Gas embolism during laparoscopic surgery: the real concern

Jeong-Rim Lee
Yonsei University, Korea

For laparoscopic surgeries, venous air embolism has been regarded as a rare complication with an incidence of 0.014 - 0.6%. However, because this incidence mostly includes the severe cases that caused significant hemodynamic deterioration, the "real clinical incidence" of gas embolism is likely to be higher than reported. [1, 2] Cases of negligible impact and no sequelae may have been simply documented as a single comment in the anesthetic record, and most likely not individually reviewed in a large case series. Using transesophageal echocardiography revealed a 69% incidence of CO_2 embolism during laparoscopic cholecystectomy. [3] In laparoscopic hysterectomy cases, venous air embolism was observed in all enrolled patients (82 patients), with 37.5% showing significant amounts of gas embolism. [4]

The most important mechanical factors that decide the impact of a venous air embolism are the volume of air and the rate of entry. While the lethal amount of air is known to be 200 - 300ml or 3 - 5ml/kg in adults, [5] the median lethal volume of CO_2 embolism was found to be 25ml/kg in dogs, which corresponds to roughly 1750ml in a 70kg person. [6] However, CO_2 is not always safe despite its high solubility. In addition, some authors have warned that air in the CO_2 insufflation tube may lead to fatal complications. [7, 8] Higher intra-abdominal pressures are also known to increase the event of gas embolism. [9-11]

Most cases of CO_2 embolism are thought to occur in the initial phase of surgery or during surgical interventions; however, cases of delayed development have been also reported. A CO_2 emboli that is too large to be dissolved in the bloodstream may remain entrapped in the portal system, and be gradually released into the caval system. [12] Therefore, an uneventful operation and emergence from anesthesia should not be regarded as risk-free of gas embolism. [1, 12]

The common causes of venous air embolism related with surgical procedures are as follows.

(1) Misplacement of the Veress needle directly into a vein. [13]
(2) Openings in an injured vessel, either in the abdominal wall or at the operative site. [14-17]
(3) Dissection of liver parenchyma under pnemoperitoneum. [18]

The reasons why we should be aware of subclinical venous air embolisms can be summarized as follows.

(1) A venous air emboli may enter the systemic circulation through a PFO; the incidence of PFO in the general population is about 20-30%. The mortality of systemic gas embolism is as high as 30%. [17]

(2) Venous air can enter the systemic circulation even when there are no intracardiac shunts such as PFO; paradoxical air embolism can also arise through abnormal vascular shunts in pathologic masses or trans-pulmonary passage. [19-24]

(3) Gas embolism can induce a systemic inflammatory response syndrome (SIRS) regardless of its amount. [25] When air contacts a pulmonary vessel, endothelin-1 is secreted. In addition, microvascular flow obstruction by air induces platelet aggregation and secretion of plasminogen activator inhibitors, which result in triggering of the cytokine cascade and finally SIRS. [25, 26] A CO_2 emboli as small as 0.4ml/kg was found to induce respiratory or cardiovascular detrimental effects which were maintained more than 4hours. [27]

Therefore, in order to enhance the safety of patients undergoing laparoscopic procedures, any efforts should be made toward vigilant monitoring as well as cautious manipulation in the surgical field.

References

1. Burcharth, J., et al., *Successful resuscitation after carbon dioxide embolism during laparoscopy.* Surg Laparosc Endosc Percutan Tech, 2012. 22(3): p. e164-7.
2. Park, E.Y., J.Y. Kwon, and K.J. Kim, *Carbon dioxide embolism during laparoscopic surgery.* Yonsei Med J, 2012. 53(3): p. 459-66.
3. Leonard, I.E. and A.J. Cunningham, *Anaesthetic considerations for laparoscopic cholecystectomy.* Best Pract Res Clin Anaesthesiol, 2002. 16(1): p. 1-20.
4. Kim, C.S., et al., *Venous air embolism during total laparoscopic hysterectomy: comparison to total abdominal hysterectomy.* Anesthesiology, 2009. 111(1): p. 50-4.
5. Toung, T.J., M.I. Rossberg, and G.M. Hutchins, *Volume of air in a lethal venous air embolism.* Anesthesiology, 2001. 94(2): p. 360-1.
6. Lam, A., et al., *Dealing with complications in laparoscopy.* Best Pract Res Clin Obstet Gynaecol, 2009. 23(5): p. 631-46.
7. Richter, S., et al., *Air in the insufflation tube may cause fatal embolizations in laparoscopic surgery: an animal study.* Surg Endosc, 2013. 27(5): p. 1791-7.
8. Taylor, S.P. and G.M. Hoffman, *Gas embolus and cardiac arrest during laparoscopic pyloromyotomy in an infant.* Can J Anaesth, 2010. 57(8): p. 774-8.
9. Eiriksson, K., et al., *High intra-abdominal pressure during experimental laparoscopic liver resection reduces bleeding but increases the risk of gas embolism.* Br J Surg, 2011. 98(6): p. 845-52.
10. Fors, D., et al., *Gas embolism during laparoscopic liver resection in a pig model: frequency and severity.* Br J Anaesth, 2010. 105(3): p. 282-8.

11. Otsuka, Y., et al., *Gas embolism in laparoscopic hepatectomy: what is the optimal pneumoperitoneal pressure for laparoscopic major hepatectomy?* J Hepatobiliary Pancreat Sci, 2013. 20(2): p. 137-40.
12. Capuzzo, M., et al., *Presumptive delayed gas embolism after laparoscopic cholecystectomy.* Minerva Anestesiol, 2000. 66(1-2): p. 63-7.
13. Benitez Pacheco, O.R., et al., *[Heart arrest caused by CO_2 embolism during a laparoscopic cholecystectomy].* Rev Esp Anestesiol Reanim, 2003. 50(6): p. 295-8.
14. Abut, Y.C., et al., *Venous air embolism during laparoscopic cholecystectomy.* Minim Invasive Ther Allied Technol, 2009. 18(6): p. 366-8.
15. Councilman-Gonzales, L.M., J.D. Bean-Lijewski, and R.K. McAllister, *A probable CO_2 embolus during laparoscopic cholecystectomy.* Can J Anaesth, 2003. 50(3): p. 313.
16. Kim, I.S., J.W. Jung, and K.M. Shin, *Cardiac arrest associated with carbon dioxide gas embolism during laparoscopic surgery for colorectal cancer and liver metastasis -A case report.* Korean J Anesthesiol, 2012. 63(5): p. 469-72.
17. Boghossian, T., et al., *Laparoscopic nephrectomy donor death due to cerebral gas embolism in a specialized transplant center: risk zero does not exist.* Transplantation, 2005. 79(2): p. 258-9.
18. Ammori, B.J., *Transoesophageal echocardiography shows high risk of gas embolism during laparoscopic hepatic resection under carbon dioxide pneumoperitoneum (Br J Surg 2002; 89: 870-6).* Br J Surg, 2002. 89(11): p. 1482-3.
19. Huang, Y.Y., et al., *Paradoxical carbon dioxide embolism during pneumoperitoneum in laparoscopic surgery for a huge renal angiomyolipoma.* J Chin Med Assoc, 2008. 71(4): p. 214-7.
20. Marquez, J., et al., *Paradoxical cerebral air embolism without an intracardiac septal defect. Case report.* J Neurosurg, 1981. 55(6): p. 997-1000.
21. Bedell, E.A., K.H. Berge, and T.J. Losasso, *Paradoxic air embolism during venous air embolism: transesophageal echocardiographic evidence of transpulmonary air passage.* Anesthesiology, 1994. 80(4): p. 947-50.
22. Rademaker, B.M., et al., *Paradoxical gas embolism by transpulmonary passage of venous emboli during hysteroscopic surgery: a case report and discussion.* Br J Anaesth, 2008. 101(2): p. 230-3.
23. Kim, S.H., et al., *Paradoxical carbon dioxide embolism during endoscopic thyroidectomy confirmed by transesophageal echocardiography.* J Anesth, 2010. 24(5): p. 774-7.
24. Min, S.K., J.H. Kim, and S.Y. Lee, *Carbon dioxide and argon gas embolism during laparoscopic hepatic resection.* Acta Anaesthesiol Scand, 2007. 51(7): p. 949-53.
25. Kapoor, T. and G. Gutierrez, *Air embolism as a cause of the systemic inflammatory response syndrome: a case report.* Crit Care, 2003. 7(5): p. R98-R100.
26. Cuvelier, A., et al., *[Lesional pulmonary oedema following laparoscopy for haemorrhage: aetiological assessment and possible gas embolism].* Ann Fr Anesth Reanim, 2006. 25(8): p. 888-90.
27. Jersenius, U., et al., *The effects of experimental venous carbon dioxide embolization on hemodynamic and respiratory variables.* Acta Anaesthesiol Scand, 2006. 50(2): p. 156-62.