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# Establishment of laparoscopic live donor nephrectomy in a porcine model: techniques and outcomes in 44 pigs

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ABSTRACT

*Background:* Laparoscopic live donor nephrectomy has replaced open donor nephrectomy in most patients due to numerous benefits. A live animal model is required to equip surgeons with the necessary skills to perform such a procedure with minimal risk of complications. The aim of this study was to establish the technique for laparoscopic live donor nephrectomy in a porcine (*Sus scrofa*) model.

*Materials and methods:* This study was approved by the Animal Ethics Committee of the university. Forty-four pigs underwent laparoscopic live donor nephrectomy. The left kidney was removed with a standardized four-port technique, with a small suprapubic incision to facilitate kidney delivery.

*Results:* All 44 procedures were performed successfully, with no intraoperative complications or conversion to open surgery. There was no apparent damage to any of the kidney grafts. The mean surgical time was 118.3 (±20.7) minutes. There was a small, but statistically insignificant, decrease in surgical time throughout the duration of the study. Several subjects had minor variations in the anatomy of the renal vasculature.

*Conclusions:* This series has developed and proven a training model for laparoscopic donor nephrectomy in pigs. This training model will allow surgeons to develop laparoscopic proficiency in a live donor, to be used in conjunction with human cadaveric training.



## Introduction

Laparoscopic live donor nephrectomy has been established as the standard of care. Benefits such as a smaller incision, improved wound cosmesis, lower rates of incisional hernia and adhesion formation, lower morbidity, shorter hospital stay, and a quicker return to work have been demonstrated.[1-4] Concerns regarding a longer operative time and the effects of carbon dioxide insufflation on renal perfusion have not shown a decrease in short-term graft survival compared to a conventional open approach, although a slower decline of serum creatinine after surgery has been reported for laparoscopic nephrectomy.[5,6] Given the altruistic nature of live donor nephrectomy, the selected

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procedure for live donor nephrectomy must have minimal potential for complications.[4]

As with any surgery, adequate training is essential before implementing a new procedure on live patients. The literature suggests that the learning curve to achieve proficiency for live donor nephrectomy requires 35-38 cases.[7,8] The aim of this study is to establish an animal model of laparoscopic live donor nephrectomy, which may facilitate surgical training, for eventual transition to clinical practice. We report herein the surgical technique, operative time, surgical complications, and potential learning curve during laparoscopic nephrectomy, in addition to some of the anatomic variations encountered in the pig model.

## Materials and methods

### *Animals*

The study was approved by the Animal Ethics Committee of the University of Western Australia according to the guidelines of the National Health and Medical Research Council of Australia code of practice for the care and use of animals for scientific purposes.[9] Forty-four live female pigs (*Sus scrofa*) aged between 14 and 16 weeks were acclimatized to the Large Animal Facility of the university for 2 weeks before surgery. Female pigs were used to facilitate urethral catheterization during the surgical procedure. The pigs were housed in raised pens, fed a maintenance diet (Grower; West Feeds Pty Ltd, Australia) and allowed free access to tap water. Forty-four pigs were included in this prospective study. The mean (standard deviation [SD]) weight of the pigs was 50 (7.9) kg. The laparoscopic nephrectomy procedure was performed as the first part of a larger study evaluating the feasibility of laparoscopic kidney transplantation.[10]

### *Anesthesia*

Anesthesia was performed as previously described by an experienced veterinary anesthetist.[11] In brief, after a 12-hour fast, with free access to water, the pigs were anesthetized with a combination of xylazine (2.2 mg/kg, intramuscular (IM)) and tiletamine/zolazepam (4.4 mg/kg, IM) delivered into the trapezius muscle of the neck. Induction of anesthesia was further facilitated with propofol (1 mg/kg) intravenously, if required, via a cannula in an auricular vein. The trachea was intubated using a laryngoscope, with a cuffed endotracheal tube (Portex Soft Seal Cuff, 8.0 mm internal diameter; SIMS Portex Ltd, Hythe, UK), and anesthesia was maintained with isoflurane in 100% oxygen. Mechanical ventilation was commenced immediately after oral intubation of the trachea with tidal volumes of 10-15 mL/kg and peak inspiratory pressures up to 25 cm $H_2O$. Adjustments were made to achieve and maintain normocapnia (expired $CO_2$ 35-45 mmHg). An arterial cannula was placed in an auricular artery for continuous invasive blood pressure measurement. A triple-lumen central line was placed in either the left or the right internal or external jugular (typically the external jugular) under ultrasound guidance for continuous measurement of central venous pressure and for fluid and drug administration. A Foley urethral catheter was placed under direct visualization using a previously described technique for the quantification of urine output throughout the procedure.[11] Oxyhemoglobin saturation, end-tidal $CO_2$, pharyngeal temperature, and the electrocardiogram were also observed continuously and recorded every 5 min. Hartmann's solution was administered intravenously (10 mL/kg/h) and increased if mean arterial blood pressure was less than 60 mmHg for more than 5 minutes. Either atracurium (25 mg/pig) or pancuronium (4 mg/pig) was administered as needed, based on monitoring of the train-of-four peripheral nerve stimulation of the facial nerve throughout the procedure, for neuromuscular blockade.

### *Surgical procedure*

Pigs were positioned in right lateral recumbency for left nephrectomy. Hair was removed from the right lateral body wall with standard #40 clippers, and a routine surgical preparation by alternating chlorhexidine gluconate and ethyl alcohol was done. A thick pad was placed under the right flank of the pig to elevate the body wall off the table caudally. The surgical site was defined by drapes to create a sterile field from the left axilla cranially to the left inguinal region caudally and the level of the transverse processes of the vertebrae dorsally to approximately 5 cm contralateral to the midline ventrally (Fig. 1). The surgeon and an assistant stood on the ventral side of the pig, with the camera tower placed opposite. A consultant urological surgeon performed each surgery, with assistance from either a specialist veterinary surgeon or surgical registrar.

The camera port was placed first using the modified Hasson technique, positioned 4 cm lateral to the midline on the left approximately 10 cm cranial to the umbilicus. The port was sutured in place with 2/0 polyglactin 910. After insufflation with $CO_2$ to a maximum pressure of 12 mmHg, a 10-mm 30° forward oblique laparoscope was introduced. The remaining ports were placed as follows: in the caudal abdomen, at two-thirds of the distance between dorsal and ventral midline (right hand), at or immediately caudal to the umbilicus (fan retractor), and roughly equidistant between those two ports (left hand) (Fig. 1B). These ports were placed through stab incisions with a trocar under direct visualization.

The left kidney was located under direct visualization. The small intestine was displaced ventrally using an expandable fan retractor, introduced into the midline port. The hilum of the left kidney was identified and dissection was started. Using a combination of monopolar multifunctional suction hook (Surgiwand II 5 mm Suction/Irrigator, Covidien, Minneapolis, MN) and bipolar forceps, the retroperitoneum was incised at the hilum and the ventral aspect of the renal vasculature was exposed (Fig. 2). The renal vein was dissected initially, beginning at the caudal (inferior) corner to maximize the length of the vein. The renal artery was subsequently dissected in a similar manner (Fig. 3). For both vessels, all perivascular adipose, lymphatic, and connective tissue were removed to minimize any loose tissue that could interfere with subsequent vascular anastomosis. Skeletonization of the vessels proceeded to the bifurcation