The Effect on Clinical Outcomes of Low-pressure vs High-pressure Pneumoperitoneum in Minimally Invasive Urological Surgery: A Systematic Review

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Abstract:

Introduction: Reduced pneumoperitoneum pressure has been shown to reduce postoperative pain and length of stay within the field of general surgery. There are multiple Urological operations that use laparoscopic technique using pneumoperitoneum. This paper systematically reviews the literature on the clinical effects of pneumoperitoneum pressure in urological operations.
Method: Two authors independently searched the databases embase, pubmed and medline to identify relevant studies that met the inclusion criteria. The data was extracted and presented within the paper.
Results: 10 studies met the inclusion criteria and were discussed in the paper. All papers agreed that low pressure pneumoperitoneum was non-inferior to high pressure pneumoperitoneum. There was evidence within several papers that there is less postoperative pain and rates of ileus when low pressure is used but the data was not significant.
Conclusion: Low pressure pneumoperitoneum is non inferior to high pressure pneumoperitoneum in urological operations and there is perceived reduction in pain and rates of ileus associated with it. More research is needed to validate this finding particularly in cystectomy and nephrectomy.

Introduction:

Pneumoperitoneum (PNP), the act of introducing gas into the peritoneum, is a requisite in laparoscopic surgery as it creates a space and a visual field. The pressure at which gas is insufflated into the abdominal cavity to create the pneumoperitoneum may influence both peri-operative variables and post-operative recovery (1). When compared to other surgical specialities there is a paucity of research on PNP pressures within urology.

Since the laparoscopic approach to surgery was adopted by surgeons from various specialities, there has been ongoing interest regarding the pressures required to create the artificial PNP. During the current COVID-19 pandemic, controversy has existed regarding the role of laparoscopic techniques and the aerosol-generation necessitated to create the PNP, may have on viral transmission. Limited evidence exists to suggest significant viral transmission occurs although. Recommendations, to mitigate any potential exposure to aerosolised particles, have included the lowering of pneumoperitoneum pressures (to 12mmHg) (2).

Intraoperatively, the use of a higher pressure offers advantages such as an improved visibility and larger space within which to operate in (3). The associated pressure applied to tissues, compressing them, is assumed to reduce peri-operative venous ooze. High pressures conversely have been suggested to potentially cause tissue ischaemia due to compression and diaphragmatic splinting (4).

Postoperatively, laparoscopic surgery is associated with a specific discomfort or pain secondary to the pneumoperitoneum created. This classically presents as abdominal discomfort and referred shoulder tip pain. A lower pressure pneumoperitoneum has been demonstrated in a variety of general surgical operations to reduce this postoperative pain, accelerating recovery times, analgesic use and hospital stay (5).

The Cochrane Meta-Analysis reviewing low pressure laparoscopic cholecystectomy did not demonstrate higher incidence of post-operative complications (5). The aim of this review is to assess the literature to date investigating pneumoperitoneum pressures within the field of urology.

The standard operative pressure varies between different urological operations. In Prostatectomy at present, standard pressure is often considered in the region of 15mmHg (6). For this paper, pressures of <10mmHg will be considered low pressures and high pressures as pressures >12mmHg.

Method:

The primary outcome assessed in this paper was the effect on postoperative clinical outcomes of changing pneumoperitoneum pressures. This included intraoperative blood loss, length of operation, postoperative pain, length of hospital stay, readmission within 30 days, day 1 postoperative haemoglobin and eGFR and complication rates (including ileus, fistula formation, urinary retention and haematoma). A secondary outcome was the safety and viability of the operation. Some studies allocated subjective scores to ‘difficulty’ and ‘progression’ of the operations.

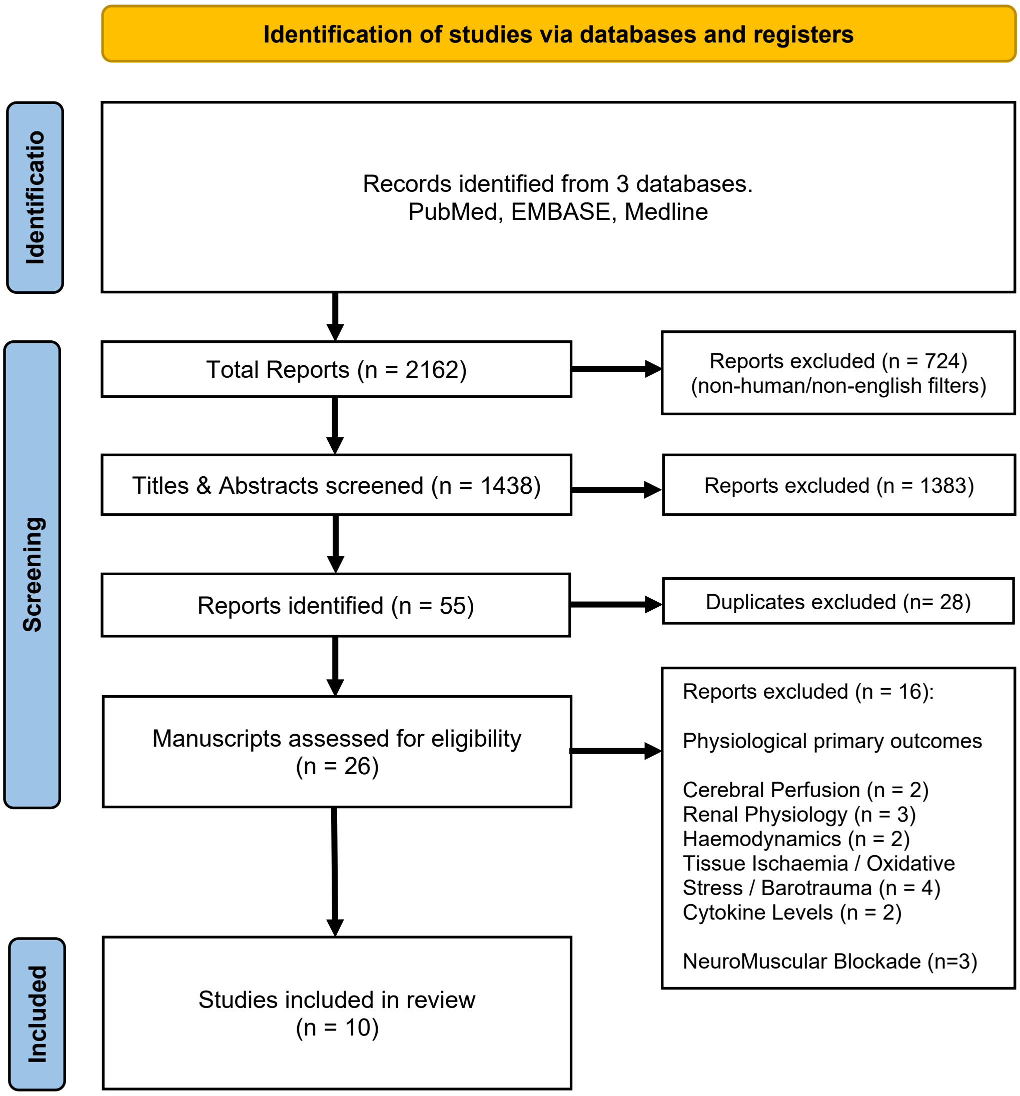
A search of PubMed, Medline and EMBASE databases was performed by two independent authors using the following search terms.
((Pneumoperitoneum[Title]) OR (Insufflation[Title]) OR ("Intra-abdominal pressure"[Title])) AND ((Nephrectomy[Title]) OR (Prostatectomy[Title]) OR (Cystectomy[Title]) OR ("Partial nephrectomy"[Title]) OR (Urol*[Title]) OR (Robot*[Title]))

The titles and abstracts of the papers were screened to ensure they met the inclusion criteria and to ascertain their relevance. The inclusion and exclusion criteria were as described below.

Inclusion	Exclusion
Operations on the Genitourinary system	Primary / Secondary Outcomes: Peri-Operative or Physiological Variables
Primary or Secondary Outcomes: Post-Operative	Non-human models used

Papers that did not report on clinical parameters as their primary or secondary outcomes were excluded. Of note, multiple papers reported from an anaesthesiologist’s perspective and evaluated parameters such as mean arterial pressure or intraoperative lactate. These papers did not meet our inclusion criteria and this data was not reported on.

The subsequent studies that met the inclusion criteria were screened by the two initial authors in full. Having been identified for the review, they were classified by type of operation.



Assessment of Bias

The Risk of Bias in Non-randomised Studies – of interventions (ROBINS-I) tool was used to assess for bias within the non-randomised papers (7). For the randomised studies, bias was assessed using the 'Revised Cochrane risk-of-bias tool for randomised trials (RoB 2).

Randomised Trials – RoB2						
Authors	Randomisation Process	Deviations from Intended Interventions	Missing Outcome Data	Measurement of the Outcome	Selection of the Reported Risk	Overall Judgement
Warle MC.						Some Concerns
Brunschot O.						Some Concerns
Rohloff M. 2020						Some Concerns
Feng T.						Some Concerns
DesrochesB.						High Risk

Unrandomised Trials – ROBINS I							
Authors	Confounding	Selection	Measurement of Intervention	Missing data	Measurement of outcomes	Reported Result	Overall Judgement
Christensen C.							Some Concerns
Rohloff M. 2019							Some Concerns

Ferroni							Some Concerns
Akkok A.							High Risk

Risk of bias	Colour
Low	
Moderate	
Serious	
Critical	

Results:

Prostatectomy

Christensen and colleagues compared a pressure of 12mmHg v. 15mmHg, following a retrospective review of their single surgeon prostatectomy database from 2012 to 2015 (8). They followed up 100 patients who had prostatectomy at 15mmHg and then 100 who had prostatectomy at 12mmHg. The groups were matched well despite there being no randomisation. The primary outcomes that they measured were operative time, blood loss, length of stay, post-operative ileus rates, fistula formation, urinary retention and haematoma formation.

They found that there was a lower rate of postoperative ileus in the low-pressure group however it was not statistically different (4% v. 8% p=0.23). Again, no statistically significant difference was found in any of the outcomes between the groups. From their study, they concluded that the lower pressure PNP was non-inferior. Then with a different group, the same surgeon once again performed a similar retrospective review.

Rohloff and colleagues performed a retrospective review of 400 patients undergoing prostatectomy over a 5-year period. A single surgeon (the same as in the Christensen et al. paper (8)) performed 209 successful prostatectomies at 15mmHg of which, 202 were included in the study (9). The same surgeon then changed practice and performed the remaining 198 prostatectomies at 12mmHg which were included as the second arm of the study. Over a 5-year period, a considerable learning curve is likely to be present and should be accounted for. All perioperative, intraoperative and postoperative parameters were standardised across the operations including the reporting of post operative ileus for which they employed a strict criterion based on symptoms.

Their primary outcomes were the rate of postoperative ileus, complications and length of stay. Secondary outcomes were blood loss intraoperatively and length of operation. Length of stay was significantly reduced in the low-pressure group (1.49 v. 1.76 p=0.022). Postoperative ileus rates were also significantly reduced at 12mmHg vs 15mmHg (10 v. 25 p=0.014). No other parameters were significantly different between the groups. Accounting for the learning curve and retrospective nature of the study, the team demonstrated a significant benefit in performing their prostatectomies at low pressure in reducing length of stay and ileus rates.

Rohloff M and colleagues then went on to perform a prospective, randomised double blind trial where they compared 105 patients undergoing prostatectomy at 12mmHg with 96 patients at 8mmHg (10). They used a computer-generated code to randomise allocation of the patients to a study arm. An unbiassed nurse programmed the pressure into the insufflation device after the DaVinci robot was docked and then the nurse covered the monitor. A single, experienced surgeon (again the same as the previous two papers) performed all the operations. Pressure was not increased during dissection of the dorsal venous complex and a standardised approach was used. At the end of the case, the surgeon was asked to guess the pressure. This was not revealed to them until 30 days after discharge. The surgeon was correct 61% of the time; at 8mmHg they guessed correctly 45% of the time and at 12mmHg they guessed correctly 76% of the time.

The primary outcome was postoperative ileus rates and secondary outcomes included length of operation, estimated blood loss, and positive surgical margin status. There was a decrease in postoperative ileus rates with lower pneumoperitoneum pressures; 2% at 8 mmHg and 4.8% at 12 mmHg however this was not statistically significant (2 v. 5 $p=0.45$). There were also more overall complications in the 12mmHg group versus the 8mmHg group (10 v. 8). Of note in the 8mmHg group, there were 3 Clavien-Dindo 3b complications including 1 delayed rectal injury requiring diversion, 1 general surgery consult for extensive adhesiolysis resulting in enterotomy and 1 small bowel injury requiring resection and anastomosis. The team analysed the video footage of the operation postoperatively and 'strongly felt that these injuries were due to anatomic aberrations and were inevitable regardless of PNP pressure'. There were no significant differences in estimated blood loss, total length of operative time and positive margin status.

No operation required the surgeon to increase PNP pressure intraoperatively due to poor views or difficult progression. Also of interest, there were two independent variables that they found were associated with postoperative ileus rate and they were smoking and the administration of intraoperative IV fluids. The team concluded that Robot Assisted Prostatectomy at low pressures is non-inferior to standard pressures.

Ferroni M and colleagues analysed their prospectively collected single surgeon database comparing 300 patients operated at 6mmHg with their prior 300 patients operated on at 15mmHg (11). Outcomes assessed included pain scores, length of hospital stay, readmission rates and complications. The pressure in the 6mmHg group did not have to be increased intraoperatively in any cases due to poor visibility or lack of progression. They noted that the mean length of operation did not vary significantly between the first 100, second 100 and third 100 cases done at 6mmHg suggesting minimal learning curve differences.

They found that the mean operating time was significantly longer by 10.5 minutes in the 6mmHg group (145.7min v. 155.2min $p<0.001$). They also found that the mean estimated blood was loss, 20 millilitres was higher at 6 mmHg however no blood transfusions were given to either group. Conversely, the mean length of stay was shorter in the 6-mmHg group at 0.57 versus 1.00 days with 43.3% of patients in the 6-mmHg group discharged home the day of surgery. There were no differences in morphine equivalents or maximum pain scores in the first 4 hours after surgery, but there was a small improvement (18%) in pain scores at 5–12 hours postoperatively in the low-pressure group. The 30-day complication rate was 8.7% in the 15mmHg group versus 4.0% in the lower pressure group, with 30-day hospital readmissions of 5.7% for the 15mmHg group vs 1.0% for the 6 mmHg groups. The paper concluded that a lower insufflation pressure provides much better outcomes even given the slight increase in operation time and blood loss.

The final paper on prostatectomy by Modi P. and colleagues retrospectively reviewed their robotic database for a single surgeon, comparing 550 consecutive patients undergoing prostatectomy at 20mmHg versus 201 patients at 15mmHg (6). Conversely, to the other papers in this review, their aim was to test whether a higher pressure was non-inferior to the standard pressure used which is 15mmHg.

Primary outcomes were change of haemoglobin (Hb) and eGFR levels, assessed pre- and post-operatively. Secondary outcomes included complication rate, operative time, and estimated blood loss. They found that the highest-pressure group (20mmHg) group had a significantly reduced estimated blood loss of 249.5ml versus 183.1ml in the standard pressure group ($p<0.0001$). This was also reflected in a significantly reduced change in mean Hb levels in the 20mmHg between the preoperative and postoperative measures (-1.18mg/dL v. -2.13mg/dL $p<0.0001$). No significant difference was demonstrated in complication rates at 20mmHg versus 15mmHg (8.55% v. 8.46%) and no other outcomes showed significant difference.

In conclusion, the team found that a higher pressure of 20mmHg was not inferior to 15mmHG and was safe to use. Though these conclusions can be drawn from this research, unfortunately the team did not perform direct studies with lower pressures as well and so it can be concluded that higher PNP is non-inferior however it does not address whether any benefit is to be gained from using lower pressures which have also been shown to be non-inferior in other studies.

Live Donor Nephrectomy

The gold standard for live Donor Nephrectomy is a laparoscopic approach. PNP pressure is particularly relevant due to the effects of tissue ischaemia on the donor organ. There were several papers on live donor nephrectomy that were not included as they assessed intraoperative physiological parameters from the perspective of an anaesthesiologist. A particular challenge faced in reducing bias in these papers was that male patients have more peri-renal fat than female patients, numbers of arteries vary between patients due to normal variation and the left kidney has more venous branches than the right. All these factors affect the difficulty of the operation.

Warlé M and colleagues undertook a randomised and blinded pilot study where 20 patients were assigned to either undergo laparoscopic donor nephrectomy at 7mmHg (n=10) in the experimental arm or at 14 mmHg (n=10) in the control arm (12). A scrub nurse, not involved in the operation installed the PNP pressure after choosing a sealed envelope allocating the patient to the relevant arm. All screens and monitors displaying the pressure were covered, and healthcare staff performing the procedure were hence blinded.

Primary outcomes were the overall pain and nausea scores rated on a linear scale of 0 to 10 immediately post operation and then every 24 hours for 3 days. The pain scores were collected by a blinded independent observer. They subdivided the pain scores into three dimensions; superficial wound pain, deep intraabdominal pain and referred shoulder pain. Secondary outcomes included length of stay, complications within the first month of the operation and a subjective score by the surgeon on a scale of 1-3 of the 'difficulty' of the operation and the 'progression' (Scores 1,2, or 3 corresponding with an easy, intermediate, or difficult procedure and quick, intermediate and slow progression). At 1 month post operation an SF-36 quality of life score was obtained.

Despite randomisation, discrepancies were observed between the final groups. The low-pressure group contained 6 patients with >1 renal artery whereas the high-pressure group contained 0 patients with >1 renal artery, a significant difference of $p=0.011$. The low-pressure group contained 7 male patients as opposed to 3 in the high-pressure group. Finally, the low-pressure group contained only 1 right kidney whereas the high-pressure group contained 3. Un-blinding occurred in two patients. In one case, conversion from low to high pressure was indicated due to lack of progression secondary to perianal fibrosis and in the other, significant bleeding of >100ml from a vein also necessitated conversion.

Skin-to-skin time was significantly longer in the low-pressure group (111min v. 149min p=0.003); due to the pneumoperitoneum phase of the procedure (86min v. 126min p=0.001). Taking account of the before mentioned discrepancies between the low- and high-pressure groups, this may explain the difference. No statistically significant difference was observed in blood loss, progression or perceived difficulty of the operation. In the low pressure group, there was significantly improved cumulative pain scores after 72 hours for the deep intraabdominal (11 v. 7.5 p=0.027) and referred shoulder pain (4.2 v. 1.8 p=0.049) categories. There was no significant difference for the remaining post-operative parameters (including nausea score, complications and SF-36). The complications included 1 haematoma in the standard pressure group and a pneumothorax and post operative pneumonia in the low-pressure group. The pneumothorax occurred in a patient with severe peri-renal fibrosis where unblinding occurred intraoperatively. Despite this an iatrogenic diaphragmatic injury was the most likely cause of the pneumothorax. As such Warlé and colleagues concluded that live donor nephrectomy is safe at low pressure pneumoperitoneum and the low pressure may convey a benefit to postoperative comfort and recovery.

Similarly, Brunschot D and colleagues (2017) performed another randomised and blinded study on live donor nephrectomy cases comparing PNPs of 6mmHg and 12mmHg (13). They took a cohort of 64 patients and randomly allocated them using a computer-generated code to the two arms of their trial, with 33 patients in the 6mmHg cohort and 30 in the 12mmHg cohort. Unlike Warlé M, they stratified for gender and side of donor kidney to reduce confounding factors however did not comment on number of renal arteries unlike Warle MC et al (12). All surgeons and members of the research team were blinded during the operation. Every 15 minutes surgical conditions were assessed using the 'Surgical Rating Score' (SRS) on a scale of 1-5 (extremely poor, poor, adequate, good and optimal) described by Martini et al (14). Where conditions were less than or equal to three, PNP was increased stepwise by 2mmHg to a maximum of 12mmHg. Where the pressure was already 12mmHg, nurses were asked to pretend to increase the PNP pressure. The primary surgeon was asked to guess which arm of the experiment the patient belonged to at the end of each operation and in 82.5% of cases they were able to guess correctly which has negative implications for the ability to fully blind the surgeon intraoperatively.

The primary outcome was the quality of recovery (QOR) which was measured using the patient reported 'QOR-40 score' on post-operative day 1. The QOR-40 score was further subdivided into sub-sections for physical comfort, emotional status, physical independence, support and pain. Secondary outcomes included analgesia requirements, operative time, blood loss and complication rates.

Intraoperatively, only 23 of the original 33 low pressure operations were completed at PNP 6mmHg which again has implications for blurring of the results in the low-pressure arm. In 2 cases, the PNP pressure was increased to 8mmHg, 2 were increased further to 10mmHg and 6 were raised all the way to 12mmHg thereby converting to standard pressure. The intraoperative timings of these pressure increases are not made clear. The most relevant intraoperative complication that occurred was an iatrogenic bladder injury in a low pressure allocated patient however this patient had been stepped up to 10mmHg before the injury took place and therefore it is difficult to attribute it to being directly caused by low pressure.

No significant difference in the overall QOR-40 score was found between the groups from day 1 to day 7. However, on analysis of the specific dimensions, the low-pressure group had significantly better scores regarding physical support at day 1 (21.9 v. 19.9 p=0.01), emotional status at day 1 (48.4 v. 46.3 p=0.03) and physical independence (21.3 v. 19.7 p=0.01) at day 2. No significant difference in analgesia consumption was observed between the low- and standard-pressure PNP group however the deep intra-abdominal pain component was significantly lower at postoperative day 2 (0.8 v. 1.8 p=0.02) in patients allocated to the low-pressure group.

This study highlights the difficulty in blinding and randomising in surgical trials. Despite this, an inference can be made that low pressure PNP conveys benefits to postoperative recovery and it is safe to begin and complete the operation at low pressure. The possibility of increasing PNP pressure is always available as a tool.

Partial Nephrectomy

Desroches B and colleagues studied 202 patients from three high volume centres to assess the safety of the Airseal insufflation system (AIS) at different PNP pressures compared to a Conventional insufflation system (CIS) at 15mmHg (15). The patients were randomised between three study arms, a 12mmHg AIS, 15mmHg AIS and 15mmHg CIS. They do not mention the method of randomisation or the number of surgeons involved across the three multicentre sites. They also do not mention the laterality of the kidneys operated on, but they do discuss the gender of the patients involved.

The primary outcome was the rate of subcutaneous emphysema. Secondary outcomes were other complications including pneumothorax, pneumomediastinum, intraoperative end-tidal CO_2, peak airway pressure, length of stay, post op pain and complication rate. They also performed a secondary analysis into surgical approach due to the high number of retroperitoneal approaches used.

They found that subcutaneous emphysema was decreased in the 12mmHg AIS group regardless of the surgical approach when compared to the CIS 15mmHg (4 v. 7 p=0.003). They also found that the intraoperative parameters such as end tidal CO_2 and diastolic blood pressure were statistically significantly improved in the 12mmHg group. The paper only mentions that the other outcomes were not statistically significantly different across the groups. The data is also not presented in the paper. The paper found AIS to be non-inferior to CIS and added that there may be benefits from a reduction in PNP pressure when used in conjunction with AIS.

Feng T and colleagues performed a study on 93 patients who they divided into three groups. They varied both the insufflation pressures but also the insufflation device between a conventional gas insufflator (CIS) and an Airseal insufflator (AIS) (16). Each arm of their study had 31 patients randomly assigned to it by a computer-generated code. The arms were AIS 12mmHg, AIS 15mmHg and CIS 15mmHg. Blinding was attempted by using envelopes with the pressures in which were set without the surgeon knowing the pressure. Of note, both a transperitoneal and retroperitoneal approach were used within all arms. Approach was decided based on tumour location with posterior and lateral masses removed by retroperitoneal approach whilst anterior and medial masses were removed trans-peritoneally. Mention is not made of the laterality of the kidney operated on which is important due to the anatomic differences between the right and left. The ratio of males to females in each group was however accounted for which is important due to the increased peri-renal fat in male patients.

Their primary outcome was the rate of subcutaneous emphysema measured intraoperatively with examinations every 30minutes and then also with a postoperative chest Xray. Secondary outcomes included rates of pneumothorax, pneumomediastinum, shoulder pain scores plus overall pain scores measured using a visual analogue scale (VAS), pain medication usage, insufflation time, recovery room time, length of stay and impact of surgical approach.

The incidence of subcutaneous emphysema was significantly lower in the AIS 12mmHg group compared to the CIS 15mmHg group (19% v. 48% p=0.03). They also found that the mean pain score was less in AIS 12mmHg compared to the CIS 15mmHg group (3.1 v. 4.4 p=0.03). There was no significant difference between morphine equivalent use, insufflation time, recovery room time and length of hospital stay. A multivariable regression analysis showed AIS 12mmHg and transperitoneal approach to be the only significant predictors for lower risk of developing subcutaneous emphysema. From the data, there is an inferred benefit to performing partial nephrectomy at a lower pressure and using the AIS system as pain and subcutaneous emphysema rates are lower and it is non-inferior.

Mixed Upper Tract Operations

Akkoc A et al looked at 76 mixed upper urinary tract operations done over a 33-month period. For their study they used three arms, a 10mmHg, 12mmHg and 14mmHg (17). These were allocated as per the table below.

Operation	Group 1 10mmHg	Group 2 12mmHg	Group 3 14mmHg
Simple Nephrectomy (LSN) n=28	9	9	10
Renal cyst decortications (LRCD) n=28	9	9	10
Ureterolithotomies (LUL) n=8	2	3	3
Pyelolithotomies (LPL) n=6	2	2	2
Pyeolplasties (LPP) n=6	2	2	2

Their primary outcome was postoperative pain measured at 6, 12, and 24 hours postoperatively using a visual analogue scale (VAS), ranging from 0 to 10 (0, no pain; 10, the most severe pain). Patients were asked to disregard localized and sharp pain around the port incision to exclude parietal pain. The patients were instructed by the physician to complete the VAS, to evaluate any diffuse, dull aching pains in the abdomen or shoulder, representing visceral and referred visceral pains. Secondary outcomes looked at duration of surgery, intraoperative bleeding volume and length of hospital stay.

They used no randomisation or blinding methods in their study. They grouped multiple different operations together for comparison with unequal numbers in each group. They did not account for the anatomical differences between the left and right kidneys however they did allocate a male to female ratio that had no significant difference. The operations were performed by four different surgeons whose experience was not mentioned or accounted for. The study ran over a 33-month period which also gives rise to the possibility of a considerable learning curve difference. The text mentions that “when necessary, an additional 5mm fourth trocar was selectively used for proper exposure or traction”. Where this was used it could be inferred that more postoperative pain may be experienced however this was not accounted for or mentioned in which operations it was used. Finally, the VAS system used was highly subjective, asking patients to ignore parietal pain and only report deep pain and shoulder tip pain.

Taking account of the considerable bias present in the method, the mean VAS score at 6 hours was significantly reduced in the low-pressure group compared with the 14mmHg group (4.13 v. 5.14 p=0.011). However, there was no significant difference in the mean VAS scores at 24h between the three groups. The mean intraoperative bleeding volume was significantly higher in the low-pressure group compared with the higher-pressure groups (115.42 v. 85.2 v. 79.25 (p=0.03 and p=0.06). They found that the mean operation time was higher in the 10mmHg group than the higher-pressure groups, but this was not statistically significant. The mean length of postoperative hospital stays was also statistically similar among the groups. They concluded that lower insufflation pressures are associated with lower postoperative pain scores in the early postoperative period however considerable bias is present within the methodology.

Discussion:

On review of the published literature to date, studies investigating the effect of pneumoperitoneum pressures during urological procedures are relatively lacking when compared to general surgery and gynaecology. The available literature is divided mostly between papers discussing prostatectomy and live donor nephrectomy with only three other papers identified that discuss partial nephrectomy and other mixed operations. Within this, the papers are divided between those discussing anaesthetic parameters such as the effects of PNP pressure on intraoperative mean arterial pressure and those that were included in this review that discuss surgical and post-operative clinical outcomes.

Though limited, the papers discussing the effects of PNP pressure on clinical outcomes in urological surgery were in agreement that low pressure pneumoperitoneum was non-inferior to standard pressure PNP. One paper by Modi P and colleagues also concluded that a higher pressure of 20mmHg is non inferior to standard pressure (15mmHg) in prostatectomy.

Some papers identified significant benefits associated with the use of low pressure PNP. Several papers identified a reduction in postoperative pain and ileus rates by using lower pressures. Both of these favour a reduced length of hospital stay and one paper had established parameters for discharging low-pressure prostatectomy patients the same day as operating. This aids patient satisfaction and reduces costs associated with overnight hospital stays and their complications.

Low pressure PNP does appear to be associated with significantly longer operating times. This may be secondary to impaired visualisation that can hamper progression. However, despite investigator blinding, patient allocation to a 'low pressure' may be strongly suspected intra-operatively by the surgeon and this will likely influence the time taken at critical operative steps. Moreover, several papers didn't use any blinding and were retrospective studies where the same caution applies.

The anaesthetic and physiological parameters of lower pressure pneumoperitoneum are demonstrated by multiple studies as previously mentioned. These include reduced lactate levels and more favourable cytokine responses (18-22). These findings have a presumptive benefit however, how they translate to reduced complication rates and reduced morbidity and mortality is to date undemonstrated. The benefits may lie in operating on patients with multiple comorbidities where small adjustments in the PNP pressure may make anaesthesia safer and thereby possible.

By starting at lower pressures, a surgeon may gain clinical benefits for their patients and there is always the option to increase PNP pressure where required in haemorrhage to apply compression. This technique is already employed by some surgeons during prostatectomy to aid in the dissection of the dorsal venous complex thereby reducing ooze.

Research is required on the feasibility and safety of performing nephrectomies and cystectomies, at lower pressures. Whether any advantage such as reduced rates of ileus, a common complication following cystectomy, is achievable in all urological procedures is yet to be demonstrated in the literature. Most studies investigated peri-operative anaesthetic parameters and few assessed the post-operative outcomes, including morbidity and mortality, as their primary outcome.

Conclusion:

On review of the published literature to date, performing laparoscopic urological operations under lower pressure pneumoperitoneum appears safe and non-inferior to standard and high pressures.

There is some early evidence to suggest benefits to clinical outcomes of using low pressure PNP but higher-powered randomised trials are required to corroborate this. Further research is needed to investigate the relationship between the cytokine cascades and inflammatory response peri-operatively, during the pneumoperitoneum. Could these be used as predictive indicators for potential postoperative complications? Further research should also include both low pressure pneumoperitoneum during both nephrectomy and cystectomy where to date, there is no literature.

Declaration of Interest:

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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