Robotic Partial Nephrectomy Using Robotic Bulldog Clamps

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ABSTRACT

Background and Objectives: The need for a skilled assistant to perform hilar clamping during robotic partial nephrectomy is a potential limitation of the technique. We describe our experience using robotic bulldog clamps applied by the console surgeon for hilar clamping.

Methods: A total of 60 consecutive patients underwent robotic partial nephrectomy, 30 using laparoscopic bulldog clamps applied by the assistant and 30 using robotic bulldog clamps applied with the robotic Prograsp instrument. Perioperative outcomes were compared between groups.

Results: All 30 patients underwent successful hilar clamping during robotic partial nephrectomy using robotic bulldog clamps with no intraoperative complications and without the need for readjustment/reclamping. Robotic bulldog clamps provided adequate ischemia even for tumors >4 cm, hilar, endophytic, multiple tumors, and multiple renal arteries. Both groups had similar baseline characteristics. Perioperative outcomes with robotic bulldog clamps were at least comparable to the laparoscopic bulldog group, with a trend to lower console time, warm ischemia time, and estimated blood loss.

Conclusions: Use of robotically applied bulldog clamps is a safe and feasible method of hilar occlusion during robotic partial nephrectomy; they perform at least as well as laparoscopic bulldog clamps while allowing the console surgeon greater autonomy and precision for hilar clamping.

Key Words: Robotic partial nephrectomy, Robotic bulldog clamps, Laparoscopic bulldog clamps, Hilar clamping, Warm ischemia.

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INTRODUCTION

Robot-assisted partial nephrectomy (RAPN) is an emerging minimally invasive option of nephron-sparing surgery for localized renal tumors.[1-7] Clamping of the renal hilar vessels during minimally invasive partial nephrectomy allows for precise tumor excision and renal reconstruction in a bloodless field. Hilar clamping during minimally invasive partial nephrectomy is generally performed using intracorporeal bulldog clamps or a Satinsky clamp, emulating the open technique.[8] During laparoscopic partial nephrectomy (LPN), the operative surgeon performs renal hilar clamping. However, during RAPN, renal hilar clamping is generally performed by the bedside assistant. The need for a skilled bedside assistant to perform hilar clamping is considered a potential limitation of RAPN.[1,9] Our aim was to assess the safety and efficacy of renal hilar clamping during RAPN using robotic bulldog clamps applied by the console surgeon and to compare performance of robotic bulldog clamps to laparoscopic bulldog clamps. We compared perioperative outcomes of RAPN using robotic bulldog clamps applied by the console surgeon with RAPN using laparoscopic bulldog clamps applied by the assistant. Our hypothesis was that robotic bulldog clamps would allow the console surgeon to control hilar clamping at optimal angles and facilitate safe, precise clamp placement.

MATERIALS AND METHODS

Between July 2010 and January 2011, 30 consecutive patients underwent RAPN performed using robotic bulldog clamps. Our study was performed under an Institutional Review Board-approved protocol with informed surgical consent obtained from all patients. Our RAPN technique has been previously described.[4] The robotic Prograsp instrument was used in the nondominant hand and was also used as a needle driver. Robotic monopolar scissors were used in the dominant hand, which was exchanged with a needle driver for renorrhaphy. The Prograsp was used for dissection, application of clamps and as a needle driver. In the minority of cases using the fourth robotic arm, a fenestrated bipolar instrument was used in the nondominant hand and the Prograsp was used as a fourth arm instrument.

Two types of robotic bulldog clamps were used (Klein Surgical Inc., San Antonio, Tx and Scanlan International, St. Paul, MN), that are reusable and allow for grasping and application with the robotic Prograsp instrument **(Figure 1)**. The Klein robotic bulldog clamp has a bayonet design **(Figure 1a)**, which allows the robotic Prograsp to dock with the notches on the sides of the clamp in an offset manner, thereby avoiding interference with the spring mechanism of the clamp. The Scanlan robotic bulldog clamp **(Figure 1b)** has notches on the ends and an internal spring, allowing the Prograsp to dock in an end-on fashion. Both clamps have a jaw length of 25mm. The closing force of the Klein and Scanlan robotic bulldog clamps are each approximately 350g.

Figure 1. a. Klein robotic bulldog clamp with a bayonet design and a grooved notch (arrow) to allow engagement of the robotic Prograsp instrument without interfering with the spring mechanism of the clamp (Klein Surgical Inc., San Antonio, TX). Figure 1. **b.** Scanlan robotic bulldog clamp with a notch (arrow) for end-on docking with the robotic Prograsp instrument (Scanlan International, St. Paul, MN).

The robotic bulldog clamps were introduced and removed by the bedside assistant through a 12-mm or 15-mm assistant trocar by using a laparoscopic Micro-France grasper engaged with the notches of the clamp. The robotic bulldog clamp was passed in a forward orientation similar to the mechanism of a laparoscopic bulldog clamp applier **(Figure 2)**. The clamp is applied to the perinephric tissue in preparation for clamping by the console surgeon. The surgeon engages the notches of the robotic bulldog clamp with the Prograsp and can squeeze the Prograsp to open the clamp and relax the grip to close and release the clamp. Robotic bulldog clamps were then applied to the renal vessels using the articulation of the robotic Prograsp for application of the clamps at optimal angles **(Figure 3)**. Robotic bulldog clamps were applied to the renal artery and renal vein separately in most cases, but the renal artery alone was clamped in select patients with smaller or more peripheral tumors. In most cases, the renal artery was clamped with a single robotic bulldog clamp. Occasionally, when clamping the renal vein with the Klein robotic bulldog clamps, which have a wider opening diameter and blunter tips, the entire pedicle was clamped en bloc to provide some additional control of the artery. A string can be tied to a hole in the back of the clamp as a tether to facilitate location and extraction of the clamp per surgeon preference.

The perioperative characteristics of 30 consecutive patients who underwent RAPN using robotic bulldog clamps were compared with the preceding 30 consecutive pa-

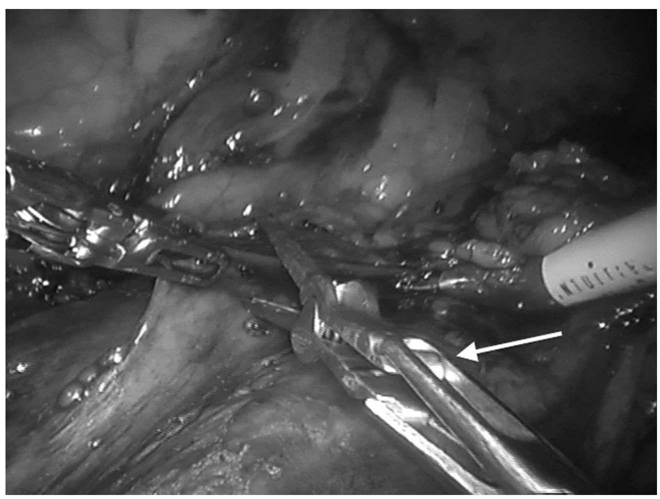

Figure 2. Introduction of the Scanlan robotic bulldog clamp by the bedside assistant in a forward direction by engaging the notches of the clamp with the MicroFrance grasper (arrow) similar to the mechanism of a laparoscopic bulldog clamp remover.

Figure 3. a. Clamping of renal artery (RA) by the console surgeon using Scanlan robotic bulldog clamps. The robotic arm with the robotic monopolar scissors can be used to help elevate the kidney (solid arrow) to place the hilar vessels on stretch for hilar clamping. The notch on the robotic bulldog clamp fits within the robotic Prograsp instrument (broken arrow). Figure 3. **b.** Clamping of renal vein (RV) by the console surgeon using a Klein robotic bulldog clamp. Note the Scanlan robotic bulldog clamp in the background (arrow) on the main renal artery. There is an accessory renal artery (RA) that is being clamped en bloc with the renal vein.

tients using laparoscopic bulldog clamps applied by the assistant (Aesculap USA Inc., Center Valley, PA). We operated on patients consecutively and successively to minimize selection bias and the confounding effect of our learning curve, which was negligible given our experience of over 150 cases. RAPN done off-clamp (n=2) or with a Satinsky clamp (n=5) during the study period were excluded from the analysis. The demographic, preoperative, and perioperative variables were compared between groups. Calculation of estimated glomerular filtration rate (eGFR) at discharge was performed using the Modification of Diet in Renal Disease formula (MDRD).

The independent samples *t* test and Mann Whitney-U test were used for comparing the 2 groups. Fisher's exact *t* test and Pearson's chi-square were used for comparing groups as indicated. All tests were 2-tailed with the significance set at 0.05. All statistical analyses were performed using PASW software (PASW 17, IBM, Chicago, IL).

RESULTS

All 30 patients in the robotic bulldog group underwent successful hilar clamping during RAPN using robotic bulldog clamps with no intraoperative complications and without the need to readjust clamps or reclamp. Patient demographics and preoperative variables are shown in **Table 1**. Baseline demographic and clinical characteristics were similar between the robotic and laparoscopic bulldog clamp groups. Robotic bulldog clamps provided adequate ischemia during RAPN, even for tumors >4cm in size (n=4; largest-8.5cm), hilar tumors (n=3), completely endophytic tumors (n=8), multifocal tumors (5 tumors in 1 kidney, n=1), multiple renal arteries (n=4; 1 patient with 4 renal arteries), and a retroperitoneal approach (n=1).

Perioperative outcomes are demonstrated in **Table 2**. The group with robotic bulldogs had perioperative outcomes at least comparable to the laparoscopic bulldog group for median console time (174 min vs. 189.5 min, P=.09), mean warm ischemia time (19.4 min; range: 8-30; vs. 22.1 min; range: 10-32; P=.08), and median EBL (75mL vs. 125mL, P=.06). There was one pseudoaneurysm requiring embolization in each group, and one pulmonary embolism in the laparoscopic bulldog group, but no other complications.

We tried different methods of introducing and removing the robotic bulldog clamps, both a reverse orientation holding one jaw of the clamp and a forward orientation with the MicroFrance laparoscopic grasper engaging the notches of the clamp. We found the technique of passing the clamp backwards and transferring to the Prograsp to be more cumbersome than the technique of passing the clamp in a forward direction, and it took an average of 15 seconds longer to transfer the clamp to the Prograsp. When removing the Klein robotic bulldog clamps through a 12-mm trocar, the clamp occasionally caught on the lip of the trocar impeding extraction but could be removed by twisting the clamp while extracting. The Klein robotic bulldog clamp could also be removed by pulling a tether string tied to the back of the clamp, but this was not possible with the Scanlan clamps as they would catch on the trocar. There were no issues with introduction or removal of either clamp through a 15-mm trocar.

DISCUSSION

RAPN is a minimally invasive treatment option for nephron-sparing surgery for localized kidney tumors.[1-7] Although the initial pioneering reports of LPN by McDougall et al[10] and Winfield et al[11] were described without clamping of the renal hilum, it has become common to perform minimally invasive partial nephrectomy under temporary renal ischemia by clamping the renal vessels. Clamping of renal hilar vessels during minimally invasive partial nephrectomy allows for precise tumor excision and

Table 1.
Comparison of Demographic and Preoperative Characteristics Between Groups With Robotic and Laparoscopic Bulldog Clamps

Characteristics	Robotic Bulldogs (n=30)	Laparoscopic Bulldogs (n=30)	P Value
Age	60 (32–78)	62 (39–77)	.49
Sex-male, n (%)	21 (70%)	19 (63%)	.58
BMI[a]	29.2 (22–42)	31.4 (21–48)	.19
ASA[ab]	3 (2–3)	3 (2–3)	.17
Pre-operative eGFR[a]	76 (40.6–119.1)	79.9 (56.5–107)	.54
Comorbidity, n (%)			
Hypertension	12 (44)	19 (66)	.11
Diabetes	6 (22)	6 (20)	.84
Chronic kidney disease (eGFR<60)	3 (13)	2 (7)	.65
Previous abdominal surgery, n (%)	10 (39)	14 (48)	.46
Right-sided, n (%)	14 (47)	9 (30)	.18
Radiographic tumor size	2.64 (1–8.5)	2.70 (1–6.5)	.86
Tumors >4cm, n (%)	4 (13	4 (13)	1.00
Hilar tumors, n (%)	3 (10)	2 (7)	1.00
Completely endophytic, n (%)	8 (27)	4 (13)	.19
Multifocal tumors, n (%)	1 (3)	1 (3)	1.00
Multiple renal arteries, n (%)	4 (13)	2 (7)	.67

[a] BMI=Body mass index; ASA=American Society of Anesthesiologists; eGFR= estimated glomerular filtration rate (Modification of Diet in Renal Disease formula).

[b]Median (Interquartile range). All other continuous variables expressed as mean (range).

renal reconstruction in a bloodless field. Hilar clamping is generally performed using intracorporeal bulldog clamps or with a Satinsky clamp, emulating the open technique.[8] During LPN, the operating surgeon performs renal hilar clamping; however, during RAPN, the surgeon must depend on the assistant to perform this important task.[1,9] We report successful hilar clamping during RAPN using robotic bulldog clamps under complete control of the operative surgeon. To the best of our knowledge, this is the first series to evaluate the use of robotic bulldog clamps for RAPN and to compare perioperative outcomes to RAPN using laparoscopic bulldog clamps.

The ideal renal hilar clamp for RAPN should have several characteristics including control and application by the console surgeon without the need for a dedicated assistant port, sufficient clamping force to ensure a bloodless surgical field while on clamp, sufficient opening size to include hilar vessels, and maneuverability to allow placement at different angles while minimizing the potential for vascular injuries. Intracorporeal bulldog clamps avoid the need for a dedicated port for a Satinsky clamp, avoid the risk of the robotic arms colliding with the clamp, and offer increased mobility of the kidney compared with a Satinsky clamp. Robotic bulldog clamps offer these same advantages, with the added benefit that the console surgeon controls hilar clamping and can use the articulating robotic instruments for optimal clamp placement.

Rogers et al[12] initially described robotic application of a laparoscopic bulldog clamp (Klein Inc.) RAPN using a robotic Prograsp as a fourth robotic arm instrument to grasp the flat surface of the clamp.[12] The laparoscopic bulldog clamp could only be grasped at a 90-degree angle, which limited articulation, it did not open widely enough to accommodate larger vessels, and it had a tendency to slip out of the Prograsp due to lack of notches on the flat surface. The robotic bulldog clamps we used in the current study allowed the console surgeon to control hilar clamping while taking full advantage of the precision and articulation of the robotic instruments. We did not experience any cases of slippage or loss of the clamps, as the Prograsp and Micro-

Table 2.
Comparison of Perioperative Outcomes Between the Groups with the Robotic and the Laparoscopic Bulldog clamps

Characteristics	Robotic Bulldogs (n=30)	Laparoscopic Bulldogs (n=30)	P Value
Console time[a]	174 (150–205)	189.5 (153–233)	.09
Warm ischemia time	19.4 (8–30)	22.1 (10–32)	.08
EBL[a]	75 (50–200)	125 (69–213)	.06
Histology, n (%)			.50
Clear cell RCC	12 (40)	17 (57)	
Papillary RCC	6 (20)	4 (13)	
Chromophobe RCC	4 (13)	4 (13)	
Unclassified RCC	2 (7)	0	
Benign Tumor	6 (20)	5 (17)	
Positive surgical margin, n (%)	1 (3.7)[b]	0	1.0
Postoperative complications, n (%)	1 (3.3)[c]	2 (6.7)[c]	1.0
Length of Stay[a]	2 (2–3)	2 (2–3)	.35
Postoperative eGFR (discharge)	70.3 (44–119)	68.8 (45–113)	.73
% Decrease in eGFR	6.7	10.5	.41

[a] Median (Interquartile range). All other continuous variables expressed as mean (range).

[b] Focal microscopic positive margin at base of tumor where focal enucleation performed for hilar tumor. Patient elected for close surveillance.

[c] Pseudoaneurysm requiring angioembolization in each group. The laparoscopic bulldog group also had a case of pulmonary embolization.

EBL=estimated blood loss, eGFR=estimated glomerular filtration rate (Modification of Diet in Renal Disease formula), RCC=renal cell carcinoma.

France graspers securely engaged the notch on the robotic bulldog clamp.

Robotic bulldog clamps performed at least as well as laparoscopic bulldog clamps, with a trend towards improved warm ischemia time, console time and EBL, although this did not achieve statistical significance. We would not expect a major improvement in perioperative parameters with robotic bulldog clamps over laparoscopic bulldog clamps, because the technique of tumor excision and renal reconstruction is the same after the clamps are applied. In our opinion, the advantage of using robotic bulldog clamps is having surgeon control hilar clamping and the ability to utilize the precision and articulation of the robot for optimal clamp placement.

Robotic bulldog clamps provided adequate renal ischemia during RAPN for a variety of complex cases such as tumors >4cm in size, hilar tumors, endophytic and multiple tumors, multiple renal arteries, and a retroperitoneal approach. The closing force of the robotic bulldog clamps is similar to the closing force listed for laparoscopic bulldog clamps (Aesculap USA Inc.) of the same size. The Klein robotic bulldog clamp has a wider jaw length (4.7mm), which distributes force over a greater width and the clamp has a wider opening distance along the entire jaw length. The clinical significance of these differences is unclear. Our aim was to conduct an initial feasibility study of robotic bulldog clamps. Future studies to directly compare the different robotic bulldog clamps are indicated. We did not need to double clamp the renal artery in our study, as a single robotic bulldog clamp provided adequate renal ischemia. However, it is possible that there could be a decrease in closing force over time with use, as has been described with laparoscopic bulldog clamps.[13]

Our study is limited by its retrospective, nonrandomized, unmatched design. We designed our study to only include consecutive and successive patients undergoing RAPN with laparoscopic and robotic bulldog clamps, thereby minimizing selection bias. Our experience of >150 cases is well beyond the learning curve proposed by Mottrie et al[3] (30 cases) and Haseebuddin et al[14] (26 cases), thereby minimizing the confounding effect of the learning curve in our study.

Our study demonstrates the safety and feasibility of performing hilar clamping independent of the bedside assistant. However, it should be emphasized that a skilled assistant is still important for other essential steps, such as exposure during tumor excision and efficient passage of sutures during renal reconstruction. Robotic bulldog clamps eliminate the need for the assistant to manipulate laparoscopic bulldog clamps near the renal hilum, which could potentially reduce the likelihood of injuring renal vessels or prolonging warm ischemia times when clamping angles are difficult. The bedside assistant in our study was an experienced registered nurse first assistant. Robotic bulldog clamps may be particularly beneficial when the bedside assistant is less experienced, because the surgeon has autonomy over hilar clamping. However, we feel that robotic bulldog clamps can be beneficial even with an experienced assistant, because the console surgeon can utilize robotic articulation to place the clamps at optimal angles to help ensure complete clamping.

Although we did not experience any vascular injuries with robotic bulldog clamps, our study was underpowered to detect a difference in vascular complications. We recognize that some surgeons may prefer to use other robotic grasping instruments besides the Prograsp, but these do not have sufficient closing force to apply the robotic bulldog clamps. We already routinely use a Prograsp instrument, which also doubles as a needle driver to reduce costs. We did not perform a formal cost analysis in this study, but robotic bulldog clamps cost between $3000 and $3400 for a set of 4 clamps, and a MicroFrance grasper costs approximately $700 for a total cost of about $4000. In contrast, a set of 4 laparoscopic bulldog clamps along with a laparoscopic applier and a remover can cost up to $8000. Therefore, robotic bulldog clamps, as judged by their current market price, are not more expensive than laparoscopic bulldog clamps.

In our experience using robotic bulldog clamps, we have learned several technical points to optimize their use. We recommend having the assistant use a MicroFrance laparoscopic grasper to introduce and remove the clamps, because this instrument securely engages the notches of the clamp in a similar fashion as a laparoscopic bulldog clamp applicator. We already routinely use a MicroFrance grasper for our robotic cases, which avoids the need and expense for a specialized instrument for application and removal of the clamps. We prefer to have the assistant leave the clamps attached to the lateral sidewall of perinephric tissue to allow the surgeon to easily engage the clamp with the Prograsp without the need to transfer the clamp between instruments or to drop the clamp. A finder string can be tied to the back of the robotic bulldog clamps that could be used to help locate a dropped robotic bulldog clamp or for extraction of the Klein robotic bulldog clamps, but we do not routinely use this. We have found that using a 15-mm trocar as the assistant port can make it easier to pass robotic bulldog clamps, pass needles and extract the tumor, but it is not required. We do not feel that a 15-mm assistant port adds to the invasiveness of the procedure, because tumor extraction from a 12-mm port site generally requires the incision to be slightly enlarged.

CONCLUSION

Robotic bulldog clamps are a safe, feasible method of hilar occlusion during RAPN with outcomes at least comparable to those with laparoscopic bulldog clamps. Robotic bulldog clamps offer the console surgeon control over hilar clamping with full robotic articulation for precise and accurate clamp placement.

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