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UPPER TRACT SURGERY
REVIEW

Laparoscopic renal surgery is here to stay

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KEYWORDS

Laparoscopic/open/robotic renal surgery;
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Donor nephrectomy;
Partial nephrectomy;
Pyeloplasty

ABBREVIATIONS

BMI, body mass index;
(L)(LESS-)DN, (laparoscopic) (lapar-

Abstract ***Objectives:*** To review the current literature comparing the outcomes of renal surgery via open, laparoscopic and robotic approaches.

Materials and methods: A comprehensive literature search was performed on PubMed, MEDLINE and Ovid, to look for studies comparing outcomes of renal surgery via open, laparoscopic, and robotic approaches.

Results: Limited good-quality evidence suggests that all three approaches result in largely comparable functional and oncological outcomes. Both laparoscopic and robotic approaches result in less blood loss, analgesia requirement, with a shorter hospital stay and recovery time, with similar complication rates when compared with the open approach. Robotic renal surgeries have not shown any significant clinical benefit over a laparoscopic approach, whilst the associated cost is significantly higher.

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oendoscopic single-site-) donor nephrectomy;
eGFR, estimated GFR;
LOS, length of hospital stay;
NOTES, natural orifice transluminal endoscopic surgery;
(L)(O)(RA)PN, (laparoscopic) (open) (robot-assisted) partial nephrectomy;
PUJO, PUJ obstruction;
(L)(O)(RA)PY, (laparoscopic) (open) (robot-assisted) pyeloplasty;
RCT, randomised controlled trial;
(L)(O)(RA)RN, (laparoscopic) (open) (robot-assisted) radical nephrectomy;
WIT, warm ischaemia time

Conclusion: With the high cost and lack of overt clinical benefit of the robotic approach, laparoscopic renal surgery will likely continue to remain relevant in treating various urological pathologies.

Introduction

Laparoscopy in humans was first performed > 100 years ago by the Swedish surgeon Hans-Christian Jacobaeus; to which he originally named the technique *laparothorakoskopie* [1]. Initially only performed for diagnostic purposes, several landmark innovations over the last century, such as the Trendelenburg position and the Hopkins rods-lens system, have paved the way for more complex operations to be performed via a laparoscopic approach [2].

The first laparoscopic renal surgery was performed in 1990 by Clayman et al. [3] from Washington, USA; in the *New England Journal of Medicine* they described the first case of laparoscopic nephrectomy, which involved a 7-h operation on an 85-year-old woman's 3-cm solitary right renal mass. As laparoscopic nephrectomy became more widespread, more advanced and complicated procedures were developed. In 1995, the first series of partial nephrectomies (PNs) was published by Winfield et al. [4], and in Johns Hopkins University the first laparoscopic donor nephrectomy (LDN) was performed by Su et al. [5]. Whilst the propagation of laparoscopic renal surgery was initially hampered by a significant learning curve and longer operation time, as more experience was accumulated new evidence showed laparoscopic outcomes to be comparable to an open approach, with the added advantage of significantly less blood loss, analgesia requirement, and length of hospital stay (LOS) [2,6].

Laparoscopic nephrectomy is now routinely performed for both benign and malignant pathologies, as well as DNs in renal transplantation. Laparoscopic PN (LPN) has also seen widespread use, as nephron-sparing surgery has been set as the 'gold standard' for managing small renal tumours. In centres with laparoscopic expertise, laparoscopic pyeloplasty has been increasingly performed for PUJ obstruction (PUJO).

With the advancement of robotic surgery, urology has been at the forefront in this regard, particularly for pelvic surgeries such as robotic prostatectomies [7]. Much interest has been shown in applying the robotic system to renal surgery, with its advantages of improved ergonomics, dexterity, and reduced physical strain on the operating surgeon [8]. However, to date, the cost of robotic systems remains a major stumbling block in widely implementing them; whilst there are limited comparative studies demonstrating out-right improvements in outcome when compared with established techniques.

The present review aims to gather evidence on relevant outcomes of renal surgeries (in particular, nephrectomy, PN, and pyeloplasty) performed via open, laparoscopic and robotic approaches, to ascertain whether there are any obvious benefits of one approach over the other in the three respective operations.

Materials and methods

A comprehensive literature review was performed on PubMed, MEDLINE, and Ovid between 1995 and 2017. Medical Subject Headings (MeSH) terms used for the search were 'open', 'laparoscopic', 'robotic', 'nephrectomy', 'partial nephrectomy', and 'pyeloplasty'.

Records were evaluated in accordance with the Preferred Reporting Items for Systemic Reviews and Meta-Analyses (PRISMA) criteria. Inclusion criteria were studies that focused on: comparing the immediate, short-term and long-term outcomes of either nephrectomy, PN, and pyeloplasty performed either via open, laparoscopic or robotic approach.

Exclusion criteria were: (i) studies not in English, (ii) studies that did not look at postoperative outcomes, (iii) studies in which laparoscopic approach was not performed as a comparator, (iv) letters and commentaries, and (v) studies with poor design. See Fig. 1 for the studies selection numbers.

Results and discussion

Radical nephrectomy (RN)

RN is considered a curative treatment for localised RCC, whilst retaining some roles in locally advanced and advanced/metastatic diseases [6]. It is also the first kind of renal surgery performed laparoscopically [3].

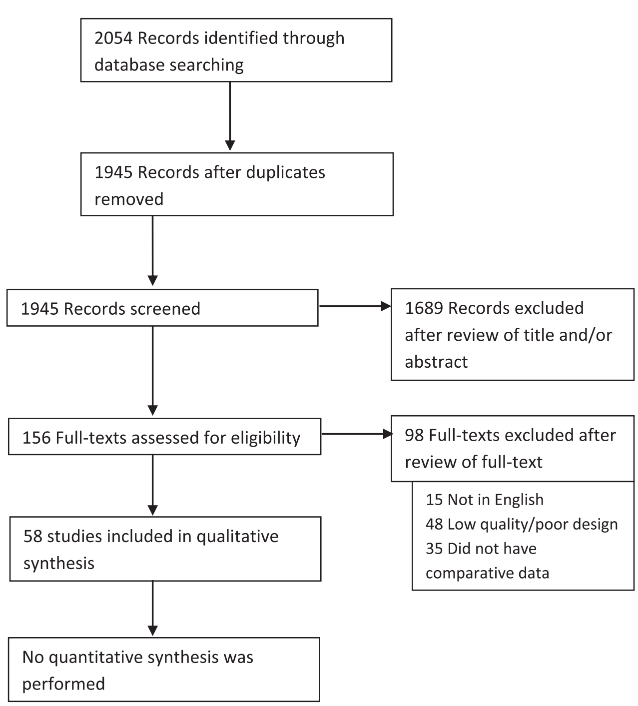

Fig. 1 Flow diagram of studies' selection.

Data from several randomised controlled trials (RCTs) comparing open RN (ORN) and laparoscopic RN (LRN) demonstrated significantly less analgesia requirement, shorter LOS, shorter convalescence time, and less blood loss intraoperatively in LRN, whilst the transfusion rate, operative time and surgical complications were similar [9–11]. One prospective series suggested postoperative quality-of-life scores were similar [12].

Two RCTs reviewed the retroperitoneal and transperitoneal approach for LRN; overall there are no significant differences in patient morbidity, surgical outcomes, and technical difficulties [13,14].

The only data available for long-term oncological outcomes between LRN and ORN are from comparative series, many of which are of low methodology quality. No differences in overall and cancer-specific survival were found with a follow-up of up to 5 years [12,15–18]. A retrospective series, looking at pT3 tumours in particular, also did not find any differences in survival with a mean follow-up of 28 and 58 months for LRN and ORN, respectively [19].

There are limited comparison data between robot-assisted RN (RARN) and LRN; in the single prospective comparative study identified, other than a longer operative time in RARN, no significant differences were found in estimated blood loss, intra/postoperative complications, LOS, analgesia requirements, and convalescence [20]. The study had a small sample size, and a mere follow-up period of < 1 year, with no cases of recurrence. Several retrospective series of heterogenic surgical techniques also did not show significantly different short-term outcomes between RARN and LPN [21–24]. A retrospective series using the Nationwide Inpatient Sample database in the USA suggested that when compared with LRN, RARN increases medical expenses without conferring an improvement to patient morbidity, with an increase of an estimated $4565 (American dollars) and $11 267 to hospital costs and charges, respectively [25].

When compared with ORN, LRN gives the advantage of shorter recovery (LOS, convalescence), less analgesia requirement and intraoperative blood loss, with similar oncological outcomes even in high-stage tumours. At present there is lack of studies comparing RARN and LRN, and what is available does not suggest any significant advantage of RARN over LRN.

Donor nephrectomy (DN)

The preferred approach for living-DN in established kidney transplant centres is laparoscopic [26]. In centres where the facility for laparoscopy is not available, the open approach, preferably by a mini-incision, is still a valid option [27].

The evidence supporting LDN arose from several systematic reviews and meta-analyses [28,29]. A Cochrane review, which analysed six RCTs (596 participants) comparing LDN vs an open approach for DN, concluded that LDN is associated with less pain, shorter LOS, and earlier return to normal physical activities, with no significant differences in postoperative complications; although the warm ischaemia time (WIT) was longer in the LDN group, this was not associated with any short-term consequences [30].

Another Cochrane review, which included three RCTs (179 participants) comparing laparoendoscopic single-site DN (LESS-DN) with LDN, suggested comparable operative time, blood loss, complication rates, WIT, LOS, and time to return to normal activities; pain scores at discharge was significantly less in the LESS-DN group (two studies, 79 patients: mean difference −1.19, 95% CI −2.17 to −0.21) [31].

In a small series comparing transvaginal natural orifice transluminal endoscopic surgery (NOTES)-assisted LDN with LDN (20 patients in each arm) in living donors, NOTES-assisted LDN appeared to be a safe and feasible surgical technique; the WIT was longer in the NOTES-assisted approach; however, this did not affect graft function [32].

A retrospective controlled trial comparing robot-assisted vs hand-assisted LDN, with 25 patients in the robot-assisted arm and 36 patients in the hand-assisted arm, showed comparable outcomes for recipient creatinine at discharge and postoperative complications [33]. The operative duration was longer for the robot-assisted arm (309 vs 135 min, statistically nonsignificant), whilst most of the patients in the robot-assisted arm were discharged within 4 days (15/25, 60% vs 10/36, 27%; $P = 0.02$).

Partial nephrectomy (PN)

PN is now the ‘gold standard’ for treating small renal tumours [6,34]; much interest has therefore arisen in performing this procedure in a minimally invasive fashion.

Multiple series (mostly retrospective, none controlled) have compared open PN (OPN) with LPN; LPN was generally found to have a longer WIT [35–38] and operative time [36,39], but a lower mean estimated blood loss when compared to OPN [35–37]. One retrospective study in Japan found that in patients who underwent LPN, high body mass index (BMI; $\geq$25 kg/m^2) did not confer longer operative time and higher estimated blood loss when compared to a normal BMI group, whilst patients who had OPN did, suggesting a possible benefit of LPN in patients with high BMIs [37]. Postoperative complications were generally reported to be similar in both groups [35,36,40].

A USA retrospective analysis using the Premier Healthcare Database looked at incidents of unsuccessful PNs (requiring conversion to RN) between 2003 and 2015 and found the rate to be highest in LPN (34.7%), and lowest in robot-assisted PNs (RAPNs) (13.6%); however, there were significant differences between surgeons with different caseload volumes, and it was noted that the overall conversion rate to RNs has dropped dramatically from 33.5% in 2003 to 14.5% in 2015 [41].

The functional and oncological outcomes are comparable between LPN and OPN. No differences were found in overall survival and progression-free survival rate between LPN and OPN [36,37,40,41]. In a matched-pair comparison, estimated GFR (eGFR) decline 24 h after surgery was significantly higher in LPN ($P < 0.001$), but no decline was identified in a mean follow-up period of 3.6 years [40]. In another retrospective comparative study, operative approach (OPN vs LPN) was not found to be an independent risk factor for development of chronic kidney disease (eGFR < 60 mL/min/1.73 m^2) after 5 years of follow-up [38].

The advancement of surgical robotic technology has been applied to LPNs in recent years; in particular, it has been advocated that the robot can facilitate renorrhaphy and reduce the learning curve of laparoscopic suturing [42]. However, at present, there are only a limited number of comparative studies examining the efficacy of RAPN over LPN, many of which are experiences of a single surgeon with no randomisation. They suggest that RAPN may have an advantage over LPN with shorter WIT, operating time and estimated blood loss [42–46]. Generally no differences were found in LOS, postoperative complications, and change in eGFR [42–47]. No difference in the positive surgical margin rate was found between the two approaches [43,45]. To date no studies have examined the long-term oncological outcomes between LPN and RAPN [46].

One retrospective comparative study in a single centre examining RAPN and LPN in complex small renal masses (R.E.N.A.L.[Radius; Exophytic/Endophytic; Nearness; Anterior/Posterior; Location] nephrometry score $\geq$7) did not find any significant differences in WIT, estimated blood loss, transfusion rate, postoperative complications, and decrease in eGFR; however, LPN was associated with a significantly higher conversion rate to RN ($P < 0.001$) [47].

LPN remains a challenging surgical procedure at times, but it has shown comparable functional and oncological outcomes to OPN. There is less estimated blood loss, and in patients with high BMI it may be a better approach, taking into account that there is a higher rate of conversion to RN. RAPN has shown some intraoperative benefits compared to LPN, but more studies are required to examine its long-term oncological results to fully justify the cost.

Pyeloplasty

Pyeloplasty is a well-recognised surgical treatment for symptomatic PUJO in both children and adults [48].

The widespread use of minimally invasive surgery has resulted in the first case of laparoscopic pyeloplasty (LPY) being performed in 1993 [49]. The number of LPY being performed has risen dramatically since, with the number of robot-assisted PY (RAPY) on the rise recently [50].

Major LPY case series found low rates of perioperative morbidities and high success rates, in both retroperitoneal and transperitoneal approaches [51–54]. Studies using renal scintigraphy to confirm postoperative LPY success have shown this to be between 92% and 95.6% [55,56]. A symptom-free success-rate was reported to be 95% [57].

When comparing with open PY (OPY), multiple comparative series suggested that LPY may have a longer operating time, but with a significantly shorter LOS and analgesia requirement, and no difference in complications and postoperative success rates [58–60]. A randomised controlled study comparing the two modalities had similar findings to the comparative series; the mean total operative time was 244.2 vs 122 min, LOS was 3.14 vs 8.29 days, and duration of analgesia was 1 vs 3.14 days for LPY and OPY respectively, with similar success rates [61].

One comparative study looked at re-do pyeloplasty via a laparoscopic or open approach (after a failed initial OPY) in the paediatric population; LPY had a significantly shorter LOS and lower pain score, but with a longer operative time; no significant differences in estimated blood loss, complications and success rates were observed [62].

RAPY has been proposed to have an advantage over LPY by having a shorter learning curve and suturing time; however, at present there are no well-designed RCTs comparing effectiveness between LPY and RAPY [63]. Several comparative series have suggested that RAPY benefits from having a shorter operative time when compared with LPY, but no other differences were found [59,63–65]. A population-based study using the USA Perspective Database found that the median cost of RAPY was significantly higher than OPY, whilst there was no statistical difference between the median cost of OPY and LPY [50].

Overall, all three approaches (OPY, LPY, and RAPY) have comparable outcomes, with differences largely confined to operative time, LOS, and analgesia requirement. RAPY is still largely prohibited by the cost of the robotic instruments, with LPY likely to continue playing an important role.

Conclusion

Evidence with good methodological quality in comparing the outcome (in particular, long-term) of renal surgery is unfortunately scarce, probably due to the practical issues of conducting such trials. The data available to date suggest very similar functional and oncological outcomes of renal surgery regardless of using a laparoscopic, open or robotic approach. A minimally invasive approach (laparoscopic and robotic) confers less blood loss, analgesia requirement, with a shorter LOS and recovery time. An open approach on the other hand often results in shorter operative time, and whilst this may be important due to the impact on WIT in PN and DN, this does not transfer to a better functional outcome when compared with a laparoscopic/robotic approach.

Robotic surgery has often been hailed as the next stage of evolution in minimally invasive surgery. But to date there are no overt benefits demonstrated when comparing between the robotic and laparoscopic approach in renal surgery. Given the significantly higher cost associated as well, it is unlikely that robotic renal surgery will soon become the norm. Another determining factor will be individual surgeon's preference, experience, and local resource availability. Given its widespread use already, laparoscopic renal surgery will still retain a significant role to play in the near future.

Conflict of interest

None.

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