VENTILATORY AND HEMODYNAMIC CHANGES DURING RETROPERITONEAL AND TRANSPERITONEAL LAPAROSCOPIC NEPHRECTOMY: A PROSPECTIVE REAL-TIME COMPARISON

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ABSTRACT

Purpose: Nephrectomies are currently performed via the transperitoneal or retroperitoneal laparoscopic approach. We compared the ventilatory and hemodynamic effects of these approaches.

Materials and Methods: After institutional ethics committee approval was obtained patients requiring nephrectomy in a 9-month period were prospectively allocated to the retroperitoneal (24) or transperitoneal (15) approach. All were initially ventilated in the volume controlled mode (10 ml kg⁻¹ tidal volume). Intraoperative fingertip, pulse derived arterial oxygen saturation less than 97%, end tidal CO₂ partial pressure greater than 40 mm Hg and peak inspiratory pressure greater than 36 cm H₂O necessitated changes in ventilatory parameters, as deemed necessary by the anesthetist. If tidal volume decreased greater than 25% of baseline, pressure controlled ventilation was begun instead.

Results: Peak inspiratory and plateau pressures increased for the transperitoneal approach by approximately 30% more than in the retroperitoneal group (p <0.05). Volume controlled ventilation was changed to pressure controlled ventilation in 8 transperitoneal vs zero retroperitoneal cases (p <0.05). Heart rate, and systolic and diastolic blood pressure increased by approximately 13% more in the transperitoneal than in the retroperitoneal group (p <0.05).

Conclusions: Nephrectomy via the retroperitoneal laparoscopic approach interferes with ventilatory and hemodynamic functions less than nephrectomy via the transperitoneal approach.

Key Words: kidney, nephrectomy, laparoscopy, pulmonary ventilation

Laparoscopic nephrectomy has recently emerged as a safe and reliable procedure with certain advantages over the open approach.¹ ² This approach has become the technique of choice at an increasingly number of centers for several indications, including simple nephrectomy, living donor nephrectomy, partial or radical nephrectomy and nephroureterectomy.³ There are 2 widely accepted approaches to the 2 latter procedures, namely transperitoneal laparoscopy (TPL) and retroperitoneal laparoscopy (RPL). Although to our knowledge no prospective, comprehensive comparative studies of the 2 approaches have been published, some groups believe that RPL might be advantageous over TPL due to safe port placement, visceral handling with a lesser risk of injury, more rapid access to the renal pedicle and easier renal artery control.⁴ ⁵ Conversely RPL may be technically more challenging because of the smaller working space and port proximity with resulting problematic ergonomy.⁶

Little is known about the impact of RPL insufflation on ventilatory function. We compared the effects of the 2 approaches on ventilatory (primary goal) and hemodynamic (secondary goal) parameters during laparoscopic nephrectomy.


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MATERIALS AND METHODS

Patients who underwent nephrectomy (RPL or TPL) during a 9-month period starting January 2003 were enrolled in this prospective study. The surgical technique was based on the department to which patients were admitted. Procedures were performed by 2 surgical teams, that is a urology team for RP (AN and HM) and a transplantation unit team for TPL (AS and RN), and by 2 anesthetists (AF and YC, respectively). The surgical teams had performed greater than 100 such nephrectomies in the past and, as such, they were experienced with the technique used.

Inclusion criteria included American Society of Anesthesiologists (ASA) physical status I to III, age older than 18 years and body mass index less than 28 kg m⁻¹. Exclusion criteria were asthma, chronic obstructive pulmonary disease, New York Heart Association class 3 or greater, severe liver or kidney disease, previous laparotomy or any emergency situation.

All patients underwent N₂O/O₂ based, isoflurane enriched, intravenously supplemented (propofol-fontanyl-rocuronium), standardized general anesthesia. For TPL patients were positioned in a 60-degree lateral position and pneumoperitoneum was obtained by the Veress needle technique. A standard 3 or 4 port technique was used. RPL procedures were performed with the patient positioned in a 90-degree lateral
position using an open access technique and a retroperitoneal dilation balloon. Gas tight sutures around the first port were used to prevent gas leakage. In all cases insufflation pressure was maintained constantly at 15 mm Hg.

Data were prospectively recorded in a real-time manner and continuously introduced into a database sheet, which was kept by a third party who did not take part in the study. At the end of the study the data were pooled, compared and statistically analyzed. Heart rate via 5 lead electrocardiogram, systolic and diastolic noninvasive blood pressure, respiratory rate, tidal volume, patient side ventilatory pressures, end tidal CO₂ (EtCO₂) and fingertip, pulse derived arterial oxygen saturation (SpO₂) were continuously and automatically recorded via an AS/ST™ monitor. Predetermined time points represented specific anesthesia and surgical events, namely 3 minutes after induction, 3 minutes after patient positioning, 3 minutes after CO₂ insufflation, and at 15, 30, 60, 120 and 180 minutes intraoperatively. Data 5 minutes after desufflation were also representatively recorded.

Prerequisite respiratory conditions that had to be maintained throughout surgery were arterial SpO₂ greater than 97% (or at baseline values), EtCO₂ less than 40 mm Hg and peak inspiratory pressure less than 36 cm H₂O. To maintain them the anesthesiologist could change the respiratory rate, tidal volume or positive end expiratory pressure, or change from volume controlled to pressure controlled ventilation.

Statistical analyses were performed using the 2001 SPSS Release for Windows, version 11.01 (SPSS, Chicago, Illinois). A pre-study power table with δ = 4.2 ± 2.2, where δ represents the 180-minute mean plateau pressure difference recorded in a pilot study, α = 0.05 and power = 0.94 resulted in the need for 10 or greater patients per group. Demographic data (patient age and weight), background characteristics (ASA physical status, baseline heart and respiratory rates, and systolic and diastolic blood pressure), surgery duration, amount of fentanyl administered intraoperatively and intraoperative blood loss were compared between the groups using 1-way ANOVA. Hemodynamic and respiratory values were statistically analyzed. Heart rate via 5 lead electrocardiogram, systolic and diastolic noninvasive blood pressure, respiratory rate, tidal volume, patient side ventilatory pressures, end tidal CO₂ (EtCO₂) and fingertip, pulse derived arterial oxygen saturation (SpO₂) were continuously and automatically recorded via an AS/ST™ monitor. Predetermined time points represented specific anesthesia and surgical events, namely 3 minutes after induction, 3 minutes after patient positioning, 3 minutes after CO₂ insufflation, and at 15, 30, 60, 120 and 180 minutes intraoperatively. Data 5 minutes after desufflation were also representatively recorded.

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**RESULTS**

Of the 24 patients with RPL and 15 with TPL enrolled in the study 18 and 6 with RPL underwent radical and simple nephrectomy, respectively, while 10 with TPL underwent living donor nephrectomy and the remainder with TPL underwent simple nephrectomy. Procedures in either group were comparable with regard to patient demographic and background data, surgery duration and anesthesia aspects (table 1). The latter were also comparable in RPL cases with radical and simple nephrectomy (data not shown).

Figure 1 and table 1 show changes in ventilatory parameters at predetermined time points. Peak inspiratory pressure and plateau pressure changed more extensively in TPL cases than in their RPL counterparts (p < 0.05).

| Table 1. Demographic, surgery and anesthesia data |
|---------------------------------|------------|------------|
| **Parameter**                   | RPL        | TPL        |
| No. pts                         | 24         | 15         |
| Mean age ± SD                   | 58 ± 18    | 55 ± 20    |
| No. men/women                   | 9/16       | 8/17       |
| Mean wt ± SD (kg)               | 74 ± 10    | 73 ± 11    |
| Mean ASA physical status ± SD   | 2.1 ± 0.6  | 1.7 ± 0.6  |
| Mean surgery duration ± SD (min)| 171 ± 23   | 196 ± 33   |
| Mean fentanyl ± SD (µg/kg)      | 293 ± 93   | 335 ± 114  |
| Mean endotracheal tube size ± SD| 8.0 ± 0.5  | 7.9 ± 0.7  |
| Mean total intraop fluid ± SD (ml)| 2,694 ± 540| 2,759 ± 998|
| Mean estimated intraop blood loss| 174 ± 54   | 131 ± 28   |
| Mean operative time ± SD (min)  | 241 ± 40   | 214 ± 74   |

There were no intraoperative complications and significant differences between the groups for listed parameters.

![Figure 1](image-url) **Fig. 1.** A, mean peak inspiratory pressure increased in 2 groups to similar extent during preparations for surgery, although during surgery mean pressure increased more significantly in TPL than in RPL group. Asterisk indicates ANOVA with repeated measures p = 0.03. B, mean plateau pressure increased similarly in 2 groups during patient positioning, although during surgery mean pressure increased more significantly in TPL than in RPL group. Asterisk indicates ANOVA with repeated measures p < 0.02. C, mean calculated lung compliance changed during surgery in TPL and RPL group to dissimilar magnitudes. Asterisk indicates ANOVA with repeated measures p = 0.03. 0, time point just before anesthesia induction. A+3min, 3 minutes after anesthesia induction. P+3min, 3 minutes after patient positioning. C+3min, 3 minutes after CO₂ insufflation.
compliance also decreased more in patients with TPL (25% vs 50%, p <0.05). These differences were statistically significant starting from the time of CO2 insufflation throughout the operative procedure but not during induction and positioning. Ventilatory parameters returned to pre-insufflation values in all RPL cases after desufflation and in almost all TPL cases. Changes in volume controlled to pressure controlled ventilation were made in 8 TPL and zero RPL cases (p = 0.001).

Figure 2 shows changes that occurred hemodynamically during the procedures. Heart rate, and systolic and diastolic blood pressure in the TPL group were higher than in the RPL group for the entire duration of surgery, starting at insufflation time (p <0.05). The fluid that was required to achieve acceptable urine output (1 ml/kg-1/hour-1) was similar between the 2 groups by the end of surgery (table 1).

A vein was torn in 1 patient in each group. Bleeding was immediately identified and the vasculature was repaired. All patients were transferred from the post-anesthesia care unit to the ward uneventfully and discharged home according to customary departmental standards.

DISCUSSION

Laparoscopic surgery is a safe and reliable option for kidney surgery with possible advantages over the open procedures. It is associated with a lower degree of postoperative morbidity and pain, and discharge home is much more rapid. Many renal procedures are currently performed laparoscopically via 2 possible approaches, namely TPL and RPL. With pros and cons for each type, and to our knowledge no comparative controlled randomized studies the surgical approach remains a matter of surgeon preference. In contrast to other studies, which compared laparoscopy vs laparotomy in different patient populations, we studied the pulmonary and cardiovascular effects of pneumoperitoneum vs pneumoretroperitoneum in patients undergoing nephrectomy and nephroureterectomy.

Hemodynamic and respiratory changes have several implications that may impact patient outcome. Thus, there is significance to a decrease in intraoperative cardiovascular and pulmonary disturbances. Briefly, interference with the autonomic nervous system via insufflated CO2 may lead to serious perioperative consequences, such as cardiac arrhythmias. Pneumoperitoneum associated hemodynamic changes in kidney donors negatively affect transplanted kidney function. Finally, laparoscopic surgery may cause atelectasis and hypoxemia postoperatively, which are usually associated with compromised baseline lung function. There are several fundamental anesthesia related differences between the RPL and the TPL approaches, namely 1) exposure to CO2 of the retroperitoneal space or transperitoneal cavity, 2) patients lateral positioning for RPL vs 60-degree lateralization for TPL and 3) pressure on 1 (RPL) or 2 hemidiaphragms (TPL).

The physiological aspects of CO2 insufflation during TPL have been widely studied. Conversely the effects of retroperitoneal insufflation have been studied in limited fashion. Little is known about its interference with ventilatory and circulatory functions in humans during general anesthe-
Our study, which is to our knowledge the first of its kind, demonstrated fewer changes in various ventilatory and hemodynamic parameters when RPL was used compared with TPL. Notably our protocol mandated the maintenance of normal EtCO₂. Several studies have shown that CO₂ absorption during RPL or TPL increases significantly during the first 30 minutes of surgery, attaining a steady state thereafter.19 This coincides with the hemodynamic changes in most of our patients with TPL. Which of the approaches ultimately results in greater CO₂ absorption remains a matter of debate. Bannenberg et al compared the influences of extraperitoneal and transperitoneal insufflation with CO₂ at 15 mm Hg in pigs ventilated at a fixed rate of 12 breaths per minute.15 They observed that TPL was associated with significantly higher peak airway pressure (CVP), EtCO₂, and the appearance of respiratory acidosis attributable to increased CO₂ absorption during transperitoneal laparoscopy. An explanation for this could be the greater surface area for CO₂ absorption (Fick’s principle) during insufflation. Since our protocol mandated the maintenance of a fixed EtCO₂ level, we draw no conclusions regarding this issue except to eliminate the possible peripheral effect of CO₂ on vascular tone.

From studies of the physiological consequences of pneumoperitoneum it is clear that, except for the CO₂ load, there are direct pulmonary and cardiovascular effects from as little as a 10 mm Hg increase in transabdominal pressure14 during CO₂ insufflation. There is cephalad displacement of the diaphragm, causing decreased lung functional residual capacity which, if lower than closing capacity, causes shunt. Increased pressure on the diaphragm also directly compromises pulmonary compliance, which is a measure of lung and chest wall static elasticity. In our series the immediate increase in peak airway pressure and decrease in compliance seen in laparoscopic cases 3 minutes after CO₂ insufflation is consistent with decreased chest wall elasticity secondary to fixed extrinsic pressure on the diaphragm. These measurements are also consistent with data on patients with laparoscopic cholecystectomy, in whom peak airway pressure increased by 18.7% and compliance decreased by 33% upon peritoneal insufflation.7 Similarly compliance was decreased by 27% to 35% in adults undergoing laparoscopic hiatal or inguinal hernia repair,15 during gynecological procedures15 as well as in children,16 correlating almost precisely with our data. The noted, significantly lesser changes in airway pressure and compliance in the RPL group support the hypothesis that a less significant disturbance in pulmonary mechanics occurred in this group. This assertion is consistent with data on piglets,17 in which ventilatory peak airway pressures increased during the TPL approach and remained unchanged during the RPL approach to laparoscopic surgery. Finally, in our study the difference in compliance reflects the greater impact of diaphragmatic excursion when the peritoneal space is insufflated compared with the RPL space. The airway pressure required to maintain normal EtCO₂ was also significantly higher in the TPL group.

Compliance is also affected by patient position. It is established that the Trendelenburg position decreases compliance by about 17%16 and the reverse Trendelenburg position actually improves compliance by about 4%. All of our patients were held flat with varying degrees of the lateral decubitus position. We found insignificant changes in pulmonary mechanics due to positioning alone in our population.

Finally, the hemodynamic effects of RPL CO₂ insufflation were also less than the effects in the TPL group. Systolic and diastolic blood pressure decreased in each group with the induction of general anesthesia, demonstrating the myocardial depressant effects of general anesthesia. Whereas each pressure increased in the 2 groups after CO₂ insufflation, the increase was smaller in the RPL group. Hemodynamic changes with CO₂ insufflation depend on many factors, including patient position, volume status, anesthetic agents, partial CO₂ pressure, transthoracic pressure and transabdominal pressure of insufflated CO₂.15 With CO₂ insufflation pressure less than 20 mm Hg it was reported that CVP and pulmonary capillary wedge pressure (PCWP) as well as cardiac output (CO) increase, probably secondary to increased venous return from the abdominal visceral venous beds. In contrast, when CO₂ is insufflated to a pressure greater than 20 mm Hg CVP, PCWP and CO decrease secondary to decreased venous return from the lower body. When transabdominal pressure is kept between 10 and 15 mm Hg, as in our study and as is clinically relevant, volume status and patient position must be considered. For example, in patients undergoing laparoscopic cholecystectomy the reverse Trendelenburg position is used. CVP and PCWP as well as mean arterial blood pressure (MAP) decrease with positioning but increase with CO₂ insufflation, although CO, which decreases with positioning, further decreases with CO₂ insufflation as systemic vascular resistance (SVR) clearly increases.19 In contrast to these morbidology studies, during laparoscopic nephrectomy patients are euvelemic and are positioned laterally and then, whereas CVP, PCWP and MAP again increase with pneumoperitoneum, CO increases and calculated SVR decreases.20 We assume that this is what occurred in our patients, although we did not measure CO or SVR. The only study that we found that compares retroperitoneal and transperitoneal insufflation in this regard was done in pigs.12 Similar to our results, MAP, CO, and pulmonary artery, central venous and iliac venous pressures for the same insufflation pressure were significantly greater with TPL than with extraperitoneal CO₂ insufflation. Using this animal model Giebler et al concluded that cardiovascular and respiratory changes are much smaller during RPL than TPL CO₂ insufflation even at the same insufflation pressure,14 as shown in our patients. This confirms a less significant hemodynamic effect of retropneumoperitoneum compared with pneumoperitoneum in euvelemic patients positioned on the side. Lateral vs 60-degree positioning alone seems to have had no significant effects on systolic and diastolic blood pressure parameters.

The changes that we observed in heart rate may represent different autonomic system stimulations during transperitoneal vs retroperitoneal laparoscopy. Autonomic system stimulation during CO₂ insufflation is best evaluated by heart rate variability analysis using a fast Fourier transform algorithm.8 We did not use this type of analysis and cannot draw any definite conclusions regarding differences in autonomic stimulation between our study groups.

This study has a limitation, in that there were no radical nephrectomy cases in the TPL group. This was because our general surgeons do not perform radical nephrectomy, whereas urologists do not perform donor nephrectomy. Nevertheless, since radical nephrectomy is a more traumatic procedure than simple nephrectomy, the fact that patients with RPL were even so less disturbed in terms of hemodynamics and pulmonary functions compared with patients with TPL ones makes it even more convincing that the RPL technique is more favorable.

To our knowledge our study is the first to prospectively compare ventilatory and hemodynamic clinical changes during retroperitoneal and transperitoneal laparoscopic renal surgery in humans when EtCO₂ and peak inspiratory pressure limits were predetermined. Retropneumoneoscopy associated ventilatory and hemodynamic implications are less deleterious than during transperitoneal laparoscopy. This might indicate an advantage of the former, especially in patients at high risk in whom compromised ventilatory and cardiac function may be less affected by retroperitoneal insufflation. Further experience and larger studies are needed to more precisely define patient specific indications for each of the 2 approaches.
Statistical analyses were performed at the Statistical Laboratory, School of Mathematics, Tel-Aviv University.

REFERENCES


