Comparison of the Effects of Sevoflurane and Desflurane on Thiol-Disulfide Homeostasis in Patients Undergoing Laparoscopic Cholecystectomy

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ABSTRACT

Objective: This study aims to compare the effects of different inhalation anesthetics on oxidative status by measuring thiol-disulfide homeostasis in laparoscopic cholecystectomy surgeries. The effect of inhaler agents on thiol-disulfide homeostasis that shows the oxidative status in laparoscopic cholecystectomy is unknown.

Materials and Methods: In this study, 71 patients planned to undergo laparoscopic cholecystectomy under general anesthesia were included. They were divided into two groups: desflurane (group D, n: 35) and sevoflurane (group S, n: 36). Blood samples were taken before induction (T1), at 30th minute of insufflation (T2) (30th min of ischemia), and at 30th min postdeflation (T3) (30th min of reperfusion). The native thiols (–SH) and total thiols (–SH+ –SS) were determined. The amounts of disulfide (–SS), disulfide/native thiol percent ratios (–SS/–SH), disulfide/total thiol percent ratios (–SS/–SH+–SS), and native thiol/total thiol percent ratios (–SH/–SH+ –SS) were calculated.

Results: In the sevoflurane group, preoperative values and intraoperative 30th-minute SS–SH ratio were significantly reduced (p=0.017). In the desflurane group, intraoperative native thiol values and postdeflation levels significantly decreased compared to those in the preoperative values (p<0.001).

Conclusion: We think that the usage of sevoflurane was more protective in terms of the oxidative damage occurring during laparoscopic surgery.

Keywords: Laparoscopic cholecystectomy, sevoflurane, desflurane, thiol-disulfide homeostasis

Introduction

Due to its advantages, laparoscopic cholecystectomy has become a common procedure. However, due to the creation of pneumoperitoneum, increase in intraabdominal pressure causes liver, splanchnic vessels to undergo mesenteric hypoxia, ischemia-reperfusion injury, and associated increase in oxidative stress [1]. Enzyme systems, ischemia-modified albumin, protein carbonyl content, protein sulfhydryl, malondialdehyde, lipid peroxides, and total antioxidant capacity were measured to understand the impact at tissue level. The gastric pH values were measured to determine oxidative status [2, 3]. One of these methods is to measure the thiol disulfide balance. It can measure thiol at only one side of this balance. Erel et al. [4] have succeeded in measuring this balance through thiol disulfide hemostasis. Given the advances in technology, it is obvious that a number of abdominal surgical procedures can be performed with laparoscopic or robotic surgery. Selection of anesthetic agents in these patients is particularly critical. The protective effect of sevoflurane on cardiac and cerebral ischemia has been established. The effects of anesthetic volatile agents on oxidative and cytotoxic mechanisms have been previously studied, but their effects on thiol-disulfide homeostasis has not yet been investigated [5].

In this study, we aimed to investigate the effect of general anesthetic drugs such as sevoflurane and desflurane on thiol-disulfide homeostasis in patients undergoing laparoscopic cholecystectomy.

Materials and Methods

This study was approved by the Yıldırım Beyazıt University ethics committee (approval no: 26379996/238 number 231), and performed in accordance with the Declaration of Helsinki. Written consent forms were obtained from all patients.

In this study, after obtaining approval from the local ethics committee, we included 71 patients aged between 20 and 60 years with American Society of Anesthesiologist physical status classification I–II.

Among patients with diabetes mellitus, coronary artery disease, conditions unsuitable for general anesthesia, emergency surgical interventions, smokers, patients with hepatic renal cerebral neurological disease, and alcohol and drug abusers, those diagnosed with cancer and neuromuscular disease and patients with difficult intubation expected, and those with high BMI (25) were excluded from the study. Prior to induction of anesthesia, all patients were randomly divided into two groups by drawing lots from an envelope with equal numbers of papers on which the group was specified. Before the operation, the patients' heart rate (HR, systolic blood pressure (SBP), diastolic blood pressure (DBP), mean blood pressures (MBP), and peripheral O2 saturation (SpO2) were monitored.

Intravenous vascular access was provided using a 20-gauge (G), and 5-10 mL/kg/h 0.9% sodium chloride (NaCl) infusion was initiated. For the induction of anesthesia, 1 mg/kg lidocaine (Aritmal 2%, Osel), 1 µcr/kg remifentanil (Ultiva 5 mg, GlaxoSmithKline) and 2 mg/kg propofol and 0.6 mg/kg rocuronium IV were administered to patients. After preoxygenation carried out by administration of 100% O_2 with face mask for 3 min, orotracheal intubation was performed when adequate muscle relaxation was observed, and the patient was ventilated with Dräger (Lübeck, Germany) anesthesia device to provide a tidal volume of 10 ml/kg and frequency of 12/min. Soda-lime (Sorbo-lime, Berkim, Turkey) was used as CO_2 absorbent. During the surgery, Storz (Gentec Ltd. Tuttlingen, Germany) electronic laparoflator was used to maintain the abdominal pressure at 14 mmHg. Among the patients randomly divided into two groups, maintenance of anesthesia was provided with 6% desflurane (Forane, Abbott Lab. UK) in patients in the first group and 2% sevoflurane in patients in the second group mixed with 40% O2 and 60% air. In both the groups, remifentanil infusion was administered at 0.25 µcr/kg/min for maintenance. At the end of the operation, decurarization was provided in all patients with 0.5 mg atropine and 1.5 mg neostigmine. In all groups, 0.5 mg of atropine was given when the HR dropped below 40, and 10 mg ephedrine was administered when the MAP was below 50 mg, and the infusion dose is reduced. Thirty minutes before the operation ended, all patients received IV 1 mg/kg tramadol and 10 mg metoclopramide. The hemodynamic and respiratory parameters (SBP, DBP, MAP, HR, SpO_2, $etCO_2$) were recorded at baseline and at the time of induction, intubation, 5th min, 10th min, 15th min, 30th min, extubation, and reperfusion. The blood samples were taken before induction (T1) (before the anesthesia), 30th minute insufflation (T2) (30th min of ischemia), and 30th minute postdeflation (30th min of reperfusion) (T3). The blood samples were centrifuged at 3600 rpm for 10 min, and serum plasma samples were removed and stored at -80°C until analysis. A new spectrophotometric technique that was previously described by Erel and Neselioglu [4] was used to establish thiol/disulfide homeostasis.

Reducible disulfide bonds were reduced to create free functional thiol groups. Unused reductant sodium borohydride was eliminates using formaldehyde, and all thiol groups including native and reduced groups were identified after the reaction with 5, 50-dithiobis-(2-nitrobenzoic) acid. The amount of dynamic disulfide was then calculated by taking half of the difference between the native thiol and the total thiols. After the native thiol (-SH) and total thiols (-SH+ -SS) were determined, amounts of disulfide (-SS), disulfide/native thiol percent ratios (-SS/-SH), disulfide/total thiol percent ratios (-SS/-SH+ -SS), and -SH/total thiol percent ratios (-SH/-SH+ -SS) were calculated [4]. When undergoing an operation, decreased native and -SH+-SS levels mean that these compounds have been consumed due to oxidative stress during surgery. If -SS/-SH+ -SS decrease, it means antioxidant mechanism is effective. The major oxidative parameters that we measured were –SH, –SH+ –SS, and –SS.

Measurements were carried out by utilizing an automated clinical chemistry analyzer (Cobas 501, Rochen Diagnostics, Mannheim, Germany). Serum thiol/disulfide homeostasis values are expressed as µmol/L.

Sample Size Estimation

This study primarily aimed to compare the differences in percentage changes in total oxidative stress parameters (i.e. -SH, disulfide, -SH+ -SS) between desflurane and sevoflurane groups. A sample size of 34 per group was required to detect at least 20% difference in percentage change of in any oxidative stress parameter between groups with a power of 90% at the 1.67% significance level regarding for the Bonferroni correction. The difference of 20% was taken from both pilot study and our clinical experiments. Sample size estimation was performed by using G*Power (Franz Faul, Universität Kiel, Kiel, Germany) version 3.0.10.

Statistical Analysis

Data analysis was performed by using the The Statistical Package for the Social Sciences (SPSS) version 17.0 software (SPSS Inc., Chicago, IL, USA). The normal distribution of continuous variables was determined by using Kolmogorov–Smirnov test. Descriptive statistics for continuous variables were shown as mean±SD or median (25th-75th) percentiles, where applicable. Categorical data were expressed as number of cases and percentages. While the mean differences between groups were compared by Student's t test, the Mann-Whitney U test was applied for the comparisons of not normally distributed variables. Categorical data were analyzed by continuity corrected chi-square test. The statistical significance of the differences among measurement times within groups regarding for total oxidative stress parameters was evaluated by Friedman test. The p-values from the Friedman test statistics were statistically significant to know which measurement time differs from which others by using Wilcoxon Sign Rank test. The repeated measurements of ANOVA by Wilks' Lambda test was applied to determine whether the mean differences in hemodynamic parameters among follow-up times were statistically significant. When the p-values from the Wilks' Lambda test were statistically significant to know which measurement time differ from which others by using Bonferroni adjusted multiple comparison. A p-value less than 0.05 was considered statistically significant. However, for all possible multiple comparisons, the Bonferroni correction was applied for controlling Type I error.

Results

The mean age was 49.0±9.5 years in the desflurane group and 47.7±11.0 years in the sevoflurane group. Distribution of males and females was statistically similar between the groups (p=0.473) (see Table 1). In the desflurane group, intraoperative and postoperative levels of –SH were significantly lower than preoperative values (p<0.001 and p=0.003, respectively). However, in the sevoflurane group, no statistically significant changes were observed (p=0.080). In all patients, the intraoperative and postoperative levels of –SH+ –SS decreased as compared to preoperative values (p<0.001 and p<0.001, respectively). No significant changes were observed in the disulfide levels between the desflurane and sevoflurane groups at the preoperative, ischemia, and reperfusion times (p=0.110, p=0.219). The SS–SH levels were similar in the desflurane group (p=0.053). Within the sevoflurane group, the SS–SH levels statistically decreased intraoperatively (p<0.001). There was no statistically significant difference

between the desflurane and sevoflurane groups in terms of mean SBP values over Bonferroni correction (p>0.0056) (Table 2). In the repeated measures, as the result of variance analysis, DBP, MBP, HR, and SpO_2 were similar between the desflurane and sevoflurane groups (p=0.571, p=0.751, p=0.113, p=0.723, respectively).

Discussion

Thiol, which is also known as a mercaptan, contains a hydrogen atom bound to a carbon atom and a sulfur atom, and is a functional group of sulfhydryls [6].

Dynamic thiol/disulfide rate plays a critical role in antioxidant defense, apoptosis, detoxification, transcription, regulation of enzyme activities, and mechanisms of cellular signal transduction [7, 8]. The proteins' sulfhydryl groups turn into a reversible pattern of disulfides under oxidative conditions. In turn, disulfide bonds can be reduced again to thiol groups. When undergoing an operation, decreased native and -SH+ -SS levels mean that these compounds have been consumed due to oxidative stress during surgery. If -SS/-SH+-SS decrease, it means antioxidant mechanism is effective. Antioxidant activity was found to be significantly higher during ischemia as the -SS/-SH+-SS value dropped in the sevoflurane group. Whereas in the desflurane group, -SH showing antioxidant activity significantly decreased in both intraoperative ischemia and reperfusion period compared to preoperative value. Independent of both anesthetic agents, laparoscopic surgery was shown to shift thiol homeostasis toward oxidation [9]. Anesthesia triggers inflammatory processes in patients. This process, which begins with the production of leukocytes in the alveolar macrophages, continues with the emergence of inflammatory mediators and free radicals. As a result, this process also causes peroxidation products to occur in general anesthesia due to the formation of membrane damage [10]. In addition, during laparoscopic procedures, the organ perfusion and portal ve-

Table 1. Demographical characteristics of patient groups

	Desflurane (n=35)	Sevoflurane (n=36)	p
Age (years)	49.0±9.5	47.7±11.0	0.612†
Sex			0.473‡
Male	8 (22.9%)	12 (33.3%)	
Female	27 (77.1%)	24 (66.7%)	

†Student's t test, ‡Continuity corrected chi-square test.

Table 2. Repeated measurements of total oxidative stress parameters

	Preop Mean (Min-Max)	Intraop (Ischemia 30 min) Mean (Min-Max)	Postop (Reperfusion 30 min) Mean (Min-Max)	p †
-SH				
Desflurane	368.7 (326.0-432.4)[a,b]	324.7 (262.9-383.3)[a]	324.2 (293.5-395.6)[b]	<0.001
Sevoflurane	342.5 (264.4-404.2)	318.5 (257.9-365.0)	323.1 (268.6-382.9)	0.080
p ‡	0.035	0.743	0.765	
Disulfide				
Desflurane	15.0 (10.5-19.8)	12.1 (8.4-25.7)	16.6 (12.3-24.3)	0.110
Sevoflurane	17.6 (12.2-23.2)	12.2 (9.0-22.6)	15.9 (10.6-23.9)	0.219
p ‡	0.298	0.963	0.476	
-SH+-SS				
Desflurane	408.4 (351.4-459.8)[a,b]	326.9 (198.5-385.1)[a]	344.5 (273.2-402.4)[b]	<0.001
Sevoflurane	371.7 (302.4-438.1)[a,b]	299.0 (190.7-361.6)[a]	320.0 (130.9-374.5)[b]	<0.001
p ‡	0.062	0.206	0.155	
SS-SH				
Desflurane	4.3 (2.8-6.2)	4.4 (2.9-5.3)	4.5 (3.8-6.3)	0.053
Sevoflurane	5.5 (3.3-6.8)[a]	3.6 (2.4-4.9)[a]	4.3 (3.2-5.9)	0.017
p ‡	0.123	0.262	0.388	
SS-total				
Desflurane	3.9 (2.6-5.5)	4.1 (2.8-4.8)	4.1 (3.6-5.6)	0.053
Sevoflurane	4.9 (3.1-6.0)[a]	3.4 (2.3-4.5)[a]	4.0 (3.0-5.3)	0.017
p ‡	0.123	0.262	0.385	
SH-total				
Desflurane	92.1 (88.9-94.7)	91.8 (90.4-94.4)	91.7 (88.9-92.8)	0.053
Sevoflurane	90.1 (88.0-93.7)[a]	93.2 (91.0-95.3)[a]	92.0 (89.4-93.9)	0.017
p ‡	0.123	0.257	0.388	

SH: -SH, SS: disulfide, SS-SH: disulfide-SH
Data were expressed in median (25^{th}-75^{th}) percentiles, †Intra-group comparisons, Friedman test, according to the Bonferroni Correction; [a] p-value less than 0.025 was considered statistically significant, ‡Inter-group comparisons within each measurement time point, the Mann-Whitney U test, according to the Bonferroni correction; [a] p-value less than 0.0167 was considered statistically significant, [a]: Preop vs Intraop (p<0.001), [b]: Preop vs Postop (p<0.0083). Preop: preoperative; intraop: intraoperative; postop: postoperative.

nous flow could reduce because of the decrease of cardiac output and accompanying mesenteric vasoconstriction [11]. Polat et al. [12] showed decreased levels of sulfhydryl during laparoscopic surgery. In another study, the levels of -SH, -SH+-SS, and disulfide were found to fall intraoperatively during laparoscopic surgery [13]. The effect of many anesthetic drugs on oxidative stress during surgery has been studied. Desflurane and sevoflurane are the most recently developed and widely used anesthetic agents. Antiinflammatory and antioxidant properties of these agents have been previously studied. Schilling et al. [14] demonstrated that desflurane and sevoflurane suppress proinflammatory cytokine release following re-ventilation after single lung ventilation. In studies performed with the human heart, protective effect of desflurane occurs by modulating mitochondrial K^+[ATP] channels and adenosine A1 receptors when preconditioning was performed. Desflurane is considered more effective than sevoflurane in the late period, because it is also have adrenoceptor modulation [15]. The application of sevoflurane in preconditioning and postconditioning forms has been shown to protect against ischemia-reperfusion injury in vital organs such as the heart, lung, and kidney [16]. Although the antioxidant properties of sevoflurane and propofol were statistically significant, an elevation in the oxidative status was observed in the desflurane group compared to the preoperative level [5]. In another study conducted with rats, sevoflurane was found to have high antioxidant activity during cerebral ischemia reperfusion [17]. Sevoflurane postconditioning concentration-dependently significantly increased blood and brain superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GSH-Px), and glutathione reductase activities. Sevoflurane postconditioning concentration-dependently decreased blood and brain malondialdehyde (MDA) and increased reduced glutathione (GSH) concentrations.

Sivaci et al. [18] also demonstrated that desflurane increases MDA and protein carbonyl content, and as a result, during laparoscopic surgery, desflurane increases free oxygen radicals more than sevoflurane does. In this study, the MDA levels and protein carbonyl contents of the desflurane group went up, and SH groups were reduced. These parameters of sevoflurane group did not change.

Yalçın et al. [19] also found that desflurane was more associated with oxidative stress when used in thoracic surgery.

Consistent with the literature, in our study, we also observed that the antioxidant properties of sevoflurane were statistically higher. The protective properties of volatile agents have been determined in terms of cerebral, cardiac, renal, thoracic, and ischemia-reperfusion injury. In animal studies, xanthine oxidase activity was elevated in rabbit colonic tissue after only 20 min of laparoscopic insufflation [20]. And in human studies, level of thiobarbituric acid-reactive substances were significantly higher in laparoscopic versus open cholecystectomy; this was seen only at 5 min postdeflation, with no significant difference at 24 h [21]. In open and laparoscopic procedure at the end of the surgery in all groups, higher levels of MDA and advanced oxidation protein products were observed.

In the laparoscopic group, oxidative parameters had essentially normalized at 24 h. The level of the oxidative stress in the laparoscopic group related with the volume of gas and the duration of insufflation [22]. So, in this study, it was decided to take blood samples at the same time of the insufflation and the postdeflation for all patients because it was planned not to compare the open procedure with laparoscopic surgery, to compare the volatile anesthetics.

The limitations of our study may be the lack of comparison with different oxidative parameters that gives long-term oxidation information.

In conclusion, for the first time in the literature, it was demonstrated that sevoflurane has more protective effects on thiol-disulfide homeostasis than desflurane. Acknowledgment: The authors declare that they have no financial and nonfinancial competing interests. The authors alone are responsible for the content and writing of the paper.

Ethics Committee Approval: This study was approved by Yıldırım Beyazıt University Ethics Committee (approval no: 26379996/238 number 231).

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References

1. Nesek-Adam V, Vnuk D, Rasić Z, Rumenjak V, Kos J. Krstonijević, Z. Comparison of the effects of low intraabdominal pressure and pentoxifylline on oxidative stress during CO2 pneumoperitoneum in rabbits. Eur Surg Res 2009; 43: 330-7. [CrossRef]
2. Biler A, Yucebilgin S, Sendag F, et al. The effects of different intraabdominal pressure protocols in laparoscopic procedures on oxidative stress markers and morphology in rat ovaries. Adv Clin Exp Med 2014; 23: 885-92. [CrossRef]
3. Sammour T, Mittal A, Loveday BP, et al.Systematic review of oxidative stress associated with pneumoperitoneum. Br J Surg 2009; 96: 836-50. [CrossRef]
4. Erel O, Neselioglu S. A novel and automated assay for thiol/disulphide homeostasis. Clin Biochem 2014; 47: 326-32. [CrossRef]
5. Erbasa M, Demiraran Y, Yildirim HA, et al. Comparison of effects on the oxidant/antioxidant system of sevoflurane, desflurane and propofol infusion during general anesthesia Rev Bras Anestesiol 2015; 65: 68-72. [CrossRef]
6. Sen CK, Packer L. Thiol homeostasis and supplements in physical exercise. Am J Clin Nutr 2000; 72: 653-69. [CrossRef]
7. Circu ML, Aw TY. Reactive oxygen species, cellular redox systems, and apoptosis. Free Radic Biol Med 2010; 48: 749-62. [CrossRef]
8. Biswas S, Chida AS, Rahman I. Redox modifications of protein-thiols: emerging roles in cell signaling. Biochem Pharmacol 2006; 71: 551-64. [CrossRef]
9. Polat M, Ozcan O, Sahan L, et al. Changes in Thiol-Disulfide Homeostasis of the Body to Surgical Trauma in Laparoscopic Cholecystectomy Patients. J Laparoendosc Adv Surg Tech A 2016; 26: 992-6. [CrossRef]
10. Koksal GM, Sayilgan C, Aydin S, Uzun H, Oz H. The effects of sevoflurane and desflurane on lipid peroxidation during laparo-scopic cholecystectomy. Eur J Anaesthesiol 2004; 21: 217-20. [CrossRef]
11. Jakimowicz J, Stultiëns G, Smulders F. Laparoscopic insufflation of the abdomen reduces portal venous flow. Surg Endosc 1998; 12: 129-32. [CrossRef]
12. Polat C, Kahraman A, Yilmaz S, et al. A comparison of the oxidative stress response and antioxidant capacity of open and laparoscopic hernia repairs. J Laparoendosc Adv Surg Tech A 2003; 13: 167-73. [CrossRef]
13. Schilling MK, Redaelli C, Krahenbuhl L, Signer C, Buchler MW. Splanchnic microcirculatory changes during CO2 laparoscopy. J Am Coll Surg 1997; 184: 378-82.
14. Schilling T, Kozian A, Senturk M, et al. Effects of volatile and intravenous anesthesia on the alveolar and systemic inflammatory response in thoracic surgical patients. Anesthesiology 2011; 115: 65-74. [CrossRef]
15. Sivanna U, Joshi S, Babu B, Jagadeesh AM. A comparative study of pharmacological myocardial protection between sevoflurane and

desflurane at anaesthestic doses in patients undergoing off pump coronary artery bypass grafting surgery. Indian J Anaesth 2015; 59: 282-6. [CrossRef]
16. Luo C, Yuan D, Zhaon W, et al.Sevoflurane ameliorates intestinal ischemia-reperfusion-induced lung injury by inhibiting the synergistic action between mast cell activation and oxidative stress. Molecular Medicine Reports 2015; 12: 1082-90. [CrossRef]
17. Zhang Y, Zhang F, Meng C, et al. Inhibition of Sevoflurane Postconditioning Against Cerebral Ischemia Reperfusion-Induced Oxidative Injury in Rats. Molecules 2012; 17: 341-54. [CrossRef]
18. Sivaci R, Kahraman A, Serteser M, Sahin DA, Dilek ON. Cytotoxic effects of volatile anesthetics with free radicals undergoing laparoscopic surgery. Clin Biochem 2006; 39: 293-8. [CrossRef]
19. Yalçın Ş, Özgencil E, Serdaroglu H, Oba Ş, Enön S, Demiralp S. Anesthetics modulate oxidative stress during one-lung ventilation in lung cancer patients: Comparison of target-controlled propofol infusion and desflurane. Afr J Pharm Pharmacol 2012; 6: 407-11.
20. Emir H, Akman M, Belce A, Gumustas K, Soylet Y. Is intestinal ischemia a risk of laparoscopy? An experimental study in rabbits. Eur J Pediatr Surg 2001; 11: 158-62. [CrossRef]
21. Glantzounis GK, Tselepis AD, Tambaki AP, et al. Laparoscopic surgery-induced changes in oxidative stress markers in human plasma. Surg Endosc 2001; 15: 1315-9. [CrossRef]
22. Bentes de Souza AM, Rogers MS,Wang CC, Yuen PM, Ng PS. Comparison of peritoneal oxidative stress during laparoscopy and laparotomy. J Am Assoc Gynecol Laparosc 2003; 10: 65-74. [CrossRef]