Anaesthesia for laparoscopic urological surgery

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Laparoscopy for urological surgery is a relatively recent surgical innovation. Some centres have substantial experience of single operations, but very few have experience with a comprehensive range. Our programme began with nephrectomy and pyeloplasty, and has expanded to provide for a living related kidney donor programme and for other procedures usually conducted open. Recently, it has included prostate and bladder cancer surgery. The learning curve and implications for anaesthesia are described on the basis of the experience of one anaesthetist with 124 patients. Perioperative care issues, in common with other abdominal laparoscopic procedures, relate to operating positions, the consequences of carbon dioxide under pressure in the abdomen and postoperative analgesia. There is only a small requirement for regional anaesthesia supplementation and invasive analgesia. The corporate laparoscopic cholecystectomy experience was used as the foundation for anaesthesia and to delineate specific organ system issues and any interventions. Significant differences were found in the spectrum of the urological patient population and comorbidity, notably renal function or dysfunction, and complications.

Keywords: donors, organ transplantation; kidney, transplantation; pain; surgery, laparoscopy; surgery, urological

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Background

The effects of carbon dioxide under pressure in the abdomen were determined more than 30 years ago, largely in gynaecology. They include effects on the cardiovascular system, mechanical consequences of pneumoperitoneum, neurohumoral responses, systemic absorption of carbon dioxide and physiological changes associated with patient positioning. Working practice and insufflation pressures that minimize the haemodynamic, compression and absorption consequences have been established. Many potential pitfalls, including changes in functional residual capacity and physiological deadspace and tracheal tube movement, have been defined and complications such as gas embolism have been reported.

Although renal and upper urinary tract procedures have sufficient in common for laparoscopic cholecystectomy to be the model, it was anticipated that there would be other dynamics, some due to handling the genitourinary system, some organ-specific issues, some important differences in

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case mix and comorbidity, and some differences in positions for operations.2328

Stability of renal function during laparoscopic cholecystectomy is obtained by limiting inflation pressure and minimizing movement of the kidney.16 Nevertheless, renal cortex and medullary blood flow, glomerular filtration and creatinine clearance fall, and urine production decreases. Handling the kidney increases plasma renin and antidiuretic hormone release.15 16 28

The required patient position for prostate and bladder surgery (head down/Trendelenburg) means that there is an additional carbon dioxide pressure dynamic on the cerebral circulation. Paradoxical forces act on cerebral blood flow (CBF): rises in carbon dioxide blood tension increase it, whereas intra-abdominal pressure and central haemodynamic effects reduce it.15 16 28 In an animal model, a rise in intra-abdominal pressure combined with adoption of the head-down position caused a 150% rise in intracranial pressure (ICP).19 20 Both CBF and ICP will tend to increase but any additional rise in carbon dioxide tension is potentially catastrophic.

The pathophysiological knowledge indicated where intervention might be required. Firstly, for renal protection and preservation a clinical decision about diuresis, its enhancement or forcing and its timing, was required. Secondly, and at a later date, it was recognized that the necessity for the Trendelenburg position would mean that measures might be required to protect the dependent cerebrum.

**Patient selection**

In assessing the patient preoperatively, the consequences of the rise in intra-abdominal pressure were a primary consideration. Some sense was gained of how the individual might react to positive pressure ventilation, fluid challenges and other mechanisms normally employed to counter rises in intra-abdominal pressure. However, the factoring for anaesthesia included the known benefits of laparoscopy. Reduced blood loss and tissue trauma, less pain and shorter hospital stays make laparoscopy better in the longer term for the less fit patient.

The need for the Trendelenburg position negates some of the advantages of laparoscopy. Thus selection for operation depends on clinical judgement and assessment as to whether the patient could withstand a prolonged period in the head-down position. A history of significant cardiovascular comorbidity, cerebrovascular disease or glaucoma are viewed by those with extensive experience as absolute contraindications for pelvic procedures such as prostatectomy and cystectomy.25

**Anaesthetic technique**

Premedication with temazepam 20 mg orally was followed by induction of the non-depolarizing muscle relaxant propofol 100–200 mg and tracheal intubation. An anaesthetic mix of remifentanil (5 mg in 50 ml at 0.5–1.0 µg kg⁻¹ min⁻¹) and sevoflurane (0.8–1.5 MAC) was used for maintenance.26 The choice of muscle relaxant was vecuronium 8–10 mg. The less cumulative atracurium was used for five patients, because of pre-existing renal dysfunction or total absence of function, and an anticipated operating time of ~2–3 h. Oxygen 30–40% in air was used for ventilation and to carry the volatile agent.

A 22 g i.v. cannula was dedicated to the remifentanil infusion, a 14 g cannula was used for i.v. fluid maintenance, drugs and blood, and a long antecubital or forearm line (Cavafix 50 or 75 cm) was used for central venous pressure measurements. These were sited well away from any vascular access for dialysis. In bilateral nephrectomies and for patients with major comorbidities, such as poorly controlled hypertension, a triple-lumen cannula was sited in the internal jugular vein. In five patients who had a definite or high likelihood of being rendered anephric, a large-bore (12Fr) multilumen catheter was inserted into the right internal jugular vein after induction of anaesthesia for early postoperative dialysis.

Initially, invasive radial arterial monitoring was used reluctantly. Indications were large lesions in patients with severe renal and/or hypertensive disease, patients with significant cardiac comorbidity and patients requiring prolonged Trendelenburg positioning. It was felt that arterial cannulation used unselectively would be a significant risk factor as in the early learning phases the site was potentially difficult to see for more than 6 h. Later, less reserve was shown as the time for all procedures fell to <6 h.

Analgesics and antiemetics were introduced towards the end of the procedures, usually as the remifentanil was reduced or stopped and completion of the operation was anticipated. These were usually ketorolac 10–20 mg, ondansetron 4 mg and diamorphine 5–10 mg. Dexamethasone 4 mg was added for patients at high risk of postoperative nausea and vomiting.10 Non-steroidal anti-inflammatory drugs were avoided in patients with borderline renal function.

**Intravenous fluid management**

In ASA I and II patients, routine preloading with approximately 1 litre of colloid–crystalloid was used to replace any fasting deprivation and to counteract any immediate effect on venous return of the increase in intra-abdominal pressure. In ASA III and IV patients and those with renal failure, ranging from unilateral and global dysfunction to anephric patients, a more cautious and judicious use was made of fluid loading. Those already on dialysis were prepared to be in the normal electrolytic range and of normal dry weight. Because of the requirement for the adoption of the Trendelenburg
position in prostatectomy, it was felt that initial fluid loading would be inappropriate for these patients (see below).

Experience base
To date some 250 procedures have been carried out (Table 1). The total experience is tabulated, together with the experience and analysis of the anaesthetist (IDC) who performed the unit’s first procedures and covered the surgeons’ learning periods.

Operating positions and conduct
Renal operations and pyeloplasties were conducted in a near-full lateral position with some extension break at the waist. The upper limbs rested, folded at the elbow, close to the head in a convenient neutral position. Prostatectomy and cystectomy required the patient to be supine and a steep Trendelenburg (>30%) applied. If robotic systems such as Aesop (voice-modulated camera function) or Da Vinci (three-dimensional manipulation) are adopted, a steeper Trendelenburg may be required.

Several other precautions were taken. The upper limbs of supine patients (prostatectomy, cystectomy) were placed at the side so that surgical access was not restricted. Particular care was taken in padding pressure points. As arterial lines and venous lines were out of sight for up to 12 h, the number of junctions and three-way taps was minimized.

In some units it is routine to insert nasogastric tubes in laparoscopic prostatectomies,25 because conjunctival burns have occurred as a result of spillage of acid content on to the face. Our practice was to insist on a constant view of the patient’s face, and only use nasogastric tubes in those with a history symptomatic of reflux (not implemented).

Monitoring and measuring
Much of the operation takes place in low-light conditions in order to reduce the amount of light pollution on the VDUs. Good-quality highly visible monitoring signals are essential.

In addition to routine monitoring of the ECG, non-invasive blood pressure, pulse oximetry and end-tidal gas, particular attention was paid to end-expired carbon dioxide, central venous pressure changes and urine output (when accurate). Summary data for the end-expired carbon dioxide and central venous pressure changes relative to pre-insufflation values, and if and when the Trendelenburg position was adopted, are given in Table 2.

There was no observed evidence of the changes from baseline not being tolerated and little indication that significant adaptation occurs over time. There was some evidence that ventilation periodically needed resetting to maintain a normal end-expiratory CO₂, and that this was a more frequent requirement during retroperitoneal laparoscopy. Marked and sudden changes were accounted for (see below).

Accurate monitoring of urine output was regarded as important, but in several operations (pyeloplasty, nephroureterectomy, prostatectomy) there were interruptions to the urinary tract and urine flow that made it unrealistic.

Suction, made up of a mixture of flush (saline), blood and urine, was not a reliable measure of blood loss. A significant amount pooled within dependent parts of the abdomen, occasionally tracking into the thorax as a result of diaphragmatic perforations, notably, in our experience, when working in the vicinity of the spleen. In long operations and when there was evidence of excessive blood loss, haemoglobin

Table 1 Laparoscopic operations. *Single anaesthetist series

<table>
<thead>
<tr>
<th>Operation</th>
<th>n</th>
<th>Mean age* (range) (yr)</th>
<th>Mean weight* (range) (kg)</th>
<th>Mean operating time (range) (min)</th>
<th>Median blood loss (range) (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nephrectomy (simple and radical)</td>
<td>60</td>
<td>28/25</td>
<td>83 (54–132)</td>
<td>164 (70–270)</td>
<td>&lt;100 (&gt;700)</td>
</tr>
<tr>
<td>Pyeloplasty</td>
<td>28</td>
<td>15/13</td>
<td>74 (47–98)</td>
<td>162 (70–270)</td>
<td>&lt;100 (&gt;700)</td>
</tr>
<tr>
<td>Nephroureterectomy</td>
<td>13</td>
<td>7/6</td>
<td>78 (48–108)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Donor nephrectomy</td>
<td>1</td>
<td>32</td>
<td>71</td>
<td></td>
<td>(140–180)</td>
</tr>
<tr>
<td>Bilateral nephrectomy</td>
<td>3</td>
<td>2/1</td>
<td>55 (40–62)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partial nephrectomy</td>
<td>4</td>
<td>2/2</td>
<td>83 (61–127)</td>
<td>(230–660)</td>
<td></td>
</tr>
<tr>
<td>Prostatectomy</td>
<td>12</td>
<td>12</td>
<td>76 (66–92)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cystectomy and ileal conduit</td>
<td>1</td>
<td>1/0</td>
<td>72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (e.g. abdominal orchidectomy, renal cysts)</td>
<td>2</td>
<td>2/1</td>
<td>21–29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>124</td>
<td>260</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2 Intraoperative changes in end-tidal carbon dioxide (E\(_{\text{CO}_2}\)) and central venous pressure (CVP) from pre-insufflation levels

<table>
<thead>
<tr>
<th>Operation</th>
<th>n</th>
<th>Mean E(_{\text{CO}_2}) (range) (kPa)</th>
<th>Mean CVP (range) (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nephrectomy (simple and radical)</td>
<td>27</td>
<td>1.75 (0.4–4.0)</td>
<td>8.6 (2–16)</td>
</tr>
<tr>
<td>Pyeloplasty</td>
<td>14</td>
<td>1.3 (0.3–2.6)</td>
<td>8 (2–16)</td>
</tr>
<tr>
<td>Nephroureterectomy</td>
<td>4</td>
<td>1.45 (0.8–2.2)</td>
<td>8.5 (4–14)</td>
</tr>
<tr>
<td>Donor nephrectomy</td>
<td>1</td>
<td>4.3</td>
<td>13</td>
</tr>
<tr>
<td>Bilateral nephrectomy</td>
<td>4</td>
<td>1.3 (0.7–2.2)</td>
<td>9 (4–14)</td>
</tr>
<tr>
<td>Partial nephrectomy</td>
<td>7</td>
<td>2.3 (0.4–4.8)</td>
<td>17 (11–23)</td>
</tr>
<tr>
<td>Prostatectomy</td>
<td>1</td>
<td>2.3</td>
<td>23</td>
</tr>
<tr>
<td>Cystectomy and ileal conduit</td>
<td>1</td>
<td>2.3</td>
<td>23</td>
</tr>
<tr>
<td>Other (e.g. abdominal orchidectomy)</td>
<td>58</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Laparoscopic urology
levels (Hemocue) were measured hourly. Prior to the adoption of this practice, there were occasions when postoperative anaemia suggested that a blood loss of 100 ml h⁻¹ may not have been accounted for by estimates made during surgery.

**Diuresis**
Mannitol 10% or 20% at 1–2 g kg⁻¹ was the routine method for forcing urine flow. The rationale was intuitive and three-fold: to promote urine flow to flush out and maintain urinary tract patency, to preserve renal tissue and conserve renal function, and as a prophylactic against cerebral swelling. Application and timing were empirical to the operation (Table 3). In the case of donor nephrectomy, a urine flow of 300–500 ml h⁻¹ is sought. Frusemide may also be required to maintain this level until the kidney is removed.

**Cerebral protection**
In addition to an osmotic diuresis towards the end of the procedure, the routine for the prolonged head-down position included restricted fluid loads and maintenance while so positioned and increases in ventilation rates to adjust for rises in end-tidal carbon dioxide. Two patients were given a loop diuretic (frusemide 20 mg) at induction. So far, no other clinical measures have been necessary. One patient with a previous posterior fossa craniotomy for removal of a cerebellar haemangioma underwent laparoscopic nephrectomy. In recognition of the presence of a ventriculoperitoneal shunt, the operative approach was extraperitoneal and insufflation pressure was minimized. Ravaoherisoa and colleagues have suggested the use of intraoperative transcranial Doppler monitoring for similar cases.

### Complications
The conversion rate to an open procedure in the first 140 cases of the unit series was 4% (two simple nephrectomies, three radical nephrectomies, one nephroureterectomy). Two of these patients returned to theatre because bleeding problems; one, with abnormal renal vasculature, may have had a splenic infarct. Two patients went to a high-dependency unit postoperatively. The remainder returned to the ward after stabilization and pain control in the recovery unit.

The surgical complication rate, again for the first 140 cases, was 6%. These were re-exploration for bleeding (as above), haematoma and ileus (two patients), diaphragmatic tear (two patients; see below), small bowel obstruction (one patient), prolonged drain loss (one patient), prolonged post-pyeloplasty urine leak (one patient) and subcutaneous haematoma requiring drainage (one patient). The non-surgical complication rate was 2.7%, and consisted of postoperative hypoxia in a patient who had previously had a pneumonectomy and was overhydrated, one readmission to hospital with a chest infection, and two patients with *Clostridium difficile* diarrhoea.

Neither of the deaths in the unit series has been operative, although one, totally unexpected and still largely unexplained even after post-mortem, was categorized as a cardiac event and occurred an hour after discharge to recovery. The other was that of an ASA III patient with cardiac comorbidity and a large renal cell carcinoma who had to be converted to an open procedure and later died from the complications of a massive (>5 litre) haemorrhage.

Unexpected intraoperative events were rare. In two patients with adherent kidneys, a small tear occurred in the diaphragm behind the spleen. Both events were initially suspected to be a result of changes in ventilation-compliance values and/or an unexplained rise in central venous pressure. Both were managed by intracorporeal suturing with a

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**Table 3** Encouraging a diuresis. *Early, shortly after CO₂ insufflation started (prophylactic); Late, once urinary tract repaired and contiguous (therapeutic flushing)*

<table>
<thead>
<tr>
<th>Operation</th>
<th>Rationale</th>
<th>Method</th>
<th>Timing*</th>
<th>Perceived problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nephrectomy (simple and radical)</td>
<td>Conserve other kidney</td>
<td>Mannitol</td>
<td>Early</td>
<td>Urine volume measure inaccurate; urine leaks into abdomen</td>
</tr>
<tr>
<td>Pyeloplasty</td>
<td></td>
<td>Mannitol</td>
<td>Late</td>
<td></td>
</tr>
<tr>
<td>Nephroureterectomy</td>
<td>Conserve other kidney; flush urinary tract</td>
<td>Mannitol</td>
<td>Early</td>
<td></td>
</tr>
<tr>
<td>Donor nephrectomy</td>
<td>Preserve donation; conserve other kidney</td>
<td>Transplant protocol</td>
<td>Early</td>
<td></td>
</tr>
<tr>
<td>Bilateral nephrectomy</td>
<td>Preserve transplant function if applicable</td>
<td>Mannitol</td>
<td>Early</td>
<td></td>
</tr>
<tr>
<td>Partial nephrectomy</td>
<td>Preserve operated kidney; conserve other kidney; flush urinary tract</td>
<td>Mannitol</td>
<td>Early</td>
<td></td>
</tr>
<tr>
<td>Prostatectomy</td>
<td>Cerebral protection Flush urinary tract</td>
<td>Frusemide</td>
<td>Early</td>
<td>Urine volume measure inaccurate; urine leaks into abdomen; interferes with surgery</td>
</tr>
<tr>
<td>Cystectomy and ileal conduit</td>
<td>Cerebral protection Flush urinary tract and ileal conduit</td>
<td>Frusemide</td>
<td>Early</td>
<td></td>
</tr>
<tr>
<td>Other (e.g. abdominal orchidectomy)</td>
<td></td>
<td>Mannitol</td>
<td>Late</td>
<td></td>
</tr>
</tbody>
</table>

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Postoperative pain considerations

The main experience in advanced laparoscopic techniques has been gained outside the UK, and some cultural differences in anaesthesia may be influencing opinion. Based on the assumption that minimally invasive approaches are less traumatic, some units avoid opioids and neuraxial techniques. Whether this is based on medical, nursing or operational reasoning is debatable, but our experience is that there is a requirement for strong analgesics, certainly initially, and sometimes on a regular basis by patient-controlled anaesthesia (PCA).

Once in recovery, most patients needed further doses of opioid (morphine or pethidine in this series) for the first postoperative night to reinforce that administered prior to the end of the anaesthetic. The mean total morphine requirement for radical nephrectomy in our series was 35 mg (range 0–116 mg), and that for nephroureterectomy was 41 mg (1–91 mg). Using opioid PCA systems as the default was found to be counterproductive, increasing the incidence of nausea and vomiting, delaying return of gastrointestinal function to normality and possibly prolonging hospital stay.

Essentially, this aspect of the experience has been hazardous. Currently, as the numbers involved in the service increase, so too has the number of analgesic regimens. Three of these are to be subject to audit: minimal administration of opioids, using simple analgesics (tramadol and diclofenac) in those where renal function is not at risk and opioids for any breakthrough pain; regular oral opioids; full morphine PCA systems.

Generally, the only indication for epidural-based anaesthetic–analgesic techniques is cystectomy and ileal conduit formation, where sympathetically blocked pain can be controlled for a short period of time, but requires a lengthy recovery period. In our experience, the epidural has been found to be useful in this group of patients, but in many cases has led to a delay in discharge due to the need for close monitoring.

Port pain, low abdominal incisions (to extract the kidney), pelvic organ nociception, diaphragmatic irritation (shoulder-tip discomfort from residual pneumoperitoneum), ureteric colic and urinary catheter discomfort have in some part, and on occasion discernibly, contributed to total pain experience and could be analysed and treated using the logic of disaggregation.

Discussion

Surgical outcomes are impressive. The overall experience confirms that of other surgical studies. Surgery endpoints (blood loss, complications, days in hospital, etc.) support the view that once surgical routines are established and practised, the less fit patients are major beneficiaries of procedures with less operative trauma, less postoperative disability and shorter hospital stays. The uncomplicated nephrectomy, once an open operation lasting on average 2 h with a blood loss of 1 litre and a hospital stay of 7–10 days, has been reduced to a 2.5–3 h laparoscopic procedure with a blood loss of less than 300 ml and a hospital stay of 2–5 days. It is only a matter of time before performing a simple nephrectomy by any method other than laparoscopically will be questioned by patients; that is, it is at the same stage in surgical evolution as laparoscopic cholecystectomy and many gynaecological procedures once were. Pyeloplasty has evolved to a similar level (median 3 day hospital stay). Other urological operations are at various stages, from questionable viability (cystectomy) to potential to revolutionize (donor nephrectomy, pyeloplasty, partial nephrectomy, radical prostatectomy). Prostatectomy, which is still in the learning phase, has been reduced from 10 h with operative problems to <6 h. It is anticipated that the routine 3–4 h achieved by centres with experience of >1000 operations will be achieved within a year.

One of the significant lessons that has been learnt is the importance of defining the boundaries for intervention from other disciplines. There is a small requirement for high-dependency or intensive care; only a minority need these to be pre-planned (two in this unit series), and very few need them as an emergency (three in this series).

The range of renal problems faced has been large. In our experience anephric, transplant and other dialysis patients have proved the most problematical. Transplant recipients need considerable planning with their primary renal physicians before undergoing laparoscopic procedures to remove non-functioning or diseased kidneys, as do those with uncontrolled hypertension of renal origin. In the early postoperative period it is important that surgical management takes precedence, and that incidents, such as postoperative bleeding are not further complicated by imperatives for heparinization for dialysis. Four patients with bilateral renal cancer in this series were rendered anephric by surgery and had large-bore dialysis size catheters inserted into the right subclavian vein after induction of anaesthesia. Because of the close proximity of a ventriculoperitoneal shunt, another patient, who was to be left with half a kidney, had a single lumen internal jugular line inserted through which a wire and dilator could be inserted. In the event, this was not required.

Although laparoscopic cholecystectomy has proved a relevant model and yardstick for the processes of surgery, measuring the effect and effectiveness of anaesthetic interventions is handicapped by a lack of robust markers, discriminatory endpoints and the presence of confounders. The routine of monitoring central venous pressure has proved informative, not least for its ability to detect problems or the risk of a potential fatal complication developing, and for monitoring the effects of mannitol infusion. It is recommended. The decision to focus on diuresis as specific and
central to the anaesthetic management of laparoscopic urology has been intuitive and empirical. True urine output is often difficult to gauge, as much may not be captured. However, as far as can be ascertained, the policy of forcing a diuresis has not caused harm or hindrance.

In the main, the anaesthetic experience is that most of the management and techniques adopted have proved near optimal. Small adjustments have been required for the technique to be applied to, for instance, the fully fit donor nephrectomy, the pregnant patient for nephrectomy, the hepatitis B positive alcoholic, the pneumonectomy patient for nephroureterectomy and much of the spectrum of renal morbidity. On the whole, the challenges have been managed safely, counter to the prevailing perception of a need for excessive and invasive monitoring, and the aggressive use of pain-relieving techniques. It is now possible to be confident that methods, experience and proficiency have reached a level such that the application of laparoscopy can be broadened. With the operating time for laparoscopic prostatectomy approaching that of open operation and the overall investment in analgesia being less, it should be possible to downgrade the risk of raised intracranial pressure from an absolute to a relative contraindication to pelvic laparoscopy. This will make the surgery more inclusive, enabling the less fit to reap the benefits of less painful procedures and shorter hospital stays.

References