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Simple Technique to Verify CO_2 Diffusion with the CarbonAid™ Device

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ABSTRACT

It has become common practice in cardiac surgery to flood the operative field with CO_2 to facilitate deairing of the heart. However, CO_2 delivery is variable and verification of CO_2 delivery can be challenging. We report a simple, reliable method to confirm CO_2 delivery. This technique ensures that the benefits of CO_2 delivery are provided to the patient during the operation.

INTRODUCTION

Cerebral air microemboli are implicated as a cause of postoperative neurocognitive dysfunction [Braekken 1998], which has an incidence rate of 4% to 33% within seven days after cardiac surgery [Raymond 2006]. Despite standard deairing techniques during reanimation of the heart, air embolization can occur from residual intracavitary air [Al-Rashidi 2011]. In addition, gaseous microbubbles can enter the cardiopulmonary bypass (CPB) circuit leading to cerebral microembolization. For more than fifty years, flooding the operative field with carbon dioxide (CO_2) insufflation has been used to reduce the risk of air embolization [Nichols 1958], and there are many reports on the benefits of CO_2 insufflation. This report's emphasis, however, will be to demonstrate a reliable technique for CO_2 insufflation from the perspective of the surgeon, anesthesiologist, and perfusionist.

METHODS

CO_2 is 25 times more soluble in blood and tissue than air, resulting in a decrease in the formation of air microemboli. Because the density of CO_2 is 50% greater than air, CO_2 settles to the bottom of the pericardial well facilitating air displacement from the wound [Mitz 1979]. CO_2 insufflation into the pericardial wound cavity with the CarbonAidTM CO_2 Diffuser (Cardia Innovation; Stockholm, Sweden) has been shown to markedly decrease the number of microemboli in the left atrium, left ventricle, and ascending aorta following open-heart surgery [Svenarud 2004]. Displacement of air from the pericardial well by CO2 can reduce gaseous microemboli to the brain and may reduce postoperative neurocognitive injury [Braekken 1998].

The amount and adequacy of CO_2 delivery into the pericardial well is difficult to quantify. Surgeons use a variety of techniques for CO_2 application including standard perfusion lines with 2-3–mm inner diameters or perforated Jackson-Pratt drains at flow rates of CO_2 ranging from 2 to 10 L/minute. The assumption has been that adequate CO_2 delivery is occurring. However, the percentage of air remaining in the pericardial well with simple open-end tubes delivering CO_2 is highly variable because of gas swirling effects ranging between 18% and 96% [Persson 2003]. This inconsistency may explain why a recent review of CO_2 insufflation and neurocognitive outcomes found mixed results [Chaudhuri 2011]. Optimal CO_2 delivery occurs when it is delivered into the wound bed with a gas diffuser as is present on the CarbonAid® device [Persson 2004].We routinely insufflate CO_2 into the wound during all open-heart surgeries using a CarbonAid® gas diffuser. The diffuser is positioned 5 cm below the wound opening adjacent to the diaphragm (Figure A). CO_2 is infused at 8 L/min. Early in our experience, it became apparent that we could not verify adequate delivery of the odorless and colorless CO_2. We had experienced kinking and disconnection of the tubing and even failure of the CO_2 source to be turned on. As a result, we developed a simple method confirming CO_2 delivery into the field and have used it in over 700 cases.

The CO_2 tubing running from the gas source to the diffuser in the surgical field is transected and a three-way connector and stopcock is inserted. A sampling tubing line is then connected from the port on the CO_2 delivery tubing (Figure B) to the end-tidal CO_2 monitoring line (Philips IntelliVue G5 M1019A® monitoring system; Philips, Amsterdam, the Netherlands). This configuration requires that the anesthetic end of the sampling line be disconnected from the endotracheal tube after CPB is initiated and the ventilator stopped. This procedure allows for simple confirmation of CO_2 delivery through the tubing by observation of the end-tidal CO_2 waveform monitoring screen (Figure C).

The sampling tubing can be disconnected from the three-way stopcock, and the pericardial gas can be sampled from inside the wound bed at the level of the aorta (Figure D) and the right atrium (Figure E). This step verifies CO_2 delivery

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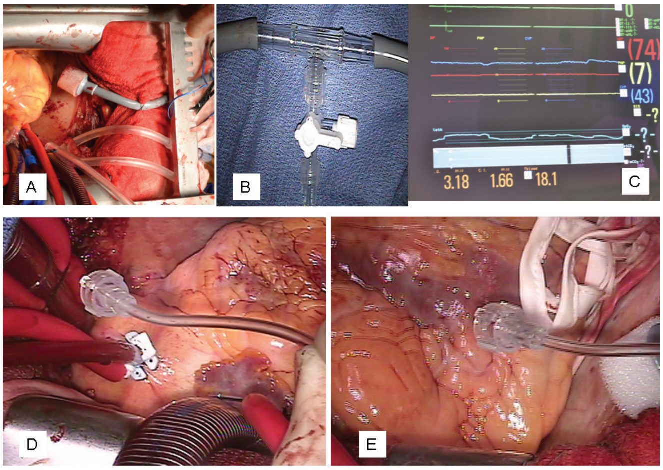

Figure A, CarbonAid® Diffuser is positioned along the inferior/diaphragmatic surface 5 cm below the wound edge. B, CO_2 inflow tubing has been transected and a three-way stopcock inserted. To the right is the CO_2 gas source, to the left is the patient, and inferiorly is the pressure tubing leading to the end-tidal CO_2 monitoring line. C, End-tidal CO_2 monitoring shows 100% CO_2 insufflation. D, Pressure tubing detached to sample pericardial well at level of aorta. E, and right atrium/ventricle.

into all parts of the wound by looking at the end-tidal CO_2 waveform and it only takes seconds to perform. The sampling tubing is then reattached to the three-way stopcock, and the operation proceeds in the standard fashion. When CPB weaning begins, the end-tidal CO_2 sampling tube is returned back to the original connection with the endotracheal tube.

When utilizing CO_2 insufflation, it is recommended that the perfusionist use an in-line blood gas analyzer (CDI™ Blood Parameter Monitoring System 500; Terumo Cardiovascular, Ann Arbor, MI, USA) as part of the CPB circuit. This recommendation is based on the potential for rapid changes in both the PCO_2 content and the pH of the blood requiring perfusionist interventions. The perfusionist may need to make air "sweep" gas adjustments (Air Oxygen Gas Mixer, Model 3500 CP-G; Sechrist, Anaheim, CA, USA) to account for both the location of the cardiotomy suckers and the LPM (Liters Per Minute) of the roller heads required to maintain a bloodless surgical field in order to normalize the PCO_2.

DISCUSSION

Although we have not quantified the results, it appears that there are fewer microbubbles with CO_2 insufflation on transesophageal echocardiography facilitating deairing of the heart. This finding is consistent with quantitative observations from other investigators [Kalpokas 2003; Svenarud 2004]. Although CO_2 insufflation and this technique are clearly useful with a median sternotomy incision, their role in minimally invasive valve surgery, where deairing maneuvers are more difficult, may be especially valuable. Theoretical benefits of CO_2 insufflation include a vasodilatory effect on cerebral circulation, which may be protective in patients with cerebrovascular disease. We have observed that the regional cerebral tissue oxygen-saturation measurements, obtained by Near-Infrared Spectroscopy monitoring (Fore-Sight Cerebral Oximeter; Cas Medical Systems, Branford, CT, USA), appear to be improved in general since using CO_2 insufflation. These areas warrant further investigation. Other advantages of CO_2 pericardial insufflation include reduced coronary air embolization, reduced right heart dysfunction, and less difficulty weaning from CPB [Martens 2001]. Finally, flooding the operative field with CO_2 has also been shown to change the wound temperature [Frey 2010] and reduce the local wound pH [Persson 2008] inhibiting bacterial growth in the open wound. These effects on temperature and pH may render the operative wound less susceptible to postoperative wound infection.

CONCLUSION

Although not the focus of this report, there is ample evidence to support a beneficial role of CO_2 insufflation in open-heart surgery. The method described here to verify CO_2 delivery is simple, reliable, and requires no new equipment, yet it is very effective in confirming CO_2 delivery in the surgical field.

REFERENCES

Al-Rashidi F, Landenhed M, Blomquist S, et al. 2011. Comparison of the effectiveness and safety of a new de-airing technique with a standardized carbon dioxide insufflation technique in open left heart surgery: a randomized clinical trial. J Thorac Cardiovasc Surg 141:1128-33.

Braekken SE, Reinvang I, Russell D, Brucher R, Svennevig JL. 1998. Association between intraoperative cerebral microembolic signals and postoperative neuropsychological deficit: comparison between patients with cardiac valve replacement and patients with coronary artery bypass grafting. J Neurol Neurosurg Psychiatry 65:573-6.

Chaudhuri K, Marasco SF. 2011. The effect of carbon dioxide insufflation on cognitive function during cardiac surgery. J Card Surg 26:189-96.

Frey JM, Svegby HK, Svenaud PK, et al. 2010. CO_2 insufflation influences the temperature of the open surgical wound. Wound Repair Regen 18:378-82.

Kalpokas MV, Nixon IK, Kluger R, et al. 2003. Carbon dioxide field flooding versus mechanical de-airing during open-heart surgery: a prospective randomized controlled trial. Perfusion 18:291-4.

Martens S, Dietrich M, Walls S, et al. 2001. Conventional carbon dioxide application does not reduce cerebral or myocardial damage in open heart surgery. Ann Thorac Surg 72:1940-4.

Mitz MA. 1979. CO_2 biodynamics: a new concept of cellular control. J Theor Biol 80:537-51.

Nichols HT, Morse DP, Hirose T. 1958. Coronary and other air embolization occurring during open heart surgery prevention by the use of gaseous carbon dioxide. Surgery 43:236-44.

Persson M, Svenarud P, van der Linden J. 2004. What is the optimal device for carbon dioxide deairing of the cardiothoracic wound and how should it be positioned? J Cardiothor Vasc Anesth 18:180-4.

Persson M, Van Der Linden J. 2003. De-airing of a cardiothoracic wound cavity model with carbon dioxide. Theory and comparison of a gas diffuser with conventional tubes. J Cardiothor Vasc Anesth 17:329-35.

Persson M, Van Der Linden J. 2008. Intraoperative CO_2 insufflation can decrease the risk of surgical site infection. Med Hypotheses 71:8-13.

Raymond PD, Hinton-Bayre AD, Radel M, et al. 2006. Assessment of statistical change criteria used to define significant change in neuropsychological test performance following cardiac surgery. Eur J Cardiothor Surg 29:82-8.

Svenarud P, Persson M, van der Linden J. 2004. Effect of CO_2 insufflation on the number and behavior of air microemboli in open-heart surgery. Circulation. 109:1127-32.