handling the graft during performance of vascular anastomoses, could improve exposure especially in obese recipient, and could be useful in case of sudden hemorrhage. However, with all the limitations of comparisons made between single case descriptions, our warm ischemia period was identical to the one reported by the Chicago group. Further experience will clarify which incision is more suitable. Perhaps, the periumbelical incision will eventually be preferred in obese patients and the suprapubic incision be reserved to thinner recipients.

Giulianotti *et al.* decided to place their kidney graft intraperitoneally. Although grafts placed in this location are known to work efficiently, this option is not routinely adopted in conventional KT. Intraperitoneal renal graft placement may actually be associated with unique complications, such as paratransplant hernia [18] and renal pedicle torsion [19].

The technique used at the Saint Barnabas Medical Center has not been published yet, but we have learned of it directly from Dr. Geffner at the 5th International Conference: "Living donor abdominal organ transplantation: state of the art." (June 25–26, 2010; Florence, Italy). Dr. Geffner places the kidney graft extraperitoneally, through a small incision made along the line that would be followed in case of conventional KT. A working space is hence created, using the same technique employed in retroperitoneoscopic nephrectomy, and the anastomoses are performed robotically. At the end, the graft lies in the classic retroperitoneal location.

The technique that we have adopted, which might be identified as "hybrid", employs a transperitoneal approach, but eventually leaves the graft in the retroperitoneum. In our view, working transperitoneally avoids the traditional disadvantages of retroperitoneoscopy, such as limited working space, ease collapse during suction, and blurred vision, while maintaining the advantage of eventual graft placement in a retroperitoneal pocket. The most prominent advantage of Geffner's incision is that in case of conversion to open surgery, there would be no additional incision. Of course, the periumbelical incision used by Giulianotti *et al.* [16] should be extended significantly to gain full access to iliac vessels. Prolonging our small transverse suprapubic incision, toward the iliac fossa where the kidney is being transplanted, would result in a "hockey stick" incision, probably only a bit larger than the one performed under standard conditions.

Minimally invasive KT might require more time to complete vascular anastomoses thus prolonging second warm ischemia time and possibly resulting in higher incidence of delayed graft function [20]. It is indeed known that kidney temperature increases according to a logarithmic curve and at a speed of 0.48 °C/min. Kidney temperature at the time of revascularization depends on anastomotic time and is inversely proportional to kidney weight [21]. A prerevascularization graft temperature ≤15 °C is associated with reduced incidence of acute tubular necrosis [20]. Topical graft cooling may slow the rate of graft rewarming [20], but is impractical to use during laparoscopic KT, as cold irrigation would blur the vision of the vessels to be anastomosed and would require concurrent suction, decreasing the level of pneumoperitoneum. The use of a cooling pocket [22,23] might be advantageous. However, the ideal laparoscopic cooling pocket should be friendly to use. To our knowledge, none of the described laparoscopic devices [24,25] has been tested enough as to prove its efficacy and ease of use. On the other hand, the yet limited experience with KT through minimal skin incision [26–28], sharing with laparoscopic KT the issue of graft rewarming, do not demonstrate a detrimental effect on kidney function. Our decision to avoid additional renal graft cooling during robotic transplantation was based on all these considerations. The consequences of progressive graft rewarming occurring during minimally invasive KT cannot be defined at the moment. We anticipate that this issue will be debated extensively and will provide new impetus to research.

In conclusion, our experience confirms that KT can be performed laparoscopically in selected recipients and under optimal operative conditions. Overall, including our case, there have been only three descriptions of laparoscopic KT. It is likely that these embryonic experiences will foster a debate in the transplant community.

Authorship

UB: conceived the operation, performed the operation, coordinated the surgical team, wrote the manuscript, and prepared the figures. FV: obtained informed consent from donor and recipient, participated in operative planning, carried out postoperative care and follow-up. SS: provided significant contribution to operative planning. SD: collected, operative and postoperative data, obtained intraoperative pictures. GA: conducted anesthesia in donor and recipient, in cooperation with GC. GC: conducted anesthesia in donor and recipient, in cooperation with GA. FG: coordinates anesthesia team, specifically dedicated to robotic activities at Pisa University Hospital. FM: coordinates robotic activities at Pisa University

Hospital, made the system available for dry training. AM: houses the daVinci surgical system in the Department he heads, made the system available for dry training. FM: counseled in planning the operation.

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