ORIGINAL ARTICLE

The laparoscopic nephrectomy learning curve: a single centre's development of a de novo practice

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Objective: There has been a dramatic increase in the interest and practice of laparoscopic urology, with nephrectomy having become the commonest laparoscopic urological procedure. Compared with open nephrectomy, it results in reduced morbidity and shorter convalescence times while maintaining oncological safety. However, while these results predominately stem from institutions with well developed laparoscopic programmes, little is known about the results in centres that have newly adopted this technique. The introduction of a laparoscopic urological service at the Royal Hallamshire Hospital provided an opportunity to study these factors.

Methods: Since the appointment in October 2000 of a urological surgeon (N Oakley) to develop the laparoscopic service, there have been over 200 laparoscopic procedures including 121 nephrectomies performed at this centre. Full details were collected for each of these cases, and in addition, compared with retrospective data for 50 open nephrectomies performed during the same time period.

Results: With increased operator experience the median operative duration, complication, transfusion, and conversion rates significantly improved. While a learning curve was evident, the overall operative complication (9%) and conversion rates (6%) were low, in addition to patient morbidity (16.5%) and mortality (0%) rates, showing that this learning curve had no deleterious effects upon patient care. The median hospital stay was four days, which reduced to three with experience and was significantly shorter than for open nephrectomy at this institution ($p = 0.001$).

Conclusions: The development of a successful laparoscopic programme can be achieved with a comparatively short learning curve and without detriment to the patient provided the necessary steps are observed.

After the initial description of laparoscopic nephrectomy,[1] there has been a dramatic increase in the interest in and practice of laparoscopic urology. Coincident technological and surgical developments[2] mean that advanced laparoscopic procedures, such as radical prostatectomy, can be performed in many units. The upper urinary tract is particularly suited to the laparoscopic approach and nephrectomy has become the commonest laparoscopic urological procedure.[3] Reports of this procedure have shown that, when compared with open nephrectomy, it results in reduced morbidity, shorter convalescence times, and potentially reduced costs.[4–6] Despite initial concerns regarding tumour dissemination, recent work has established the oncological safety of the laparoscopic approach[7 8] and it is now an established method for performing radical and partial nephrectomy for renal cell carcinoma (RCC)[9] and nephroureterectomy for upper tract transitional cell carcinoma (TCC).[10]

However, there is a significant learning curve with laparoscopy[11] and the widespread introduction of this technique requires careful monitoring and supervision. While the excellent results of laparoscopic surgery from experienced institutions are well established,[12] little is known about the development of laparoscopy and its results outside these institutions. The introduction of a laparoscopic urological service at our institution provided an opportunity to study these factors in a large British teaching hospital.

METHODS

The Royal Hallamshire Hospital (RHH) is a tertiary referral centre in the North Trent region of the UK, covering 500 000 patients. Since the appointment, in October 2000, of a urological surgeon (NEO) to develop the laparoscopic service, there have been over 200 laparoscopic procedures (including 121 nephrectomies). Full details were collected for each patient including their source of referral, indications for nephrectomy, and details of their postoperative rehabilitation. Intraoperative details, such as duration, surgical complications, and blood loss, were collected prospectively at the time of surgery. Operative duration was measured from the time an anaesthetised patient entered theatre (including positioning and draping) to extubation. Incomplete data were present in 20 patients.

Surgical procedure for nephrectomy

The retroperitoneal approach to the kidney is our preferred route to perform the nephrectomy. For this the patient is positioned laterally with a minor degree of table break to remove any obvious skin crease. Our standard approach uses three ports, with an open Hassan's cut down to obtain the initial access and balloon dissection of the retroperitoneal space (Tyco Healthcare).[13] Subsequent ports are inserted under direct vision, and additional 5 mm ports are inserted, when required, for secondary retraction by an assistant.

The nephrectomy is performed outside Gerota's fascia and the peri-renal fat, using a similar plane as for the open radical procedure. The renal artery is clipped five times (using titanium clips) and divided between clip number 3 and 4, leaving three clips on the patient's renal artery stump. The vein is also clipped five times, with non-absorbable locking clips (Hemolock Weck closure system), and divided between number 3 and 4. The specimen is placed into an impermeable sack before removal via an iliac fossa port. For benign pathology, the specimen is morcellated with scissors and

Abbreviations: RCC, renal cell carcinoma; TCC, transitional cell carcinoma

Table 1 Indications for nephrectomy

Indication		Number
Malignant	Renal cell carcinoma	31
	Transitional cell carcinoma	21
Benign	Staghorn calculus	24
	PUJ obstruction	22
	Chronic infection	17
	Other (tuberculosis, polycystic disease, medullary sponge kidney, oncocytoma, malignant hypertension)	6
	Total	121

grasping forceps, before removal of the fragments piecemeal. The specimen is removed intact for malignant disease, permitting formal pathological staging. Nephroureterectomy is performed by combining laparoscopic mobilisation of the kidney with either endoscopic resection and closure of the VUJ (for upper ureter and renal pelvic TCC) or an open approach to the VUJ (for lower ureteric tumours).

RESULTS

The patients undergoing nephrectomy had a median age of 60 years, a median weight of 71 kg, and the majority were female (61%). Previous abdominal surgery had been performed in 38 patients, 15 cases of which involved the retroperitoneum. Patients were referred from three sources; general practitioners for a urological opinion (29%) or RHH consultants (47%) and non-RHH consultants (24%) for a laparoscopic opinion. Complete nephrectomy was performed in 115 cases, of which 61 were simple, 29 were radical, and 25 were nephroureterectomies. Partial nephrectomy (for renal carcinoma (4) and localised symptomatic stones disease (2)) was performed in six patients. Table 1 shows the indications for nephrectomy.

The nephrectomy frequency increased steadily throughout this three year period (fig 1), reflecting both unit development and an increase in patient referral as the service is established. For example, the first case from another hospital was the 13th patient, while 7 of 26 of the most recent cases were from other hospitals. Retroperitoneoscopic nephrectomy, our preferred route, was performed in 87% of cases, with perinephric inflammation (n = 13) or large tumour size (n = 3) in the remaining cases making the transperitoneal route preferable. Nephrectomy was performed using three ports in 89% of patients, with 13 patients requiring additional ports (four ports in 10 cases and five in three cases).

While the overall median operative duration was 150 minutes (IQ range130–180), the median duration and variance of the operative time reduced with increased surgical experience (fig 2). The median (SD) duration of the first quarter of cases (169 (67) minutes) was significantly longer than that of the final 30 cases (138 (42) minutes, *t* test $p = 0.05$). Furthermore, if nephroureterectomies are excluded, the median operative time was less, and for the last 30 cases was 120 minutes.

All operations were completed successfully, with seven cases (6%) requiring conversion to open nephrectomy (table 2). The reasons for conversion were failure to progress secondary to adhesions (in three cases), uncontrollable haemorrhage (two cases), IVC trauma (one case), and intraperitoneal port placement resulting in inability to maintain the pneumoretroperitoneum (one case). With the exception of the cross stapled IVC (repaired through a rooftop incision), each conversion was accomplished through an incision created by joining two of the laparoscopic port sites. The conversion rate decreased with experience (six

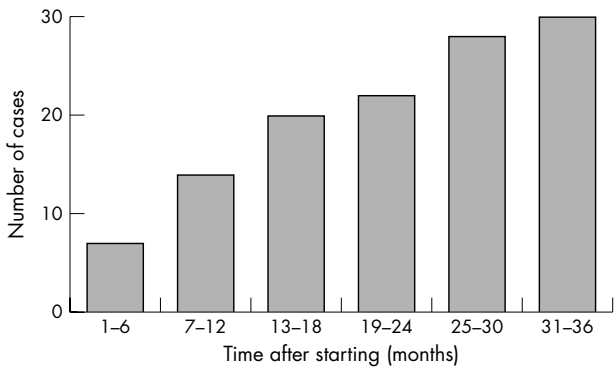

Figure 1 Increasing workload with unit development. The number of nephrectomies performed in each six month interval steadily increased over the three year period.

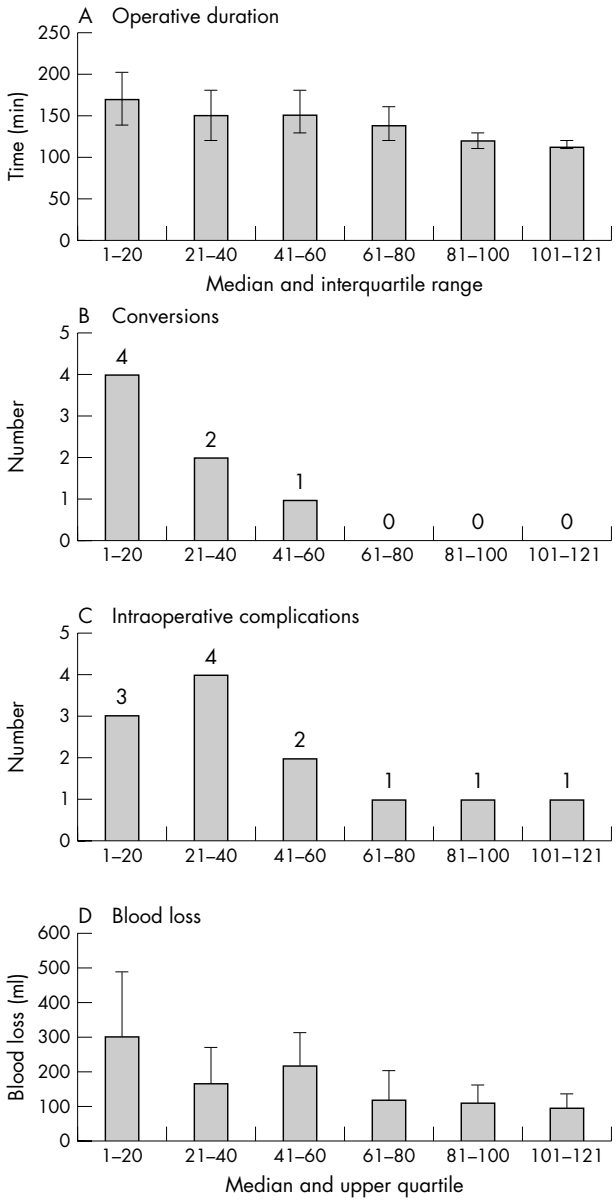

Figure 2 Intraoperative details for the 121 consecutive laparoscopic nephrectomy cases.

Table 2 Reasons for conversion to open nephrectomy (seven patients (6%) required conversion)

Reason for conversion	Number
Adhesions	3
Uncontrollable haemorrhage	2
IVC trauma	1
Intraperitoneal port placement	1

conversions in the first 18 months compared with one conversion in the last 18 months, χ^2 $p = 0.01$). The mean blood loss was 137 ml (range 0–2000 ml) and 14 patients (11.5%) required blood transfusion (mean = 3 units (range 2–8)).

While there were no patient deaths in this series, 12 patients (10%) had significant intraoperative complications, and these are listed in table 3.

Postoperatively two patients underwent open exploration of the renal bed (in the few hours after surgery) for refractory hypotension suggestive of haemorrhage, but in neither case a significant bleeding vessel was identified. Twenty patients (16.5%) suffered other postoperative complications and these are listed in table 4.

According to a developed anaesthetic protocol most patients (64%) had an epidural for analgesia, which stayed for a median of one day. A mean of 10 mg morphine and 12 g paracetamol was additionally required for analgesia. The median time for the return of functions after surgery was one day for drinking (range 0–4 days), two days for eating (range 1–7), two days for mobilisation (1–6), and four days for discharge (2–18). These compared favourably with the same parameters for the last 50 open nephrectomies performed during the same period (fig 3).

DISCUSSION

Our results represent the initiation and development of a large retroperitoneoscopic nephrectomy series. They show that there is a learning curve associated with laparoscopy, but it is of minimal consequence to the patient if undertaken by a responsible team and with the support of non-laparoscopic colleagues. They show that the benefits of the laparoscopic approach to the urinary tract are applicable to units outside those institutions with longstanding laparoscopic practices and that the retroperitoneal route to the kidney and its adnexae can be learnt without significant morbidity and mortality.

The learning curve of laparoscopic surgery is poorly defined, a concern to many potential laparoscopic surgeons[14] and may be different for individual surgeons, procedures, and routes taken. For example, retroperitoneoscopic renal surgery lacks visible anatomical landmarks, has lots of perinephric fat, and a limited working space when compared with transperitoneal surgery. To investigate the effect of operator

Table 3 Intraoperative complications (12 patients (10%) encountered complications during surgery)

Complication	Number
Bleeding	4
Peritoneal tear	5
Urine extravasation	1
IVC cross stapling	1
Rupture of the specimen sac	1

Table 4 Postoperative complications (in total, 20 patients (16.5%) suffered from 24 complications after surgery)

Complication		Number
Respiratory	Atelectasis	3
	Pneumonia	1
Cardiovascular	Myocardial infarction	1
	Heart failure	2
Wound	Haematoma	5
	Persistent leak	1
	Subcostal neuropraxia	1
	Psoas haematoma	1
Gastrointestinal	Ileus	3
	Haematemesis	1
General	Confusion	1
	Jaundice	1
	Fever ?cause	3

experience Higshihara *et al* studied eight surgeons with between 12–48 months laparoscopic experience.[11] The authors found that while the open conversion rate, transfusion rate, and blood loss did not differ with increasing experience, operations became significantly quicker. We also found that the operative duration was a good marker of the learning curve, with it (and blood loss) reaching their median values (similar to multi-institutional published results)[12] after 20 cases. While the intraoperative complication rate peaked after 20 cases (between 21–40 cases (fig 2)) this may not reflect a learning curve as there are few complications in each time period (four compared with two). Significantly, a change of practice also occurred during this phase of development as more difficult cases were performed including radical nephrectomy and complex simple nephrectomy (cases with previous surgery).

The learning curve in our series represents the improvement of both surgeon, from experience and practice, and the entire team at managing laparoscopic patients. While surgical improvement can be detected by the reduced operative duration, blood loss, and complications, it is harder to measure the improvement in other care aspects. In terms of hospital stay, our median time of four days compared less favourably than the length of stay from some of the other published series. However, our increased experience facilitated the introduction of an integrated care pathway to streamline patient rehabilitation, after which there was a trend for quicker discharge, and for our last 30 cases the median hospital stay was three days. This compared favourably against the median stay of 6.5 days from open nephrectomy at our institution (*t* test $p<0.001$), confirming the financial and rehabilitatory advantages of the laparoscopic approach.

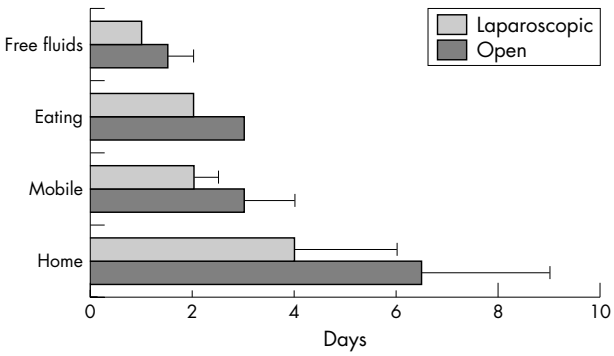

Figure 3 Open compared with laparoscopic recovery times (median plus upper quartile shown).

Table 5 Comparison with the literature from the past 10 years (2063 patients from 23 published series)

	RHH (all 121 cases)	Literature	RHH (last 30 cases)	p Value (last 30 against first 91 cases)
Duration	140 min	160 min	120 min	0.012*
Blood loss	130 ml	190 ml	105 ml	0.871
Complication rate	17%	15.4%	12%	0.847
Conversion rate	6%	5%	0 %	0.201
Oral intake	1 day	1 day	1 day	0.902
Home	4 days	4.1 days	3 days	0.192

p Values represent a Student's *t* test except complication and conversion rates, which represent χ^2 tests; *significant.

To disseminate laparoscopic urology in the UK a programme of training and education has been implemented by the British Association of Urological Surgeons (BAUS) and a mentor scheme is being developed.[15] Thus competent laparoscopic surgeons train colleagues in dry and wet laboratories before teaching progresses to mentored cases. To develop the trainee's competency, they may perform a number of cases assisted by the trainer at their own institution. Fabrizio *et al* reported the use of such a scheme for laparoscopic radical prostatectomy and found that it decreased the learning curve of individual surgeons, while maintaining operative standards.[16] Similar results were found by Frahat *et al*, using a mentored approach to train for paediatric laparoscopic renal surgery, who also reiterated the importance of continued assessment of laparoscopic results.[17] Thus, the mentored approach to laparoscopic training, when combined with objective assessment,[18] seems to be the best model for the widespread implementation of laparoscopic urology.

While our series seems to show a learning curve, improved results with increased experience, it does not detrimentally affect patient care. Seventy five per cent of our intraoperative complications and 100% of conversions to open nephrectomy occurred in the first 60 patients, and the overall intraoperative and postoperative complication rates seem similar to those from previously published reports (see table 5).[5] Fahlenkamp *et al* reviewed 2407 laparoscopic procedures from four German institutions and found the operative complication rate for nephrectomy (n = 351) was 8.2%.[19] The authors divided laparoscopic injuries into those related to access (for example, trocar related), dissection, laparoscopic technique associated (for example, hypercarbia, emphysema), and complications of the wound. Their results showed that most complications were related to surgical dissection and resulted in bleeding or visceral damage. Of note, there were fewer visceral injuries by surgeons using the retroperitoneal rather than transperitoneal approach to the kidney and the complication rate reduced with increasing experience, from 13.3% (for the first 100 cases) to 3.6%. Soulie *et al* reviewed 171 retroperitoneal nephrectomies from three French institutions and found a complication rate of 15.8%,[20] while Vallancien *et al* found in their series of 1311 laparoscopic procedures, of which 162 were renal procedures, a complication rate of 12% and a conversion rate of 7%.[21] Gill *et al* reviewed the first 185 nephrectomies performed at five centres in the USA and found a complication rate of 16%, which led to a prolonged hospital stay in most cases (77%).[22] More recent reports from the Cleveland clinic have focused on individual laparoscopic renal procedures and have shown major complications in 4% of radical nephrectomies[23] and 12% of nephroureterectomies.[24]

In conclusion, our results represent the de novo development of a contemporary laparoscopic practice at a single UK centre, and show that the development of a successful laparoscopic programme can be achieved in units outside those institutions with longstanding laparoscopic practices. The benefits of this approach to the kidney are numerous and should not be denied to patients because of lack of availability. The retroperitoneal route to the kidney and its adnexae can be learnt without significant morbidity and mortality, and the significant advantages in terms of reduced postoperative pain, shorter hospital stay, rapid convalescence, and better cosmesis make this the gold standard technique for nephrectomy, and offer strong incentives for urologists and patients alike. We believe that the laparoscopic approach to the kidney is now the default approach to the kidney for benign and malignant disease, although their remains an ever reducing number of absolute and relative indications for open nephrectomy. The acquisition of the necessary skills and experience to perform laparoscopic nephrectomy, for benign pathology and small to moderately sized renal tumours (including TCC of the upper urinary tract), can be obtained with a comparatively short learning curve and without detriment to the patient provided the necessary steps are observed. Novel techniques to deal with these pathologies should now be judged against the results from laparoscopic surgery.[25]

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