Changes in cerebral oximetry during peritoneal insufflation for laparoscopic procedures

C L Gipson, G A Johnson, R Fisher, A Stewart, G Giles, J O Johnson, J D Tobias*
Departments of Anesthesiology and *Pediatrics, University of Missouri, Columbia, Missouri

Address for correspondence: Joseph D. Tobias, Division of Pediatric Anesthesiology, Russell and Mary Shelden Chair in Pediatric Intensive Care Medicine, University of Missouri, Department of Anesthesiology, 3W-27G HSC, One Hospital Drive, Columbia, Missouri - 65212. E-mail: Tobiasj@health.missouri.edu

Abstract

Background: Changes in cardiac output may occur during insufflation for laparoscopic procedures. However, there are limited data regarding its potential effects on cerebral oxygenation. Materials and Methods: Cerebral oxygenation (ScO$_2$), end tidal CO$_2$, heart rate, blood pressure and oxygen saturation by pulse oximetry were recorded every 5 minutes prior to insufflation, during insufflation and after desufflation. Minute ventilation was increased to maintain normocapnia and the depth of anesthesia was adjusted or fluids/phenylephrine administered to maintain the blood pressure within 20% of the baseline. Results: The cohort for the study included 70 adults for laparoscopic herniorrhaphy, gastric bypass or cholecystectomy. A total of 1004 ScO$_2$ values were obtained during laparoscopy. The ScO$_2$ decreased from the baseline in 758 of the 1004 data points. The ScO$_2$ was 0-9 less than the baseline in 47.8% of the values, 10-19 less than the baseline in 24.9% of the values and 20-29 less than the baseline in 26 values (2.6%). Eighty-two (8.2%) of the values were less than 80% of the baseline value, while 25 values (2.5%) were less than 75% of the baseline value. Twelve patients had at least one ScO$_2$ value that was less than 80% of the baseline and 6 had at least one ScO$_2$ value that was less than 75% of the baseline. Four patients of the cohort had ScO$_2$ values less than 80% of the baseline for more than 50% of the laparoscopic procedure. Conclusions: Although relatively uncommon, significant changes in cerebral oxygenation do occur in some patients during insufflation for laparoscopic surgery.

Key words: Cerebral oxygenation, laparoscopy, near infrared spectroscopy

Laparoscopic surgery has become a popular surgical tool due to its less invasive nature, thereby providing a more rapid recovery and improved cosmetic outcome when compared to traditional open surgery. However, a requirement of the procedure is the insufflation of the peritoneal cavity with an inert gas, most commonly carbon dioxide (CO$_2$). Although CO$_2$ is generally accepted as the optimal gas for insufflation, increases in PaCO$_2$ and resultant alterations in cerebral blood flow may occur.[1-3] Additionally, peritoneal insufflation and the increase in intra-abdominal pressure (IAP) result in increased systemic vascular resistance and decreased cardiac output.[1-6] These alterations in systemic hemodynamics may result in alterations in end-organ blood flow and oxygen delivery, especially in patients with co-morbid cardiovascular disease. To date, there are limited data regarding alterations in cerebral oxygenation during laparoscopic procedures. The current study uses near infrared spectroscopy (NIRS) to evaluate changes in cerebral oxygenation during laparoscopic procedures, in a cohort of adult patients.

MATERIALS AND METHODS

This study was approved by the Institutional Review Board of the University of Missouri and informed consent was obtained from the patients. Patients scheduled for laparoscopic procedures of the abdomen requiring peritoneal insufflation were considered eligible for inclusion. The choice of anesthetic agents was not standardized and was at the discretion of the
attending anesthesiologist. Cerebral oxygen saturation was continuously monitored using near infrared spectroscopy (INVOS 3100A, Somanetics Corporation, Troy, MI). After the induction of anesthesia, a single NIRS sensor was placed on the right side of the patient’s forehead, with the caudal border approximately 1 cm above the eyebrow, with the medial edge at the midline according to the manufacturer’s guidelines. Cerebral oxygen saturation (\(\text{ScO}_2\)), end tidal \(\text{CO}_2\) (ET\(\text{CO}_2\)), heart rate (HR), blood pressure (BP) and oxygen saturation by pulse oximetry (\(\text{SaO}_2\)) were recorded every five minutes prior to insufflation, during insufflation and after desufflation. Peritoneal insufflation pressures were maintained at 8-12 mmHg. The surgical procedures were performed with the patient in the supine or at a 20-30° head-up position. During insufflation, minute ventilation was increased as needed, to maintain normocarbia. The blood pressure was maintained within 20% of baseline values by either increasing the concentration of the inhalational agent for increases in BP or the administration of a fluid bolus and/or phenylephrine for decreases in BP. The \(\text{ScO}_2\) values obtained prior to insufflation were averaged for each patient and used as that patient’s baseline \(\text{rSO}_2\) for subsequent evaluations. The values obtained during insufflation were then compared to the baseline values and categorized as an increase in \(\text{ScO}_2\) from the baseline or as an absolute decrease in \(\text{rSO}_2\) of 0-9, 10-19, 20-29 or \(\leq\) 30 or greater, from baseline. The number of values representing an \(\text{ScO}_2\) decrease to less than 75% and less than 80% of the baseline, were also determined. Patients who had any \(\text{ScO}_2\) value less than 80% of baseline, were compared to those without cerebral desaturation using a non-paired t-test and a contingency table, with a Fisher’s exact test. All data are presented as the mean ± SD.

RESULTS

The cohort for the study included 70 adult patients ranging in age from 27 to 80 years (50.3 ± 13.9 years) and in weight from 40 to 186 kgs (104.9 ± 31.6 kgs). Twelve patients were ASA II and 58 were ASA III. The surgical procedures included laparoscopic herniorrhaphy or cholecystectomy in 34 patients and laparoscopic gastric bypass in 36 patients. The anesthetic technique included premedication with midazolam (1-2 mg), followed by intravenous induction with thiopental or propofol. Maintenance anesthesia consisted of 1-1.5 MAC (minimum alveolar concentration) of a potent inhalational anesthetic, fentanyl (3-5 \(\mu\)g/kg) and neuromuscular blockade with intermittent doses of either cis-atracurium or rocuronium. The duration of insufflation and laparoscopy varied from 25 to 175 minutes (71.7 ± 33.3 minutes).

The baseline \(\text{ScO}_2\) varied from 47 to 95 (78 ± 11). A total of 1004 \(\text{ScO}_2\) values were obtained during laparoscopy. The \(\text{ScO}_2\) increased from the baseline during 246 of the 1004 data points and decreased from the baseline in 758 of the 1004 data points. For the 758 of the 1004 \(\text{ScO}_2\) values that decreased from baseline during insufflation, the \(\text{ScO}_2\) decrease was 0-9 less than the baseline in 480 values (47.8% of all values), 10-19 less than the baseline in 252 values (24.9%) and 20-29 less than the baseline in 26 values (2.6%) [Table 1]. No \(\text{ScO}_2\) value was greater than 30 less than the baseline value. Eighty-two (8.2%) of the values were less than 80% of the baseline value, while 25 values (2.5%) were less than 75% of the baseline value. Twelve of the 70 patients (17%) had at least one \(\text{ScO}_2\) value that was less than 80% of the baseline value and 6 (0.09%) had at least one \(\text{ScO}_2\) value that was less than 75% of the baseline value. Four of the 70 patients of the cohort had \(\text{ScO}_2\) values less than 80% of the baseline, for more than 50% of the laparoscopic procedure. The demographics of patients with an \(\text{ScO}_2\) value less than 80% of the baseline during insufflation compared to patients without cerebral oxygen desaturation, are outlined in Table 2. There was no difference in the age of these patients (53.1 ± 10.8 years vs. 49.7 ± 14.5 years) or their

| Table 1: Changes in cerebral oxygenation during laparoscopy |
|-----------------------------------------------------------|
| Absolute change in \(\text{ScO}_2\) from baseline | Number of values | Percentage of total |
|-----------------------------------------------------------|
| More than baseline | 246 | 24.5 |
| 0-9 less | 480 | 47.8 |
| 10-19 | 252 | 24.9 |
| 20-29 | 26 | 2.6 |
| >30 | 0 | 0 |
| = 80% of baseline | 897 | 89.3 |
| < 80% of baseline | 82 | 8.2 |
| < 75% of baseline | 25 | 2.5 |
ASA classification (ASA II and III: 0 and 13 vs. 12 and 45, \(P = 0.1\)). However, these patients weighed more (120.2 ± 22.2 kgs vs. 101.4 ± 32.0 kgs, \(P = 0.053\)), had longer durations of insufflation (67.5 ± 33.0 minutes vs. 90.4 ± 28.6 minutes, \(P = 0.02\)) and were more likely to be undergoing a laparoscopic gastric bypass than a laparoscopic herniorrhaphy or cholecystectomy.

### DISCUSSION

The potential use of NIRS, otherwise known as cerebral oximetry to monitor cerebral oxygenation was first suggested by Jobsis in 1977.\(^7\) NIRS is a non-invasive device that uses infrared light, a technique similar to pulse oximetry, to penetrate living tissues and estimate brain tissue oxygenation by measuring the absorption of infrared light by tissue chromophores (hemoglobin and cytochrome aa3).\(^8\) Unlike standard pulse oximetry, pulsatile flow is not required and therefore the device works during CPB and other non-pulsatile states. Once the infrared light penetrates living tissue, the relative absorption of the infrared light at different wavelengths is dependent on the concentration of the various hemoglobin species (unoxgenated vs. oxygenated). Based on the relative absorption of the infrared light at various wavelengths, the specific concentration of the hemoglobin species can be determined using a modification of the Beer-Lambert’s law and a determination of the relative degree of cerebral oxygenation can be made.\(^8-11\) Unlike other methods for monitoring cerebral oxygenation, which are typically invasive, require prolonged periods of equilibration or involve ionizing radiation, NIRS is an inexpensive and noninvasive technique that may be used at the bedside.\(^12-14\)

The ability of NIRS to detect sudden changes in cerebral oxygenation when cerebral blood flow is altered by extreme maneuvers, has been demonstrated by Levy et al.\(^15\) NIRS has also been shown to detect cerebral ischemia during less severe changes in cerebral oxygenation at frequencies similar to transcranial doppler velocimetry, thus providing important measurements of rapid and small changes in cerebral oxygenation.\(^12,16\) Additional validation studies have been performed, demonstrating the accuracy of NIRS monitoring of brain oxygenation during conditions of hypoxemia, hypercapnia and hypopcapnia in awake volunteers.\(^17,18\) Pollard et al studied the response of the INVOS 3100A to arterial hypoxemia, induced by breathing a hypoxic mixture in 22 healthy adults and demonstrated that the cerebral oximeter reading correlated well with the calculated cerebral saturation.\(^18\)

Clinical and biochemical studies have validated the correlation of NIRS monitoring with eventual neurologic outcome. Although the majority of the literature using NIRS has compared periods of cerebral desaturation with outcome assessed by clinical assessment of neurologic status, Plachky et al. compared changes in cerebral oxygenation using NIRS monitoring with neurologic damage assessed with biochemical markers, including neuron specific enolase (NSE) and S-100, a protein released during neuronal damage.\(^19\) The cohort for the study included 16 adult patients undergoing orthotopic hepatic transplantation. NSE and S-100 were measured preoperatively and then again 24 hours after reperfusion of the donor liver. They noted that the decrease in \(\text{ScO}_2\) showed a significant correlation with the postoperative increase in NSE (\(r^2 = 0.57\)) and S-100 (\(r^2 = 0.52\)).

More recently, Casati et al have demonstrated that monitoring and acting on decreased \(\text{ScO}_2\) values may actually decrease the incidence of postoperative neurocognitive dysfunction in elderly patients undergoing major abdominal surgery under general anesthesia.\(^20\) The 122 patients were randomly assigned to a treatment group in which the \(\text{ScO}_2\) value...
was monitored and maintained at ≥ 75% of preinduction values or a monitor only group, in which cerebral oximetry was monitored, but not visible to the anesthesiologist. Cerebral oxygen desaturation (≤ 75% of baseline) was observed in 11 patients of the treatment group (20%) and 15 patients in the control group (23%). The treatment protocol to treat cerebral oxygen desaturation, included ensuring adequate ventilation, checking head positioning, increasing the delivered oxygen concentration, allowing the arterial CO₂ to increase and increasing the BP with fluids or vasoconstricting medications. Postoperative neurocognitive decline was evaluated using a mini-mental status examination (MMSE). Control patients with cerebral oxygen desaturation had a lower MMSE on postoperative day 7, longer PACU stays (median time of 47 minutes) and longer hospital stays (median of 24 days), when compared with patients in the treatment group whose cerebral oxygen desaturation was reversed by interventions. The latter group had a median PACU discharge time of 25 minutes (P=0.01) and a median hospital stay of 10 days (P=0.007).

In the current study, we noted that the majority of patients experienced a decrease in cerebral oxygenation during insufflation. Although the modest decreases are unlikely to be clinically significant, if we use the criteria of Casati et al.,[20] who suggested that an ScO₂ decrease to less than 75% of baseline correlates with neurocognitive changes assessed using the MMSE, 6 or approximately 1% of our patients would be at risk. Four of our patients had ScO₂ values less than 80% of their baseline during more than 50% of the insufflation time. Patients who experienced an ScO₂ value less than 80% of the baseline, weighed more and had a longer duration of peritoneal insufflation. As the majority of the patients were ASA III, aside from body weight, we cannot comment as to whether other co-morbid features increased the likelihood of cerebral oxygen desaturation.

Previous studies have evaluated changes in cerebral oxygenation using NIRS during insufflation for laparoscopy. Kitajima et al evaluated changes in cerebral oxygenation during laparoscopy using another type of cerebral oxygenation monitor (NIRO-500, Hamamatsu Photonics KK, Japan), in a study that included 12 adult patients (ASA I or II) undergoing laparoscopic cholecystectomy with a pneumoperitoneum of 10-12 mmHg.[21] Minute ventilation was not increased during laparoscopy. ETCO₂ increased from a baseline of 33.9 ± 1.3 to a maximum of 52.8 ± 3.3 mmHg during laparoscopy. Both HbO₂ (cerebral oxy-hemoglobin) and HbR (reduced hemoglobin) increased from the baseline following insufflation, which they related to changes in cerebral blood volume induced by the hypercapnia. No change in the oxygenation status of cytochrome aa₃ was noted. The maximum increase of HbO₂ (7.3 ± 2.8 µmol/L) occurred 90 minutes after the start of laparoscopy.

A follow-up study by the same group of investigators used the same technology to evaluate changes in cerebral oxygenation and cerebral blood volume during laparoscopic cholecystectomy in 12 adult ASA I and II patients, in whom minute ventilation was increased to maintain normocapnia.[22] They noted a small decrease in HbO₂ from the baseline with insufflation (-1.4 ± 1.4 from baseline), with a more significant effect, 30 minutes after insufflation and assumption of a head-up positioning for the surgery (-5.1 ± 1.9 from baseline). No change in cytochrome aa₃ was noted during the study.

Using the INVOS cerebral oximeter, de Waal et al evaluated changes in cerebral oxygenation and cerebral blood volume in 15 ASA I-III children during laparoscopic fundoplication, with an insufflation pressure of 5 to 8 mmHg.[23] During insufflation, the ETCO₂ increased from 30.0 ± 2.8 to 38.3 ± 5.1 mmHg and PaCO₂ increased from 32.0 ± 4.7 to 40.4 ± 5.9 mmHg. Cerebral oxygenation increased by 15.7 ± 8.8% and cerebral blood volume increased by 4.6 ± 8.8%.

The data in our current study are somewhat different that what has been reported in the 3 previous studies that have been mentioned.[21-23] We would postulate that several factors may account for this. We studied a much larger cohort of patients than have been previously studied and given the relatively low
incidence of decreases in ScO$_2$ values that we noted, it is possible that smaller studies including only 10-15 patients may miss such changes. Additionally, we collected ScO$_2$ values at 5 minute intervals with 1000 values more, as compared with the other studies where cerebral oxygenation was assessed at 30 minutes intervals. We did not average our values, whereby a low value might be lost when averaged with other values, rather we compared each ScO$_2$ value to the baseline, to assess its relative change. Our cohort mostly included ASA III patients, as opposed to the ASA I-II patients of Kitajima et al. Minute ventilation was increased to maintain normocapnia. As demonstrated by the studies of Kitajima et al., this may affect HbO$_2$ values, although the greatest difference noted was when assuming the head-up position for the surgical procedure.

The current study did not separate randomized patients into treatment and non-treatment groups as was done by Casati et al and therefore we cannot comment as to whether treatment of decreases in ScO$_2$ values would have an impact on the outcome. Recommendations for the treatment of decreases in ScO$_2$ values include checking ventilator function and head positioning, increasing the FO$_2$, increasing the PaCO$_2$ for values less than 35 mmHg, increasing mean arterial pressure with fluid or vasoconstrictors, followed by decreasing the cerebral metabolic rate of oxygen by the administration of propofol or a barbiturate if the above measures fail.

In summary, we noted that although most patients tolerated insufflation without significant effects on cerebral oxygenation, a subset of patients developed significant decreases in ScO$_2$, which have been shown to correlate with neurocognitive changes in other studies. The limitations of the current study are, that we did not evaluate our patients postoperatively to see if changes in ScO$_2$ correlated with postoperative neurocognitive changes and therefore we cannot determine if monitoring and treating changes in ScO$_2$ can prevent postoperative neurocognitive changes, as has been previously demonstrated by the study of Casati et al.[20] As all the patients received a general anesthetic with a potent inhaled agent, no comment can be made on the impact of the anesthetic technique (potent inhaled agent vs. intravenous anesthesia). As we had a limited number of patients with what may be considered as clinically significant decreases in ScO$_2$ values, an analysis to determine additional “at risk” features other than body weight and duration of insufflation, such as co-morbid features or intraoperative conditions (insufflation pressure, patient positioning and anesthetic technique), was not feasible. However, given that the deleterious physiologic effects of increased intraabdominal pressure during insufflation on stroke volume, cardiac output and other hemodynamic variables have been well documented, it is likely that alterations in cerebral oxygenation may occur. Therefore, non-invasive monitoring of cerebral oxygenation appears to be warranted in this population, especially in patients with associated co-morbid conditions.

REFERENCES
1. Hodgson C, McClelland R, Newton J. Some effects of the peritoneal insufflation of carbon dioxide at laparoscopy. Anaesth 1970;25:382-90.
2. Wittgen CM, Andrus CH, Fitzgerald SD, Baudendistel LJ, Dahms TE, Kaminski DL. Analysis of the hemodynamic and ventilatory effects of laparoscopic cholecystectomy. Arch Surg 1991;126:997-1001.
3. Nguyen NT, Wolfe BM. The physiologic effects of pneumoperitoneum in the morbidly obese. Ann Surg 2005;241:219-26.
4. Ponsky JL. Complications of laparoscopic cholecystectomy. Am J Surg 1991;161:393-5.
5. Westerband A, Van De Water JM, Amzallag M, Lebowitz PW, Nwasokwa ON, Chardavoyne R, et al. Cardiovascular changes during laparoscopic cholecystectomy. Surg Gynecol Obstet 1992;175:535-8.
6. McLaughlin JG, Scheeres DE, Dean RJ, Bonnell BW. The adverse hemodynamic effects of laparoscopic cholecystectomy. Surg Endosc 1995;9:121-4.
7. Jobsis FF. Noninvasive, infrared monitoring of cerebral and myocardial oxygen sufficiency and circulatory parameters. Science 1977;198:1264-7.
8. Owen- Reece H, Smith M, Elwell CE, Goldstone JC. Near infrared spectroscopy. Br J Anaesth 1999;82:418-26.
9. Yoshitani K, Kawaguchi M, Tatsumi K, Kitaguchi K, Furuya H. A comparison of the INVOS 4100 and the NIRO 300 near-infrared spectrophotometers. Anesth Analg 2002;94:586-90.
10. Kurth CD, Steven JM, Nicolson SC, Chance B, Delivoria-Papadopoulos M. Kinetics of cerebral deoxygenation during deep hypothermic circulatory arrest in neonates. Anesthesiology 1992;77:656-61.
11. Kurth CD, Steven JL, Montenegro LM, Watzman HM, Gaynor JW, Spray TL, et al. Cerebral oxygen saturation before congenital heart surgery. Ann Thorac Surg 2001;72:187-92.
12. Lovell AT, Owen-Reece H, Elwell CE. Continuous measurement of
Authors should highlight the relation of complication to duration of diabetes. Include the referees' remarks and point to point clarification to those remarks at the beginning in the revised article.

The follow-up of patients have been included in the results section.

Kruitwagen CL, Kalkman CJ. The effects of cerebral oxygen saturation assessed by near-infrared spectroscopy during carotid endarterectomy. J Neurosurg 1995;82:756-63.

Henson LC, Calalang C, Temp JA, Ward DS. Accuracy of a cerebral oximeter in healthy volunteers under conditions of isocapnic hypoxia. Anesthesiology 1998;88:58-65.

Pollard V, Prough DS, DeMelo AE, Deyo DJ, Uchida T, Stoddart HF. Validation in volunteers of a near-infrared spectroscopy for monitoring brain oxygenation in vivo. Anesth Analg 1996;82:269-77.

Płachky J, Hofer S, Volkmann M, Martin E, Bardenheuer HJ, Weigand MA. Regional cerebral oxygen saturation is a sensitive marker of cerebral hypoperfusion during orthotopic liver transplantation. Anesth Analg 2004;99:344-9.

Casati A, Fanelli G, Pietropaoli P, Proietti R, Tufano R, Danelli G, et al. Continuous monitoring of cerebral oxygen saturation in elderly patients undergoing major abdominal surgery minimizes brain exposure to potential hypoxia. Anesth Analg 2005;101:740-7.

Kitajima T, Shinhara M, Ogata H. Cerebral oxygen metabolism measured by near-infrared laser spectroscopy during laparoscopic cholecystectomy with CO₂ insufflation. Surg Lap Endo 1996;6:210-2.

Kitajima T, Okuda Y, Yamaguchi S, Takanishi T, Kumagai M, Ido K. Response of cerebral oxygen metabolism in the head-up position during laparoscopic cholecystectomy. Surg Lap Endo 1998;8:449-52.

de Vaal EC, Vries JW, Kruitwagen CL, Kalkman CJ. The effects of low-pressure carbon dioxide pneumoperitoneum on cerebral oxygenation and cerebral blood volume in children. Anesth Analg 2002;94:500-5.

Dexter SP, Vucevic M, Gibson J, McMahon MJ. Hemodynamic consequence of high and low pressure capnoperitoneum during laparoscopic cholecystectomy. Surg Endosc 1999;13:376-81.

Cite this article as: Gipson CL, Johnson GA, Fisher R, Stewart A, Giles G, Johnson JO, Tobias JD. Changes in cerebral oximetry during peritoneal insufflation for laparoscopic procedures. J Min Access Surg 2006;2:67-72.

Date of submission: 15/05/06, Date of acceptance: 17/07/06
Source of Support: Nil, Conflict of Interest: None declared.