Review Article

The role of robotic surgery in the management of renal tract calculi

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Abstract: The role of robotic assisted surgery in contemporary urolithiasis management is in its infancy. The mainstay in the management of renal tract calculi remains ureterorenoscopy (URS), extracorporeal shock wave lithotripsy (ESWL) and percutaneous nephrolithotomy (PCNL). However, in rare clinical circumstances, such as large impacted pelvic and ureteric calculi, endo-urological techniques may not be adequate. Furthermore, patient may have a synchronous pathology such as pelvi-ureteric obstruction which preferably should be concurrently treated with the renal calculi in a single sitting. Robotic assisted laparoscopic ureterolithotomy (RALU), robotic assisted laparoscopic pyelolithotomy (RPL) with or without concurrent pyeloplasty and Robotic assisted laparoscopic anatrophic nephrolithotomy have all been described for complex stones. Additionally, technical challenges with a flexible ureteroscopy (FURS) have led to the development of robotic assisted flexible ureteroscopes. In the article we summarize the role of robotic assisted surgery in complex renal tract calculi.

Keywords: Laparoscopy; robotics; urolithiasis

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Introduction

There has been significant dissemination of robotic assisted surgery in the field of urological pelvic and upper tract oncology (1,2). The role of robotic assisted surgery in contemporary urolithiasis management is in its infancy (1). The mainstay in the management of renal tract calculi remains ureterorenoscopy (URS), extracorporeal shock wave lithotripsy (ESWL) and percutaneous nephrolithotomy (PCNL) (3-7). These options offer high stone clearance rates with minimal morbidity in a majority of cases (4-7). However, in rare clinical circumstances, such as large impacted pelvic and ureteric calculi, the aforementioned endo-urological techniques may not be adequate (8). Furthermore, patient may have a synchronous pathology such as pelvi-ureteric obstruction which preferably should be concurrently treated with the renal calculi in a single sitting (9). These select scenarios have traditionally necessitated the surgeon to employ either an open or conventional laparoscopic approach. The morbidity of open surgery can be significant, whilst renal reconstruction with conventional laparoscopic surgery is well recognized to be challenging (10). The introduction of robotic surgical system with greater maneuverability and superior vision, has the ability to mitigate the limitations of open and conventional laparoscopic techniques and

also offers the potential of successful stone clearance with fewer auxiliary procedures in challenging cases (10-12). Additionally, technical challenges with a flexible ureteroscopy (FURS) have led to the development of robotic assisted flexible ureteroscopes (13). This article aims to summarize and review the current evidence on the role of robotic assisted surgery in the management of renal tract calculi.

Robotic assisted surgery for renal tract stones

The current applications of minimal access surgery in renal tract stones are limited and mirror that of open surgery. A number of these approaches require reconstruction of the renal pelvis or ureter. The purported benefits of robotic surgery over conventional laparoscopic surgery are increased manoeuvrability, enhanced endo-wrist dexterity and tremor elimination making the reconstructive aspect of these approaches easier. Robotic assisted laparoscopic ureterolithotomy (RALU), robotic assisted laparoscopic pyelolithotomy (RPL) with or without concurrent pyeloplasty and Robotic assisted laparoscopic anatrophic nephrolithotomy have all been described for complex stones, often refractory to conventional endourological techniques. Hemal *et al.* reported a stone clearance rate was 93.2% in variety of robotic assisted stone clearance procedures (pyeloplasty with pyelolithotomy, ureterolithotomy, tailoring and ureteroneocystostomy and extended pyelolithotomy) (14). They concluded that robotic assistance has a benefit when reconstruction is required during a stone extraction procedure. RALU can be performed for large impacted ureteric stones refractory to ureteroscopic management. Dogra *et al.* reported a 100% successful stone extraction with RALU in 16 patients with large (mean size 2.2 cm), impacted lower ureteral stones with no requirement to convert to open approaches (15). The study reported a mean operative time of 45.3 min and minimal mean blood loss of 10mls. For RPL preoperative planning by way of a computed tomography (CT) with contrast is recommended for defining pelvicalyceal and vascular anatomy at renal hilum. Intraoperative retrograde fluoroscopic studies help delineation of the ureteric anatomy and evaluation of post-operative drainage. Swearingen *et al.* in a retrospective multicentre case series reported outcomes of 27 patients undergoing robotic pyelolithotomy (RPL) and nephrolithotomy (16). For a mean stone size of 2.74 cm, the study reported mean estimated blood loss and mean hospital stay of 38 mL and 1.7 days respectively, with a complete stone-free rate of 96%. Two patients had a Clavien-3b complication (hydronephrosis requiring percutaneous nephrostomy and ureteroscopy, encrusted stent requiring removal). The group concluded RPL has potential benefits of lesser bleeding and nephron loss, as the renal parenchyma isn't violated. A small, yet significant proportion of patients undergoing pyeloplasty for pelvi-ureteric junction obstruction will have synchronous renal calculi (17). Robot-assisted laparoscopic pyeloplasty increasingly regarded as the standard of care in many centers for pelvi-ureteric obstruction, can be carried out concurrently with a pyelolithotomy in these patients (9,18). Advances in laparoscopy, flexible endoscopy and wristed instruments have made it possible to visualize and access the majority of the collecting system through the pyelolithotomy incision at the time of pyeloplasty in order to remove stones. If the stone lies within the renal pelvis, forceps are commonly used for extraction. Calyceal calculi can be accessed with a flexible nephroscope via the pyelolithotomy incision. Jensen *et al.* in a retrospective case series reported a stone free rates of 94% for a median stone burden of 1.5 cm in patients who had simultaneous robotic assisted pyeloplasty and pyelolithotomy with no Grade 3–5 complication rates, concluding synchronous pyeloplasty and stone extraction is safe and feasible (9). The evidence for robotic assisted anatrophic nephrolithotomy is minimal. Kaouk *et al.* in feasibility study with porcine models, reported 100% stone free rates in 7 out of 10 pigs undergoing conventional laparoscopic anatrophic nephrolithotomy (19). Ghani *et al.* reported outcomes of 3 patients who underwent a robotic assisted anatrophic nephrolithotomy for a staghorn calculus (20). One patient had complete stone clearance and remaining two had residual fragments (13 mm and two 9 mm fragments). The mean blood loss was 100 mL with no complications. King *et al.* in a single centre prospective series of 7 patients who underwent robotic assisted anatrophic nephrolithotomy reported more than 90% reduction in stone burden and complete stone clearance in five and two patients of the cohort respectively (21).

Robotic assisted flexible ureterorenoscopy

Retrograde intra-renal surgery (RIRS) with conventional FURS has gained popularity with the technological advancements in optics, scope miniaturisation and lasers (22). Scope manipulation can, however be technically challenging with conventional FURS. Robotic assisted

FURS technologies have been recently developed (13). With better ergonomics, tremor elimination and superior vision, robotic assisted FURS may have the ability to address some of the limitations with conventional FURS. Additionally, robotic assisted FURS allows the surgeon to operate the system outside the radiation field. The Sensei-Magellan system flexi RIRS was described in 2008 (23). Desai *et al.* reported 94% technical success rate for stone disintegration and a complete stone-clearance rate of 89% in 18 patients who underwent FURS with Sensai-Magellan system (23). There was no conversion to manual URS or intraoperative complications in this study. The Sensei-Magellan system project encountered difficulties with scope design development and consequently the endeavour was abandoned. Roboflex Avicenna was the next generation of Robotic assisted FURS developed by ELMED (Ankara, Turkey). Roboflex Avicenna consists of a console for the surgeon and robotic arm for the flexible ureteroscope. The Robotic arm has capabilities of rotation (220°), advancement (150 mm), retraction and deflection (262°). The irrigation and laser fibre insertion operations can be controlled by the surgeon at the console. The system is compatible with a wide range of digital flexible ureteroscopes, access sheath, laser fibres, and baskets. Saglam *et al.* reported their experience in 81 patients undergoing robotic assisted FURS with the Roboflex Avicenna system (prototype 2) (13). They concluded console time and procedure time were within acceptable limits and only reported one technical failure requiring conventional FURS. The technical success of stone disintegration was recorded at 96% in this study. Geavlete *et al.* published a prospective comparative study between Roboflex Avicenna system (prototype 2) and conventional FURS. The study reported similar safety profile and 3-month stone free rates for the two approaches (89.4% in conventional FURS *vs.* 92.4% robotic assisted FURS) (24). Klein *et al.* in a prospective multicentre study reported a 97% technical success in stone disintegration and a device failure in only 2 patients (0.7%) for renal stones with an average size of 14 mm (25). The preliminary evidence would suggest that stone free rates with robotic assisted FURS are non-inferior to conventional FURS.

Conclusions

Robot-assisted laparoscopic techniques for urinary tract stone management are still in its infancy and early stages of implementation. The adoption of robotic assisted techniques will be influenced by the economic impact it has on healthcare systems. Whilst the preliminary evidence would suggest that robotic assisted approaches may be non-inferior to conventional endo-urological options, they do not appear to have an additional benefit in index cases. Often a lateral-thinking and pragmatic approach is required in selecting the best surgical modality for stone clearance in rare complex clinical scenarios. When one is "stuck between a rock and a hard place", a minimally invasive approach with robotic-assisted surgery may be an occasional suitable choice. For now, further evaluation with long-term follow-up and cost-analysis, ideally in a multi-centre, randomized setting will be required to define the place of robotic surgery in modern day renal tract calculi management.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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