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The effects of laparoscopic urologic surgery on cardiac functions: A pulse wave velocity study

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ABSTRACT

Objective: The aim of this study is to evaluate the effects of laparoscopic urologic surgery on cardiac functions by the parameter pulse wave velocity (PWV), a noninvasive method.

Material and methods: Between July 2012 and February 2013, a total of 47 patients were included in this prospective controlled study. Patients who have been scheduled for laparoscopic surgery (LS) (n=30) and open surgery (n=17) were enrolled in the study. Preoperative, perioperative, and postoperative cardiovascular parameters were measured by a PWV instrument, and the results were compared between laparoscopic (L) group and open (C) group.

Results: In the L group, compared to preoperative values, perioperative systolic arterial pressure, diastolic arterial pressure, and mean arterial pressure increased considerably, by 2.6%, 7.9%, and 4.7%, respectively. This was in contrary to reductions in these parameters by 9.5%, 5.7%, and 10%, respectively, in the C group. For the L group, cardiac output (CO) and cardiac index (CI) were increased in the perioperative period and decreased in the postoperative period. For the C group, there were no changes in measurements of perioperative and postoperative CO and CI. However, these changes in CO and CI were not significantly different between the L and C groups. Postoperative large artery elasticity index decreased in both groups. However, these changes did not represent significant difference between groups.

Conclusion: Compared to open surgery, LS may cause increases in perioperative blood pressures. In addition, increased blood pressures may last even on the first postoperative day. These effects may be more important for patients with high cardiovascular risk.

Keywords: Laparoscopy; pneumoperitoneum; pulse wave velocity.

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Introduction

Laparoscopic techniques have become a standard approach for therapeutic and diagnostic procedures in urology.[1] Pneumoperitoneum (PP) with CO_2 is the most common approach to achieve a surgical view and working space during surgery. PP with CO_2 has been blamed to affect cardiac functions unfavorably. Its best-known effects on the cardiovascular system are increases in mean arterial pressure (MAP), heart rate (HR), and central venous pressure (CVP).[2] Fortunately, despite increases in preload and afterload indices, clinical complications related to these effects are very rare. However, they may be severe in elderly cardiac patients undergoing prolonged surgery.[3,4] Among these aforementioned studies, to the best of our knowledge, in English literature, there was no study comparing these cardiovascular alterations between laparoscopic surgery (LS) and open surgery.

Many studies used invasive method to evaluate the effects of PP on cardiac functions.[5] Cardiac pathophysiological changes can be assessed by estimating parameters such as contractility and flow by using invasive and noninvasive methods (like echocardiogram and catheterization of large vessels). Pulse wave velocity (PWV) is a simple and reproducible method for measurement of arterial stiffness which can be estimated noninvasively by applanation tonometry.[6] Cardiac output (CO) and cardiac index (CI), which represent left ventricular function together with small artery elasticity

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index (SAEI) and large artery elasticity index (LAEI) which show cardiovascular status in its totality, can be measured in the PWV analysis.[7]

In this study, we evaluated the effect of laparoscopic urologic surgery on cardiac functions compared to open urologic surgery by using PWV.

Material and methods

Patients

After approval of the Uludag University local ethics committee (2012-9/21) and written informed consent from patients, between July 2012 and February 2013, a total of 47 nonconsecutive patients with an American Society of Anesthesiologists (ASA) score of 1 were included in this prospective study. The study group consisted of 26 (55%) men and 21 (45%) women who had been scheduled for surgery due to varied diagnoses. The patients with history of cardiopulmonary disease or taking cardiac and pulmonary medications, with excessive blood loss (intraoperative blood loss greater than 500 mL), under 18 years of age, and with comorbid diseases that may influence cardiac functions were excluded from the study. Before surgery, 8 hours of fasting was required for all patients, and balanced intravenous solution (5% dextrose in water and 0.045% NaCl) was infused at a rate of 3 mL/kg/h.

Anesthesia

Anesthesia was induced intravenously with 0.03–0.05 mg/kg^{-1} of midazolam, 1 mg/kg^{-1} of lidocaine HCL, 2.5–3 mg/kg^{-1} of propofol, 1–1.5 mg/kg^{-1} of fentanyl, and 0.6–1 mg/kg^{-1} of rocuronium and was maintained with 2% sevoflurane in a mixture of 50/50 O_2/NO_2. Positive pressure ventilation parameters were adjusted to maintain end-tidal CO_2 at 35–45 mmHg. Intraoperative crystalloid fluid (lactated Ringer's solution) was infused at a rate of 3–5 mL/kg/h in both groups.

Measurements

Preoperative measurements were performed in supine position in the morning before surgery. For the laparoscopic (L) group, perioperative measurements were gained at a PP pressure of 12 mmHg after the ports had been inserted in the abdominal cavity under the pressure of 20 mmHg in supine position. Referred to different reports, the time of perioperative measurement was performed in the first 15 minutes of operation.[8] Perioperative measurements were performed in the position of the related surgery. The mean operation time was 110±28 minutes. Postoperative measurements were obtained in supine position in the morning of postoperative day 1.

Main Points:

- A randomised study was carried out to evaluate the cardiac effects of pneumoperitoneum on urologic laparascopic procedures.
- Cardiac parameters were mesaured by the Pulse Wave Velocity with applanation tonometry technique.
- Increases in blood pressure may last even postoperative first day and this situation may be important for high cardiovascular risk patients.

The measurements of arterial stiffness were obtained on the radial artery. The Pulse Wave Profiling Instrument HDI (Hypertension Diagnostics, Eagan, MN) was used to determine HR (beat/min), systolic arterial pressure (SAP) (mmHg), diastolic arterial pressure (DAP) (mmHg), MAP (mmHg), estimated CO (EST CO) (L/min), estimated CI (EST CI) (L/min/m^2), systemic vascular resistance (SVR) (dyn.sec.cm^5), LAEI (mL/mmHg×10), and SAEI (mL/mmHg×10). This technique, which analyzes the signal-averaged radial artery waveform based on a modified Windkessel model, correlates well with other methods that measure hemodynamic parameters in humans.[9]

Statistical analysis

The Shapiro–Wilk test was used to test the normality of variables. The variables which are normally distributed are presented as mean±standard deviation. The variables which are not normally distributed are presented as median (minimum–maximum), and while two independent groups were compared by the Mann–Whitney U test, two dependent groups were compared with the Wilcoxon test for these variables. For variables meeting normality assumption, an independent sample Student's t-test was used for comparing two independent groups, and paired t-test was used for comparing two dependent groups. Categorical variables are expressed by counts and percentages. Comparisons between the groups were performed with the Pearson chi-square test for categorical variables.

Results

There were 30 patients (13 males; 17 females) in the L group and 17 patients (13 males; 4 females) in the C group. While the mean age and weight of all patients were 48.6±14.8 years and 75.1±16.2 kg, respectively, there was no significant difference between both groups. None of the patients had previous surgery. There were no significant differences in preoperative values between both groups.

For the L group, according to the baseline values, there were significant increases in both perioperative and postoperative values of DAP, EST CO, and EST CI (p=0.037 and p=0.035, p=0.005 and p=0.014, and p=0.009 and p=0.019, respectively). Postoper-

Table 1. Changes of cardiovascular parameters in the laparoscopic group

Variables	M_1	M_2	M_3	p (M_1 vs M_2)	p (M_1 vs M_3)
SAP	120.0±15.0	125.2±17.6	122.9±12.0	0.110	0.191
DAP	70.4±12.4	76.5±112.3	73.8±9.0	0.037*	0.035*
MAP†	88 (66–112)	96 (65–124)	98 (71–110)	0.090	0.015*
EST CO	5.13±1.11	5.58±0.71	4.86±1.08	0.005*	0.014*
EST CI†	2.89±0.56	3.16±0.40	2.72±0.48	0.009*	0.019*
HR†	79 (62–112)	73 (50–95)	82 (60–104)	0.001*	0.364
SVR†	1366 (589–3902)	1305 (817–2332)	1435 (912–3214)	0.902	0.742
LAEI†	12.5 (4.0–37.7)	12.7 (5.9–24.6)	11.6 (3.8–20.1)	0.323	0.000*
SAEI†	3.8 (1.0–10.3)	4.4 (1.7–16.0)	3.6 (1.6–14.7)	0.861	0.213

Systolic arterial pressure (SAP) (mmHg), diastolic arterial pressure (DAP) (mmHg), mean arterial pressure (MAP) (mmHg), estimated cardiac output (EST CO) (L/min), estimated cardiac index (EST CI) (L/min/m²), heart rate (HR) (beat/min), systemic vascular resistance (SVR) (dyn.sec.cm-⁵), large artery elasticity index (LAEI) (mL/mm Hg×10), and SAEI (mL/mmHg×10). M_1: preoperative value, M_2: perioperative value, and M_3: postoperative value. *p<0.05. †median (minimum–maximum).

Table 2. Changes of cardiovascular parameters in the control group.

Variables	M_1	M_2	M_3	p (M_1 vs M_2)	p (M_1 vs M_3)
SAP	123.5±13.7	112.5±17.3	124.5±13.0	0.010*	0.714
DAP	70.8±10.1	66.5±12.4	71.6±9.4	0.149	0.663
MAP	95 (68–115)	88 (59–116)	96 (72–111)	0.029*	0.981
EST CO	5.39±1.37	5.82±1.18	5.47±1.44	0.122	0.467
EST CI	2.89±0.56	3.11±0.38	2.93±0.66	0.095	0.366
HR	76 (63–101)	75 (52–117)	75 (60–102)	0.538	0.319
SVR	1362 (825–2407)	1117 (628–2153)	1247 (802–3648)	0.019*	0.723
LAEI	13.4 (4.4–27.9)	17.7 (6.7–41.3)	11.0 (3.9–25.5)	0.177	0.055
SAEI	5.9 (2.3–12.6)	4.9 (1.3–16.6)	4.8 (0.8–11.3)	0.865	0.635

Systolic arterial pressure (SAP) (mmHg), diastolic arterial pressure (DAP) (mmHg), mean arterial pressure (MAP) (mmHg), estimated cardiac output (EST CO) (L/min), estimated cardiac index (EST CI) (L/min/m²), heart rate (HR) (beat/min), systemic vascular resistance (SVR) (dyn.sec.cm⁵), large artery elasticity index (LAEI) (mL/mmHg×10), and SAEI (mL/mmHg×10). M_1: preoperative value, M_2: perioperative value, and M_3: postoperative value. *p<0.05. †median (minimum–maximum).

Table 3. Comparison of two groups on the basis of perioperative and postoperative percentage changes relative to preoperative values and patients' demographics

Variables	Laparoscopic surgery group	Open surgery group	p
Age (year)	48.36±14.76	49.11±15.55	0.870
Weight (kg)	72.36±12.72	75.17±16.27	0.515
†Perioperative Δ% SAP	+2.6 (-22, 37)	-9.5 (-32, 19)	0.002*
†Perioperative Δ% DAP	+7.9 (-24, 72)	-5.7 (-35, 28)	0.024*
†Perioperative Δ% MAP	+4.7 (-22, 59)	-10 (-33, 26)	0.006*

Perioperative Δ% SAP: median perioperative percentage changes in SAP. Perioperative Δ% DAP: median perioperative percentage changes in DAP. Perioperative Δ% MAP: median perioperative percentage changes in MAP. †median (minimum–maximum). *p<0.05. SAP: systolic arterial pressure; DAP: diastolic arterial pressure; MAP: mean arterial pressure. Perioperative percentage changes were calculated by the formula= perioperative value – preoperative value.

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ative MAP and perioperative HR increased, while postoperative LAEI fell significantly (p=0.015, p=0.001, and p<0.001, respectively). Table 1 shows these changes in detail.

In the C group, compared with baseline values, there was a decrease in the perioperative values of SAP, MAP and SVR (p=0.010, p=0.029, and p=0.019, respectively) (Table 2).

According to baseline values, when we compared the L group to the C group in perioperative percentage changes in cardiovascular parameters, there was a 2.6% increase in SAP for the L group in contrast to a reduction of 9.5% for the C group (p=0.002). DAP increased by 7.9% in the L group and decreased by 5.7% in the C group (p=0.024). MAP increased by 4.7% in the L group and decreased by 10% in the C group (p=0.006) (Table 3).

Discussion

Nociceptive surgical stimulation increases activity of the sympathetic nervous system activating the hypothalamic–pituitary–adrenal axis. This is generally referred to as the stress response to surgery. The magnitude of the response is directly related to the size of the wound.[10] Thus, it is commonly believed that LS is associated with less surgical stress than open surgery. During LS, it is well known that PP with CO_2 may lead to the release of numerous vasoactive agents causing vasoconstriction. Besides this, the increased intra-abdominal pressure may compress the aorta and other vascular structures resulting in an increase in right and left atrial intraluminal pressures as well as blood pressures. The data from many studies have revealed that PP with CO_2 causes an increase in arterial pressure and hemodynamic disturbances during LS which are mainly due to reduction in venous return.[11,12] Laparoscopic approach (intra/extraperitoneal) and patient's position may also change the severity of such hemodynamic increase. Also, hypercapnia due to CO_2 may cause cardiac arrhythmias and lead to CO decrease.[13,14] Consistent with the literature, we determined an increase in MAP during LS, contrary to a reduction in the C group.[15] Additionally, our study showed that there was an increase in DAP for the L group while a reduction in SAP for the C group. We observed that these three increases in arterial pressure lasted also on the first postoperative day in the L group. In contrast, they were limited to the perioperative period in the C group. This may be caused by the prolonged effect of CO_2. Thus, during both surgical course and postoperative follow-up, this condition may be of great importance for unhealthy patients undergoing LS.

Several authors have reported PP to cause consistent decrease in CI and therefore CO decline.[16-18] They found reduction in CO for normovolemic and hypovolemic groups, while it increased in hypervolemic group. They consequently emphasized the importance of hydration status. Zuckerman and Haneghan reported that patients undergoing laparoscopic cholecystectomy had a significant rise in CO, but this rise was short-lived and lost its statistical significance after the tenth minute of the surgery.[19] We determined significant increases in CO and CI during LS, contrary to the lack of considerable increase in the C group. This may be attributed to our relatively low working pressures and well-hydrated patients. After LS, CO reduced significantly below its baseline values, similar to Zuckerman's result. Our analysis showed that these changes did not differ significantly among groups.

The effect of laparoscopy on HR has been variably reported, being either increased or without change. An increase develops temporarily, if at all present, and returns to its baseline value at the end of the surgery.[5-20] A recent study reported that HR decreased after onset of PP in laparoscopic robot-assisted radical prostatectomy. HR decreased from the 10th minute to 60th minute after PP in Trendelenburg position.[21] Our study showed that HR decreased during LS and later returned to its baseline value. In the C group, perioperative HR did not differ from postoperative and preoperative HR values. These changes in HR were not significantly different between the L and C groups.

Similar to other parameters, there is no consensus on the effect of PP on SVR. The literature has reported variable results.[5-20] Schluermann et al.[22] found a decrease in SVR due to increase in intraabdominal pressure and argued that hyperthermic effect might cause the decrease. Also, SVR alterations might occur due to a patient's position during surgery and due to pulmonary complications. We did not observe any SVR alterations in the L group. We measured perioperative SVR at the fifteenth minute of the surgery. Therefore, we could not observe the course of this change, but perioperative SVR fell considerably in the C group.

LAEI and SAEI are the important parameters of PWV. They are of significant importance in evaluating cardiovascular status in its totality.[7] In the L group, compared to the baseline value, the postoperative value of LAEI reduced significantly. This may result from the late vasodilation-inducing effect of CO_2.

This study comes with limitations. The small sample size is considered the main limitation. Also, this study was conducted on patients without history of comorbidities; therefore, the cardiovascular effects of LS on patients with different ASA scores were not studied.

In the literature, many studies reported different results about the effect of PP on the cardiovascular system. There is a need to reveal clearly these effects on cardiac functions especially in patients with high cardiovascular risk. Thus, large-scale prospective studies including patients with different ASA scores are required.

In conclusion, compared to open surgery, urologic LS may cause increases in perioperative arterial pressures. In addition, increased blood pressures may last even on the first postoperative day. These effects may be more important for patients with high cardiovascular risk. Therefore, there is a need for studies on such patients.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Uludag University (2012-9/21).

Informed Consent: Written informed consent was obtained from patients who participated in this study.

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