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Off-clamp robotic-assisted partial nephrectomy: surgical experience from a single centre

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Introduction Robot-assisted partial nephrectomy (RAPN) is a minimally invasive treatment for localized renal tumours, which can sometimes result in extended warm ischaemic time and serious complications. This study reports on surgical outcomes including feasibility, positive margins, and complications during and after surgery.

Material and methods From January 2011 to November 2022, a single centre performed off-clamp sutureless RAPN on 287 patients. The study recorded preoperative patient characteristics, estimated glomerular filtration rate, and tumour features according to the preoperative aspects and dimensions used for an anatomical (PADUA) classification, and utilized the RENAL nephrometry scoring system. Intraoperative details and complications were documented. Postoperative complications within 30 days were classified according to the Clavien-Dindo system. Follow-up appointments were scheduled at 1, 3, and 6 months in the first year, followed by subsequent appointments every 6 months, and then annually.

Results The study included 145 males and 142 females, with a mean age of 58.9 years and a mean body mass index of 26.7 kg/m^2. The mean PADUA score was 8.3, the average console time was 83 minutes, and the estimated blood loss was 280 mL. The average hospital stay was 3 days, and no intraoperative complications were observed. However, 4 patients (1.4%) experienced post-operative haemorrhage that required laparotomy (Clavien-Dindo stage IIIB), and 4 patients (1.4%) had positive surgical margins.

Conclusions Off-clamp selective arterial clamping during minimally invasive partial nephrectomy is a safe and feasible approach for small renal tumours. Further randomized prospective studies are required to confirm if RAPN without clamping offers any renal functional benefits and reduces perioperative bleeding complications.

Key Words: robot-assisted partial nephrectomy ‹› renal cancer ‹› renal function

INTRODUCTION

Robot-assisted partial nephrectomy (RAPN) is widely considered the gold standard for surgical treatment of renal cancers [1, 2], particularly T1a masses [3]. While transient clamping of the renal artery is typically a key part of the procedure, surgical techniques can vary among different centres [4, 5] and may include RAPN, open partial nephrectomy, or laparoscopic radical nephrectomy, depending on the size of the tumour [6]. The use of renal pedicle clamping during partial nephrectomy has been debated due to its potential benefits, such as reduced blood loss and better visualization of the tumour margin, as well as its potential drawbacks, such as the risk of injury to the renal pedicle, spasms in the renal arteries, increased risk of postoperative adhesions and adjacent organ injuries [7], and potential loss of renal

function. After nephron-sparing surgery (NSS), the treated kidney typically experiences a 20% decrease in function immediately after the surgery. This functional decline is primarily caused by the removal of a healthy parenchymal margin, ischaemia/reperfusion damage during hilar clamping, and "reconstructive injury" resulting from renorrhaphy [8]. Renorrhaphy may cause ischaemic necrosis of the sutured parenchyma, leading to pseudoaneurysms and arteriovenous fistulas [9–12]. Studies have shown that partial nephrectomy can be performed without hilar clamping [13], and performing surgery without clamping the kidney is a good strategy for preserving functional renal nephrons and minimizing ischaemic injury. In this study, a purely off-clamp sutureless robotic technique was used, which completely avoids hilar clamping and renorrhaphy by selectively controlling feeding arteries during tumour enucleation and using monopolar cauterization for haemostasis. In this study, we present the "zero ischaemia off-clamp sutureless partial robotic nephrectomy" technique for treating renal tumours, and we analyse the perioperative outcomes at our centre.

MATERIAL AND METHODS

From January 2011 to November 2022, 287 patients underwent off-clamp RAPN at Humanitas Mater Domini, Castellanza, Varese, Italy. The preoperative characteristics and demographics of these patients, including age, gender, body mass index (BMI), comorbidities, haematocrit (HCT), serum creatinine (CR), and estimated glomerular filtration rate (eGFR), as well as tumour features, were recorded. The eGFR was calculated using the 2009 Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation [14]. In addition, early post-operative complications within 30 days, as classified by the Clavien–Dindo classification system [15], were also recorded. The tumour characteristics considered included size, location, preoperative appearance, and the preoperative aspects and dimensions used for an anatomical (PADUA) classification [16]. The RENAL nephrometry scoring system [17] was also adopted, which takes into account the radius, exophytic/endophytic properties, proximity to the collecting system or sinus, and location relative to the polar line. The histopathology and surgical margin status were also recorded. Perioperative data such as operative time, estimated blood loss (EBL), transfusion rate, and intraoperative complications were recorded, as well as the follow-up period. All patients were evaluated with computed tomography (CT) and/or magnetic resonance imaging (MRI) prior to the surgery.

The renal vascular anatomy was also studied during the procedures. The surgeries were performed trans-peritoneally using the da Vinci Si system (Intuitive Surgical, Sunnyvale, CA, United States) by 2 experienced surgeons. The AirSeal® insufflation system (ConMed, Utica, New York, USA) was used for insufflation, and the renal pedicle was identified in all cases. The tumour borders were marked using laparoscopic ultrasonography. Enucleation was the preferred method of excision, with resection performed if necessary. Follow-up appointments were scheduled at 1, 3, and 6 months in the first year, followed by subsequent appointments every 6 months, and then annually. Physical examination, biochemical tests, and sonography imaging were carried out at each visit, with a CT-scan at 12 months and then annually. Renal function was evaluated using CR and eGFR at every check-up. For trifecta outcomes, post-operative eGFR at 6 months and eGFR decrease were used. All patients had negative surgical margins. The surgical technique involved the use of 3 robotic doors (i.e. camera + scissors and ProGrasp®) and one accessory door. The kidney and lesion were isolated, and hot enucleation/tumour resection was performed with subsequent diathermocoagulation of the enucleation bed and placement of fibrin glue and haemostatic material. All data are presented as mean values (range).

RESULTS

Patients' baseline characteristics and operative data are presented in Tables 1 and 2. The study included 145 male and 142 female patients, with a mean age of 59 years (ranging from 22 to 84 years), and a mean body mass index of 26.7 kg/m^2 (ranging from 17.5 to 45.3 kg/m^2). Preoperative creatinine and estimated glomerular filtration rate were 1.01 mg/dL (ranging from 0.55 to 2.16 mg/dL) and 80.1 mL/min/1.73 m^2 (ranging from 19.6 to 168.4 mL/min/1.73 m^2), respectively. There were 8 patients with dual unilateral tumours and 7 patients with a solitary kidney. The mean diameter of the neoplasms was 39 mm (ranging from 2.5 to 5.5 mm), and they were located in the right kidney in 137 patients, left kidney in 150 patients, upper pole in 99 patients, middle pole in 63 patients, and lower pole in 125 patients. The mean PADUA score was 8.3 (ranging from 6 to 12). The mean console time was 83 minutes (ranging from 40 to 180 minutes), and the estimated blood loss was 280 mL (ranging from 58 to 100 mL). The warm ischaemia time was zero in all patients. The average hospital stay was 3 days (ranging from 2 to 15 days). There were no intraoperative complications, but 4 (1.4%) patients experienced

Table 1. *Demographic and baseline clinical data of all 287 patients*

Subjects (n)	287
Age, years, mean (range)	59 (22–84)
Sex (male/female)	145/142
Body mass index, kg/m^2, mean (range)	26.7 (17.5–45.3)
Diabetes, n (%)	58 (20.2)
Cardiovascular disease, n (%)	24 (8.3)
Tumour size, mm, mean (range)	39 (25–55)
Preoperative serum creatinine, mg/dL, mean (range)	1.01 (0.55–2.16)
Preoperative eGFR, mL/min/1.73 m^2 mean (range)	80.10 (19.6–164.4)
PADUA score, mean (range)	8.3 (6–12)

n – number of patients; eGFR – estimated glomerular filtration rate; PADUA – the preoperative aspects and dimensions used for an anatomical

Table 2. *Perioperative and pathological data of all 287 patients*

Operative time, min, mean (range)	83 (40–180)
Estimated blood loss, mL, (range)	280 (50–800)
Serum creatinine at discharge, mg/dL, mean (range)	1.13 (0.5–4)
eGFR at discharge, mL/min/1.73 m^2, mean (range)	72.6 (14.9–161.6)
Hospitalization, days, mean (range)	3 (2–15)
Positive surgical margin, n (%)	4 (1.3)

n – number of patients

post-operative haemorrhage requiring laparotomy (Clavien-Dindo stage IIIB). None of the 4 patients had bleeding from the resection margins. Two patients were bleeding from kidney fat and 2 from a robotic port. Four (1.4%) patients had positive surgical margins. The absolute median decrease in serum creatinine and estimated glomerular filtration rate at discharge were 2.6 mg/dL (ranging from 14.9 to 161.6 mg/dL) and 70.2 mL/min/1.73 m^2, respectively.

DISCUSSION

Nephron-sparing surgery is the typical treatment for small kidney tumours. This includes partial nephrectomy (PN), which aims to achieve a minimal decrease in kidney function, no positive surgical margins, and no urological complications, which is known as the trifecta assessment.

The presence of positive surgical margins (PSM) does not necessarily indicate that cancer is still present in the kidney parenchyma [18]. However, in nephron-sparing surgery it is preferable to achieve a negative surgical margin because this is associated with better oncological outcomes after partial nephrectomy [19]. The incidence of PSM in minimally invasive partial nephrectomy (MIPN) has been reported to be between 0% and 5.2% in various studies [12, 20, 21, 22]. In the current study the PSM rate was 1.4%, which is comparable to rates reported in other studies.

Recently, several studies have been published on the urological complications that can occur during and after MIPN [23-25]. Haemorrhagic events and urinary leakage are the most commonly reported complications. Haemorrhagic complications can occur during surgery or in the postoperative period. Intraoperative complications refer to excessive bleeding during surgery, while postoperative complications involve unexpected, delayed bleeding that requires a blood transfusion or angioembolization. In the present study, the mean estimated blood loss was 280 mL, which is similar to the volumes reported in previous studies [21, 24, 25, 26].

The incidence of bleeding requiring a blood transfusion during or after MIPN has been reported to be between 0% and 6.1%, while the incidence of postoperative bleeding requiring angioembolization for renal artery pseudoaneurysm (RAP) or haemorrhage has been reported to be between 0% and 6.8% [21, 24, 25, 26]. In the current study, no patients required a blood transfusion or angioembolization. The incidence of haemorrhagic complications in our cases is comparable to that in other reports. The off-clamp method, in which clamping of the blood vessels is not used, does not have a time limit, in contrast to the standard on-clamp method. As nephron-sparing surgery becomes more widely accepted, there have been more reports of RAP.

The exact cause of RAP formation after PN is not well understood. It is a rare but potentially life-threatening complication. Kondo et al. [27] suggested that using an early unclamping technique might reduce the time of ischaemia and the risk of RAP, and that ensuring there is no arterial bleeding before repairing the kidney could be a key step in preventing RAP during laparoscopic PN (LPN). Ghoneim et al. [28] reported that the incidence of RAP is higher in LPN than in open PN (OPN). During LPN, suturing is challenging because the warm ischaemic time is limited to preserve kidney function, and the pressure from the pneumoperitoneum can obscure small vascular injuries. RAP might be caused by insufficient haemostasis. In our study, however, no cases of RAP were observed in the postoperative phase. We believe this may be due to the nearly complete haemostasis achieved through soft coagulation. Additionally, in some previous studies of off-clamp LPN, no cases of RAP were reported, although the number of patients in these studies was small [24, 25]. This suggests that haemostasis without artery clamping

may be more precise than haemostasis with clamping, because clamping may only provide temporary haemostasis, which can lead to re-bleeding under normal or high blood pressure in the postoperative period. Therefore, the off-clamp technique is important for ensuring complete haemostasis.

For many years, the reconstructive injury caused by renorrhaphy has been considered unavoidable. However, it is believed to be responsible for two-thirds of the functional loss seen after surgery [28]. A study in pigs showed that the depth of the necrosis caused by renorrhaphy ranges between 7 and 15 mm [29]. Renorrhaphy can have negative effects on the glomerular filtration rate after surgery and may even lead to severe complications. Brassetti et al. suggested that achieving haemostasis through a sutureless approach could lead to improved functional and surgical outcomes [10]. The use of electrocauterization has been successful in achieving this during liver [30], lung [31], and pancreatic [32] surgery. Modern electrical scalpels can deliver the appropriate amount of energy to tissues, causing proteins to coagulate and stopping bleeding while limiting collateral carbonization. Modern electrical scalpels utilize advanced technology to deliver precise and controlled amounts of energy to tissues, resulting in localized Joule heating that coagulates proteins at a temperature range of 70–80°C, effectively stopping bleeding while minimizing the risk of collateral carbonization.

Recent studies have shown that global kidney function can decline by 9–21% after MIPN [7, 16, 33, 34]. In the current study, the change in eGFR was -7.2% at 1–3 months after surgery. Changes in overall kidney function were better than those seen after MIPN using traditional hilar clamping, selective clamping, or non-ischaemic techniques.

Anceschi et al. conducted a study comparing the perioperative functional and oncological outcomes of off-clamp and on-clamp RAPN in patients with solitary kidneys [35]. The study demonstrated that the change in eGFR was better in the off-clamp group compared to the on-clamp group [35].

We used the off-clamp sutureless technique in all cases and were able to complete the procedure successfully and safely. However, it is important to note that long-term damage to normal kidney tissue due to heat can be serious and should be avoided by limiting the procedure to tumours that do not require a long resection time. This study has several limitations, including its retrospective nature, single-centre experience, and small sample size. It also lacks a control group. Future studies with larger sample sizes and a prospective, randomized design are needed to confirm the safety and efficacy of the off-clamp sutureless technique in MIPN and to compare it to other methods. The results of this study suggest that the off-clamp sutureless technique for tumour resection in MIPN is safe and feasible for small kidney tumours and may reduce the incidence of perioperative haemorrhagic complications, but further research is needed to confirm any potential advantages in terms of kidney function.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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