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Overcoming the learning curve in hand-assisted laparoscopic live donor nephrectomy – a study in the animal model

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The demand for kidneys in South Africa is staggering. Only 38% of the kidney transplants done in 2008 were from related living donors. Laparoscopic living donor nephrectomy has been shown to have the advantages of decreased postoperative pain, better cosmesis and a quicker return to work when compared with the open technique. With limited surgical expertise, a realistic model was needed to overcome the learning curve.

Methods. A total of 21 nephrectomies were performed on 12 pigs. The transperitoneal hand-assisted laparoscopic technique was used.

Results. The median operative time was 75 minutes and the median warm ischaemic time 88 seconds. Three cases were aborted owing to major vascular injuries.

Discussion. The advent of laparoscopic techniques has been associated with an increase in morbidity and complications in donor and recipient during the initial learning curve. We found that with our porcine model, 21 nephrectomies were adequate in overcoming the learning curve. After 15 nephrectomies no complications were noted.

The demand for kidneys in South Africa is staggering. The total number of kidney transplants in 2008 was 236.[1] Only 38% of those kidneys were from related living donors; the remainder were cadaver kidneys.[1] Despite increased media awareness and other campaigns, the public remains sceptical regarding the concept of living related kidney donation. Since the first laparoscopic live donor nephrectomy (LLDN), described in 1995 by Ratner *et al.*,[2] laparoscopic retrieval has been widely applied internationally for the procurement of related living donor kidneys.

Numerous studies have been done comparing laparoscopic versus open techniques. Reasons supporting a trend towards LLDN include a decreased need for analgesia, shorter hospital stay, better cosmesis and a quicker return to work.[3-5] With the introduction of LLDN, questions arose about the efficacy and safety of the procedure. Warm ischaemic time was shown to be longer than for conventional laparoscopic techniques;[6,7] however, with the hand-assisted laparoscopic technique warm ischaemic time is comparable to that for open live donor nephrectomy (LDN). Effect on early graft function is controversial, some studies demonstrating worse early graft function with the laparoscopic procedure than with open LDN,[8] and others showing no difference. There is, however, no difference between the two techniques with regard to long-term graft function and graft survival.[4,6]

There remains a large demand for related living donors, and the attractiveness of LLDN increases public acceptance and ease of donating kidneys.[9] In units where the laparoscopic technique is well established, new trainees are taught using human subjects, under the direct supervision of appropriately trained surgeons. However, in units without this experience an alternative method of training is required. Two studies, one using a canine model and the other a porcine model, have described the efficacy of this method.[10,11] Our model has been designed to use human-size, anaesthetised pigs with which to mirror the human setup, with a view to achieve competence in a new procedure in the absence of adequate supervision. The aim of the study was to overcome the learning curve by applying laparoscopic hand-assisted LDN (HALDN) to a realistic model and to determine the effectiveness of exposure to 24 nephrectomies. This model was also intended to assist surgical staff with equipment and patient set-up. Secondary outcomes included dissection time, warm ischaemic time, blood loss and complications. A study protocol was designed and submitted for approval to the Research Review Board for Animal Ethics at the University of the Witwatersrand.

Methods and materials

Anaesthesia

Twelve pigs of appropriate weight were selected for the study. They were only considered once malignant hyperthermia had been excluded. Anaesthesia included gas induction, endotracheal intubation and maintenance with halothane. Intra-operatively a non-depolarising muscle relaxant was used and appropriate analgesia (opiates) administered. Antimicrobial prophylaxis is to be used in the human subject (not done in the porcine model). After completion of surgery each pig was euthanased.

Surgery was performed by experienced laparoscopic surgeons.

Positioning and preparation

The porcine model is positioned at a 45° angle in the lateral decubitus position, with lateral flexion to allow for maximal exposure. In the human subject placement of a pillow between the knees and prevention of traction to the arms are vital. Furthermore, a nasogastric tube and urinary catheter are inserted (not done on the porcine subject). The reverse Trendelenburg position is required during dissection.

Right nephrectomy

Access is transperitoneal. A midline incision is made, centered on the umbilicus. The exact position of the incision depends on the surgeon, some preferring to make the incision entirely above the umbilicus. Length of the incision is roughly equal to the glove size. The next step is to insert the intra-abdominal ring of a GelPort hand-access device (Applied Medical, CA, USA), making sure there is no bowel caught between the ring and the anterior abdominal wall. The GelPort device should have a snug fit. The external ring of the device is rolled down sufficiently tight to prevent any gas leak (Fig. 1). Once the device is inserted, a 10 mm port is inserted for the introduction of a 10 mm camera. Furthermore a 12 mm port is introduced which provides primary access for dissection and for insertion of the vascular stapling device for division of the hilar vessels. A 5 mm port is sometimes required for the retraction of the right lobe of the liver superiorly. Ports are placed blindly into the cup of the hand within the abdomen or can be placed under visual guidance with the camera through the GelPort device. The inferior vena cava (IVC) is identified infra-renally and the peritoneum opened. The peritoneum is further divided superiorly, exposing the junction of the renal vein with the IVC. Note there is a lymph node anterior to the vein bilaterally that needs to be dissected carefully because it has a tendency to bleed (this node seems to be specific to the porcine model). The renal artery and vein are dissected out as much as possible anteriorly before medial rotation of the kidney (loss of the lateral renal attachments makes further anterior hilar dissection difficult). The hilum is cleared completely ensuring adequate length of renal artery posterior to the IVC (Fig. 2).

It is important to ensure that the position of the vascular stapler across the renal vein and artery is checked before definitive action, i.e. ligation of the vessels. After the kidney has been removed and perfused the vascular bed is re-examined for haemostasis.

Left nephrectomy

Access is the same as for the right-hand side (Figs 1 and 3). There is no need for the 5 mm port, as splenic retraction is seldom required. The aorta is localised with digital palpation at its infra-renal extent and the peritoneum opened. The peritoneal incision is extended superiorly, exposing the junction between the renal artery and aorta and the renal vein. The renal vein is dissected, taking care of numerous venous tributaries including the gonadal, more than one adrenal and the lumbar veins. These need to be defined and divided, preferably using a Ligasure device (Valleylab, Colorado, USA). If the renal vein/IVC junction is not immediately apparent, it is safer to follow the gonadal vein superiorly to its junction with the renal vein. As on the right side, the hilum is cleared completely.

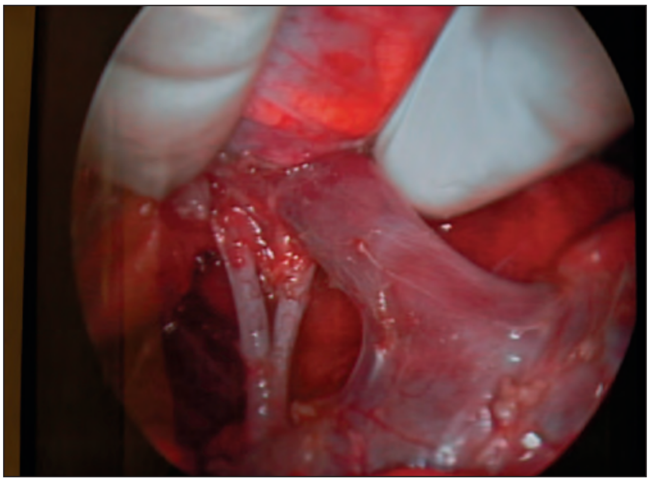

Fig. 2. Complete dissection of the hilar vessels during nephrectomy in the porcine model.

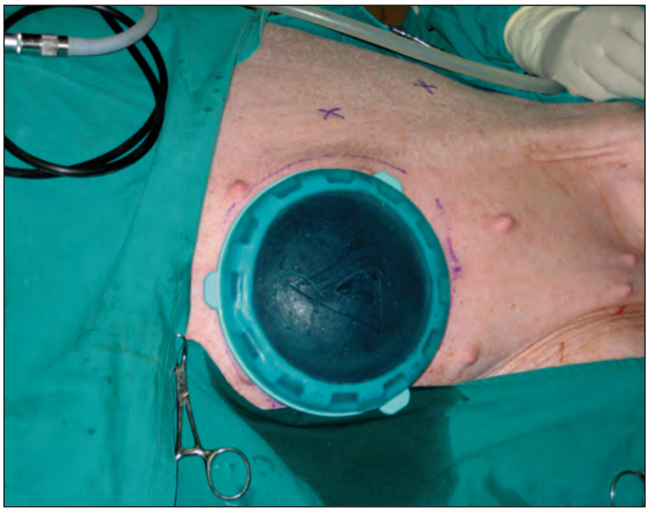

Fig. 1. Insertion of GelPort, showing the position of the device in the porcine model.

Fig. 3. Positioning of the 10 and 12 mm ports during a left-sided nephrectomy in the porcine model.

Results

A total of 21 out of 24 possible nephrectomies were performed; 3 were aborted due to major hilar injuries, which necessitated conversion to open surgery. The median weight of the pig models was 39.9 kg, ranging from 31.3 to 55 kg. Mean blood loss was 72 ml, with excessive blood loss during 2 procedures (Fig. 4 and Table I). In most cases there was less than 30 ml of blood loss, but 500 ml of blood was lost in 1 case due to an injury to the renal vein and in another 600 ml was lost due to a splenic injury. The warm ischaemic times were mostly under 120 seconds (Fig. 5). Prolonged warm ischaemic times were the result of equipment malfunction, particularly a stapler and clip applicator malfunction. Dissection times were mostly clustered between 70 and 80 minutes (median 75 minutes, Fig. 6 and Table I). Excessive dissection times resulted from excessive bowel distention, pneumoperitoneal leak (1 case) and equipment malfunction, as mentioned above.

Discussion

With the advent of LLDN, increased morbidity in both donor and recipient during the initial learning curve has been reported.[12] Concerns about LLDN, which include early graft failure (from vascular thrombosis) and surgical complications (related to transplanted ureter), have been alleviated with technical modifications of the procedure and increased experience with this new operation by overcoming the learning curve. It has been suggested that the learning curve for laparoscopic nephrectomies flattens after 37 cases by an experienced endoscopist, i.e. the operative time and incidence of delayed graft function decreases significantly.[13] Some authors have suggested that hand-assisted techniques are quicker and easier to perform, with fewer peri-operative complications. Hand-assisted laparoscopic techniques have been shown to reduce operative time and warm ischaemic time when compared with the traditional laparoscopic technique. Further benefits are facilitation of dissection and easy digital tamponade of bleeding.[15,16]

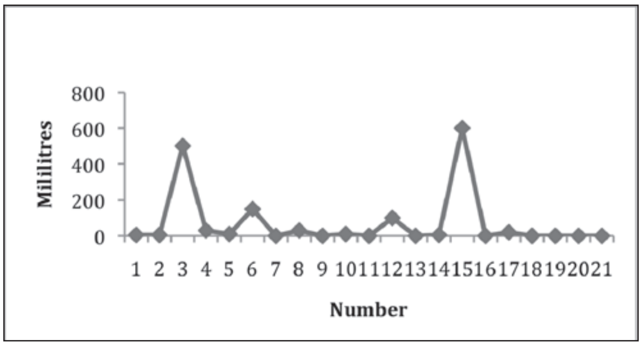

Fig. 4. Blood loss for each case (ml).

TABLE I. RESULTS OF SECONDARY OUTCOMES (MEAN VALUES AND RANGES OF BLOOD LOSS, WARM ISCHAEMIC TIMES AND DISSECTION TIMES)

Outcomes	Mean (range)
Blood loss (ml)	**72 (5 - 600)**
Warm ischaemic time (s)	**115 (62 - 237)**
Dissection time (min)	**79 (32 - 125)**

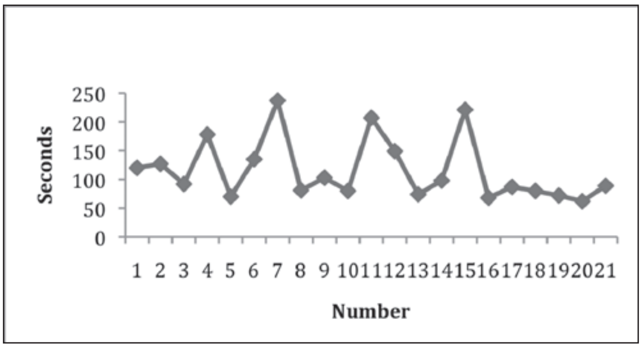

Fig. 5. Warm ischaemic times for all cases (seconds).

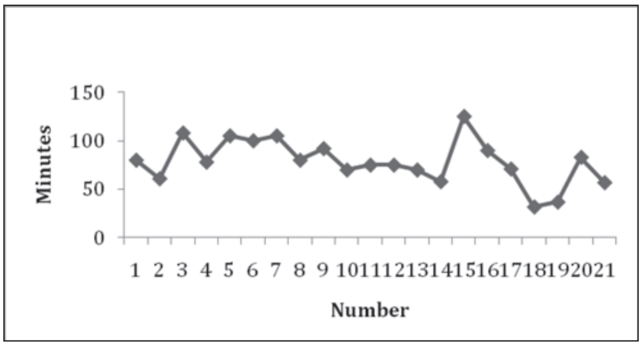

Fig. 6. Dissection times for all cases (minutes).

A swine model for laparoscopic HALDN described the efficacy of training on animal models in reducing the learning curve risks.[14] Our operative time of 79 minutes (range 32 - 125 minutes) was comparable to their operative time of 75.4 minutes (range 52 - 120 minutes); warm ischaemic time however, was not mentioned in their study.[14] Our warm ischaemic time, with a mean of 88 seconds, was below the recognised safe value. Delays in warm ischaemic time and operative time were mainly due to equipment malfunction, which presents difficulty to the beginner. Stapler application to ligate the vessels was more reliable than clips intra-operatively. Increased blood loss was seen in 2 cases due to vascular and splenic injuries. Significant intra-operative bleeding is technically more difficult to control laparoscopically, and all patients should therefore consent to open conversion. We used a trans-peritoneal approach, and with the use of increased intra-peritoneal pressures, aggressive intra-operative volume expansion is required during the procedure with the outcome of improving renal haemodynamics. After the 15th case no further complications were experienced. With a total of 21 nephrectomies, we consider that this is an adequate number to overcome the learning curve; equipment difficulties were surmounted, and no complications were experienced after 15 nephrectomies. Supervision is however initially required when performing this surgery on human subjects.

Many centres have abandoned the open technique for LLDN. The porcine model has provided a means to reach an acceptable level of experience, which is mandatory in performing theses operations.

It is preferable to use a pig model comparable to an adult human in size (at least 70 kg), bearing in mind the growing rate of obesity in the adult population and the fact that obesity can dramatically increase the level of difficulty in the human subject. A larger pig model will mimic the soft-tissue composition and consistency of humans more closely. A study comparing the open with the hand-assisted technique in vivo is required to ascertain the benefit of laparscopic HALDN in our unit.

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