Changes of gastric intramucosal pH in obese patients undergoing laparoscopic and open cholecystectomy

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Abstract

Introduction: Gastric intramucosal pH (pHi) reflects splanchnic perfusion, while pneumoperitoneum may cause disturbances in splanchnic perfusion by increasing intra-abdominal pressure (IAP). Obesity is associated with increased IAP. The aim of this study was to compare the effects of laparoscopic cholecystectomy and open cholecystectomy on pHi in obese patients.
Material and methods: Sixty obese patients (BMI 30-40 kg/m^2), aged 30-70 years, scheduled for cholecystectomy under standardized general anaesthesia were randomized to receive either laparoscopic cholecystectomy (LC group, n=30) or open cholecystectomy (OC group, n=30). pHi was calculated using gastric air tonometry. Measurements of pHi occurred in four phases: phase I (after induction of anaesthesia but before surgical incision), phase II (15 min of pneumoperitoneum in the LC group or 15 min after surgical incision in the OC group), phase III (end of operation) and phase IV (60 min after patients' awakening).
Results: Intraoperatively, a slight decrease of pHi was observed in both groups without reaching significance. In contrast, at the 1st postoperative hour a statistically significant difference was revealed between the two groups (OC: 7.41±0.038 vs. LC: 7.37±0.05, $p<0.001$), both due to the ongoing decrease of pHi in the LC group and the tendency of pHi in the OC group to increase. Despite this, pHi values were within normal ranges during our whole observation period.
Conclusions: Laparoscopic cholecystectomy in obese patients compared to open cholecystectomy caused a significant decrease of pHi in the 1st postoperative hour, although pHi remained within normal values.

Key words: laparoscopic cholecystectomy, obesity, gastric pHi.

Introduction

Laparoscopic cholecystectomy seems beneficial in obese patients, although obesity was initially considered a contraindication to this approach [1-3]. Nevertheless, a hypoperfusion-reperfusion human model has been observed during and soon after laparoscopic surgery. Pneumoperitoneum has been associated with disturbances in splanchnic micro-circulation depending on the level of intra-abdominal pressure (IAP) [4]. On the other hand, obesity has been demonstrated that is strongly associated with increased IAP [5-7].

Gastric intramucosal pH (pHi) reflects splanchnic blood flow [8-10]; thus a number of studies have been performed testing the effect of IAP on pHi in patients undergoing laparoscopic cholecystectomy, but have provided inconsistent findings with considerable clinical significance [11-14]. Noticeably, the majority of them have been carried out in non-obese patients, except one, performed in 12 extremely obese patients, who underwent laparoscopic bariatric surgery [15].

The present study was conducted to compare the effects of laparoscopic cholecystectomy and open cholecystectomy on gastric intramucosal pH in obese patients, using an automated air tonometry system (Tonocap, Datex-Ohmeda, Helsinki, Finland).

Material and methods

Sixty moderately obese patients with body mass index (BMI) 30-40 kg/m^2 undergoing elective cholecystectomy were enrolled in this study after institutional approval and written patient's consent had been obtained. All patients were symptomatic for gallstones. Patients were randomized from a computer-generated list of random numbers to either laparoscopic cholecystectomy (group LC, n=30), or open cholecystectomy (group OC, n=30), respectively. Patients with severe coexisting pulmonary or cardiac disease were excluded.

Anaesthesia

All patients were American Society of Anaesthesiologists class (ASA) I-III, aged 30-70 yrs and received general anaesthesia. Ondasentron 4 mg, ranitidine hydrochloride 50 mg and dimethindene maleate 4 mg (diluted in 100 ml normal saline 0.9%) were given slowly intravenously (iv) before induction of anaesthesia. Anaesthesia was induced with propofol 2 mg/kg and fentanyl 50 μg, while endotracheal intubation was facilitated with rocuronium bromide 0.6 mg/kg. After anaesthesia induction, an arterial catheter was inserted in the radial artery to allow continuous arterial pressure measurement and blood gas sampling, while a TRIP NGS Catheter (Datex-Ohmeda, Helsinki, Finland) was placed in the stomach via the nasogastric approach, to measure the partial pressure of CO_2 in the gastric lumen ($PgCO_2$). Its correct position was confirmed by auscultation of the abdomen during air injection in the catheter and by aspiration of gastric contents. Afterwards, the catheter was connected to the Tonocap™ Monitor (Datex-Ohmeda). After tracheal intubation, all patients inspired an oxygen/air mixture (50/50) with a fresh gas flow rate of 2 L/min, and were mechanically ventilated with a tidal volume of 10 ml/kg, a respiratory rate of 10 breaths/min, and I:E 1:2 (Datex-Ohmeda, Aestiva/5, Madison NI 53707-7550, USA). During pneumoperitoneum, appropriate ventilatory adjustments were performed to minimize high peak inspiratory pressure (by reducing the tidal volume) and to maintain normocapnia (by increasing the respiratory rate). Anaesthesia was maintained with continuous infusion of propofol (6-10 mg/kg × hr) and remifentanil (0.05-0.25 μg/kg × hr) in order to maintain BIS values within 40-60 (BIS A-2000 monitor; Aspect Medical systems, Natick, MA, USA), and arterial blood pressure and heart rate within 20% of the preoperative values, respectively. Neuromuscular blockade was achieved with additional doses of rocuronium bromide according to train-of-four indications. Ringer's solution was given intravenously at a rate of 10 ml/kg × hr throughout the operation, while no blood transfusions were used. Intraoperatively, sequential compression devices were used to minimize venous stasis.

All infusions were discontinued 10 min before the end of the operation (last stitch), while at the same time paracetamol 900 mg was injected intramuscularly, and morphine 0.1 mg/kg was given bolus iv, for postoperative pain relief. Moreover, post-incisional wound infiltration with ropivacaine 0.75% was performed at the end of surgery.

Electrocardiogram, heart rate (HR), direct mean arterial pressure (MAP), SpO_2 (Eagle 3000, Marquette Hellige GmbH, Freiburg) and end-tidal partial pressure of CO_2 (Datex-Ohmeda, 5250 RGM, Louisville, USA) were included in the perioperative monitoring.

Postoperatively, patients were observed in the PACU for one hour. Postoperative pain was estimated using the visual analogue scale (VAS score: 0-10), and morphine 2 mg was administered iv whenever VAS score was ≥4.

Surgery

The laparoscopic cholecystectomy (using the four-trocar technique) was performed after insufflation of the peritoneum with room temperature CO_2, keeping the IAP at 12-13 mmHg, while the open cholecystectomy was performed through a standard subcostal incision. Conversion to open cholecystectomy was recorded.

Measurements

pHi was calculated using a modification of the Henderson-Hasselbalch equation [16] by inserting the gastric mucosal CO_2 concentrations ($PgCO_2$) obtained by Tonocap (Tonocap, Datex-Ohmeda) and the arterial bicarbonate levels determined by simultaneous arterial gas analysis: $pHi=6.1+\log_{10}(\text{arterial } [HCO_3^-]/PgCO_2)$.

$PgCO_2$ measurements and simultaneous samples collected from the radial artery for arterial blood gas analysis were performed in four phases: phase I (after induction of anaesthesia but before surgical incision), phase II (15 min of pneumoperitoneum in the LC group or 15 min after surgical incision in the OC group, respectively), phase III (end of operation = last stitch) and phase IV (60 min after patients' awakening).

pHi was calculated using the formula described above, and pHi values were recorded. At the same time points, MAP and HR were also recorded.

Statistical analysis

For sample size calculation we assumed that a 0.05 difference in intramucosal pHi between the two groups would be clinically significant. Based on values from previous studies and given a type I error of 0.05 and a power of 90%, we estimated that the required sample size would be 26 patients per group. We enrolled 60 patients to allow for dropouts.

Statistical analyses were performed with SPSS 13.0 for Windows (SPSS Inc., Chicago, IL, USA). Results in text and tables are expressed as mean ±SD or mean (95% CI) as appropriate. Normally distributed data were analyzed using Student's t-test or analysis of variance for repeated measurements, whereas for analysis of categorical and skewed data Mann-Whitney U test, χ^2 test, or Kruskal-Wallis tests were used as appropriate. A p value of <0.05 was considered statistically significant.

Results

The two groups were comparable in age, gender, body weight and height, BMI, and ASA physical status, while the duration of surgery was statistically longer in the LC group (Table I). No conversion to an open procedure was necessary in the LC group.

In our study, intraoperative blood pressure and heart rate response were blunted with an increased

Table I. Patient and perioperative data

	OC (n=30)	LC (n=30)	P value
Age (yr)	47±9 (30-66)	48±11 (30-70)	0.951
Male/female	12/18	13/17	0.793
Weight (kg)	99±8 (82-111)	96±7 (86-110)	0.206
Height (cm)	174±8 (157-190)	171±9 (150-186)	0.365
BMI (kg/m^2)	32.7±2.2 (30-38)	32.8±2.8 (30-40)	0.929
ASA Physical Status I/II/III (n)	6/18/6	8/15/7	0.728
Duration of surgery (min)	46±15	58±21	0.0135

Data are presented as mean ±SD (range)
OC – open cholecystectomy; LC – laparoscopic cholecystectomy

Table II. Changes in intramucosal pH (pHi), mean arterial pressure (MAP) and heart rate (HR) during our study period

	Phase I	Phase II	Phase III	Phase IV
pHi				
OC (n=30)	7.42±0.042	7.4±0.032	7.4±0.029	7.41±0.038
LC (n=30)	7.42±0.051	7.38±0.05	7.39±0.042	7.37±0.05
P value	0.509	0.111	0.261	<0.001
MAP (mmHg)				
OC (n=30)	109 (104.5-113.2)	101.4 (97.3-105.5)	97.8 (94-101.8)	99.8 (96.8-102.8)
LC (n=30)	106 (101.7-110.7)	99.1 (95.5-102.7)	98.6 (94.5-102.7)	101.2 (98-104.3)
P value	0.211	0.148	0.955	0.210
HR (b/min)				
OC (n=30)	74.3 (69-79)	69 (65.3-72.7)	71.8 (67.5-76)	73 (69.5-76.3)
LC (n=30)	73 (68.9-77.2)	69.3 (65.7-73)	70 (67-73.2)	72.4 (69.3-75.5)
P value	0.226	0.199	0.698	0.284

Data are presented as mean ±SD for pHi or mean (95% CI of mean) for haemodynamic parameters
OC – open cholecystectomy; LC – laparoscopic cholecystectomy
phase I – after induction of anaesthesia and before surgical incision
phase II – 15 min of pneumoperitoneum (LC group) or 15 min after surgical incision (OC group)
phase III – end of operation (last stitch)
phase IV – 60 min after patients' awaking

rate of remifentanil infusion (Table II). Regarding postoperative values of the haemodynamic parameters under investigation, no significant difference was noticed between the two groups at the first postoperative hour (Table II).

Intraoperatively, normoventilation was achieved in all patients, because in the LC group the end-tidal PCO_2 was kept stable (35-40 mmHg) due to ventilatory adjustment.

Regarding measurements of pHi, there was no statistical significant difference noticed between the two groups, intraoperatively. In both groups, pHi slightly decreased in phases I, II and III, but ranged within normal values (Table II). In contrast, a statistically significant difference was revealed at the first postoperative hour (phase IV) between the two groups, both due to the ongoing decrease of pHi in the laparoscopic group and the tendency of pHi in the open cholecystectomy group to increase. This notwithstanding, pHi values in the LC group were within the normal range (Table II).

No difference in VAS scores and morphine requirements was found between the two groups during the first postoperative hour (data not shown). All patients showed VAS scores <4, and no rescue analgesia was needed during the first postoperative hour.

Discussion

Our study was carried out in sixty moderately obese patients. In the current study no significant difference was noticed between the two groups either at baseline values or intraoperatively. A slight decrease of pHi was observed in both groups intraoperatively, but pHi values were within the normal range. Conversely, in the 1st postoperative hour a statistically significant difference was revealed between the two groups, both due to the ongoing decrease of pHi in the laparoscopic group and the tendency of pHi in the open cholecystectomy group to increase. Besides, the pHi values at the first postoperative hour ranged within normal values (7.37±0.05), as the lower limit of normal gastric mucosal pH has been defined at value 7.32 [17]. One might advocate that a laparoscopic procedure is the gold standard for an elective cholecystectomy; however, due to our study design patients were randomised also to open cholecystectomies.

Many studies have been performed in order to test the effect of pneumoperitoneum on pHi, but it is still controversial whether it affects splanchnic blood flow or not [10-14, 18-21]. Inconsistent results may have several reasons, as splanchnic perfusion is influenced by several local and systemic factors related to the patients' characteristics, and also to the performed anaesthetic, surgical and measurement techniques.

In the current study, the studied groups were similar regarding age, body weight, height, BMI and ASA physical status. In the laparoscopic group, the conventional pneumoperitoneum method was used and the IAP was kept at 11-12 mmHg, because there is evidence arising from studies in non-obese patients that splanchnic blood flow is not affected by pneumoperitoneum at the level of 11-13 mmHg of IAP [12]. Anaesthesia and intravenous fluids were standardized. All patients in the two groups received ranitidine 50 mg iv before induction of anaesthesia. Our study protocol mandated the use of ranitidine, because the use of H_2-receptor antagonists theoretically improves the reliability of gastric tonometry by decreasing the incidence of false positive elevations of $PgCO_2$ caused by mixing of gastric acid with refluxed duodenal bicarbonate [22]. Total intravenous anaesthesia with propofol was selected, because propofol has been proven to be superior in cases of splanchnic hypoperfusion during laparoscopic procedures, due to its antioxidant activity [23], while remifentanil was chosen successfully to control the increased haemodynamic response observed in obese patients during pneumoperitoneum [7, 24]. Moreover, adjusted ventilation was performed to retain normocarbia, because an increase of end-tidal PCO_2 has been found that affects pHi. Mäkinen et al. investigated the effect of ventilation on gastric mucosal tonometric values in non-obese patients (BMI <30) undergoing laparoscopic cholecystectomy [18]. They studied two modes of ventilation, constant ventilation allowing free increase in end-tidal PCO_2 and adjusted ventilation maintaining normocarbia, and they observed a statistically significant decrease in tonometric pH in the fixed ventilation group during pneumoperitoneum (pHi: 7.33±0.04). Apart from that, intraoperative insufflation of carbon dioxide during laparoscopic surgery leads to possible harmful physiologic alterations, such as increased airway pressures and hypercarbia. In our study, the intraoperative increase of minute ventilation succeeded in avoiding hypercarbia during CO_2 pneumoperitoneum, in accordance with previous studies [18, 19], while no statistically significant difference was revealed intraoperatively between the two groups regarding pHi range.

Inconsistently with our findings, Thaler et al. did not find out any significant difference in pHi values between open and laparoscopic cholecystectomy in non-obese patients at any of the observation times, including the postoperative period [14]. In contrast to their results, Eleutheriadis et al. recorded very low pHi (7.15±0.16) during a 12 mmHg IAP [25]. A possible explanation of these conflicting results could be the fact that in both studies pHi was determined using saline tonometry, which has been proven to be less reliable [26].

Our results are partly consistent with the study of Koivusalo et al., who studied 30 patients with normal BMI and compared the effect of conventional CO_2 pneumoperitoneum technique on pHi (15 patients) versus the effect of a gasless surgical technique (the mechanical retractor method) [19], using air tonometry. They found out that pneumoperitoneum caused a statistical decrease of pHi at the first and third postoperative hour, but in contrast to our findings it ranged outside of the normal values, where the lowest value occurred at the first postoperative hour (pHi: 7.24±0.06). The different results obtained in the present study are in support of the hypothesis of Nguyen and Wolfe, that cardiac dysfunction during pneumoperitoneum is better tolerated in obese patients with an intrinsically elevated intra-abdominal pressure compared with non-obese patients, who have a lower intrinsic IAP [7]. Noticeably, Dumont et al. investigated haemodynamic changes during laparoscopic gastroplasty in obese patients (BMI >40 kg/m^2) and found that obese patients compared to non-obese patients tolerated the pneumoperitoneum better, without experiencing a fall in cardiac output [24]. Moreover, our findings are consistent with the study of Salihoglou et al., who did not find any statistical changes in pHi in 12 excessively obese patients (BMI 50 kg/m^2) who underwent laparoscopic bariatric surgery [15]. They also observed slight decreases in pHi 20 min after extubation, but ranging within the normal values (7.34±0.05). These results may indicate that no significant disturbances in splanchnic perfusion were caused in obese patients undergoing laparoscopic surgery and are also in support of the hypothesis of Nguyen and Wolfe, described previously.

Conclusions

In conclusion, we found that laparoscopic cholecystectomy in obese patients compared to open cholecystectomy caused a statistically significant decrease of pHi at the 1st postoperative hour, but pHi ranged within normal values. The clinical significance of the observed decrease in pHi in obese patients undergoing laparoscopic surgery requires investigation, as well as further confirmatory studies. Moreover, limitations of our study were reported in patients' ASA status, pattern of ventilation (adjusted, not fixed) and the duration of postoperative observation period. Patients with severe coexisting pulmonary or cardiac disease were excluded. Further investigations are needed to study pHi changes in obese patients with impaired cardiac and/or respiratory function undergoing laparoscopic surgery and to assess the value of tonometric measurements of pHi as a predictor index of worsened cardiopulmonary dysfunction. Furthermore, the use of Tonocap in the improvement of postoperative outcome may be of interest.

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