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Air Embolism during Intraoperative Endoscopic Localization and Surgical Resection for Blue Rubber Bleb Nevus Syndrome

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BLUE rubber bleb nevus syndrome, a rare vascular malformation involving the gastrointestinal tract, may result in clinically significant acute and chronic bleeding. The bleeding is generally chronic and unremitting, with continual melena necessitating transfusion or surgical management. Definitive surgical management is frustrating because the lesions are usually multiple (often numbering in the hundreds) and may be found anywhere in gut derivatives from the mouth to the anus, most often in the small intestine. The length of the instruments available and the risks of incomplete removal and perforation limit endoscopic treatment such as sclerotherapy or laser photocoagulation as an alternative. Combined approaches using transoral and transrectal endoscopic examination and endoscopic examination *via* laparotomy/enterotomy permit visualization of the entire gastrointestinal tract.[1–6]

Case Report

An 11-yr-old, 29.6-kg girl with blue rubber bleb nevus syndrome underwent simultaneous upper and lower endoscopy and exploratory laparotomy for resection of multiple vascular lesions. She had experienced gastrointestinal bleeding 2 weeks before admission.

After intravenous premedication with midazolam, anesthesia was induced with propofol, fentanyl, and pancuronium. The trachea was intubated with a 6.0-mm cuffed orotracheal tube, and anesthesia was maintained with an air–oxygen mixture and 0.5–1.2% end-tidal isoflurane. Ventilation at a tidal volume of 320 ml and a rate of 9 breaths/min was controlled by a rising-bellows pneumatic anesthesia ventilator. Standard noninvasive monitors were used, and in addition, a radial artery line was placed. An infrared spectrometer was used (Datex Capnomac Ultima; Datex Medical Instrumentation, Tewksbury, MA), and end-tidal carbon dioxide and isoflurane concentrations were recorded.

Approximately 3 h into the procedure, after laparotomy, esophagogastroduodenoscopy, and transoral proximal enteroscopy with manual assistance to advance the telescope and while undergoing colonoscopy (Olympus PCF-160-AL video colonoscope; Olympus America Inc., Melville, NY), the patient had a decrease in oxygen saturation to 88–94%, a decrease in end-tidal carbon dioxide to 22 mmHg, and hypotension (51/31 mmHg; baseline, 93/43 mmHg). Simultaneously, there was an increase in the peak inspiratory pressure (33 cm H_2O; baseline, 22 cm H_2O) and mean airway pressure (17 cm H_2O; baseline, 5 cm H_2O). The small bowel was distended approximately 6 cm and attenuated. The insufflation was stopped, the bowel was allowed to decompress, the isoflurane and air in the inspired gas were discontinued, and the oxygen saturation improved to 99–100%. A bolus of lactated Ringer's solution (19 ml/kg) was given. After the patient became hemodynamically stable, the surgeon examined the bowel and found small air bubbles with a "Rice Krispies®" appearance in the mesentery (fig. 1).

Gas delivery system dysfunction accounting for a sudden decrease in end-tidal carbon dioxide was quickly checked for and ruled out: There was no leak in the endotracheal tube cuff, the patient did not show evidence of spontaneous breathing either by physical examination or notching of the capnographic waveform, and there were no disconnects or ventilation system obstructions. No further treatment was required, and the case proceeded uneventfully to the conclusion of surgery, emergence, and the perioperative period.

Discussion

Venous air embolism (VAE), now commonly reported with many surgical procedures, has rarely been reported with gastrointestinal endoscopy. This case offered a unique opportunity to examine the external surface of the bowel and mesentery during upper and lower gastrointestinal endoscopy. The most likely cause of the VAE was direct transmucosal to intravascular introduction of enteric air under high pressure, with additional entrapment in the mesentery.

The pathophysiology of VAE has been well described[7]; typical intraoperative signs include hypotension, a decrease in end-tidal carbon dioxide, and alterations in airway pressure. The biochemistry of these multisystem findings may result from the release of vasoactive mediators, complement, and cytokines.[8–10] However, early detection remains the basis for monitoring in higher risk cases. Although not usually employed during lower risk cases, transesophageal echocardiography, precordial Doppler ultrasonography, or a pulmonary artery catheter, in descending level of sensitivity, reveal evidence of VAE.[11] The pneumomesentery with crunchy "Rice Krispies®"-like pockets of air and the rapid resolution of the signs of VAE after decompression of the bowel and removal of the colonoscope serve to further support the intraoperative diagnosis of VAE.

The choice of insufflation gas has been a matter of considerable investigation. Almost all surgical endoscopy at this point is conducted with carbon dioxide as the insufflation gas, whereas the gastrointestinal endoscopy insufflation gas most commonly used continues to be air. Other gases less frequently used include nitrous

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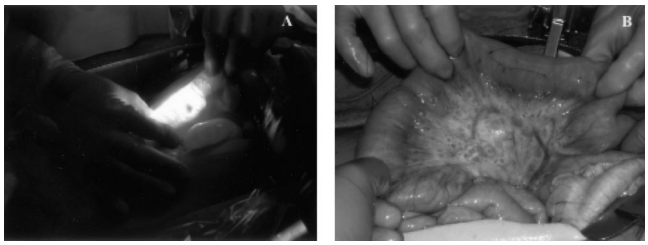

Fig. 1. (*A*) Intraoperative enteroscopy demonstrating nevus location by transillumination. (*B*) Pneumomesentery.

oxide, helium, argon, nitrogen, and oxygen. Although nitrous oxide is somewhat less soluble than carbon dioxide (130 *vs.* 170 ml/100 ml water), it supports combustion. Even the use of nitrous oxide as part of the anesthetic technique is less frequently chosen because of its possible contribution to expanding any entrained or insufflated air.[12] The choice of carbon dioxide as an insufflation gas is based on its high aqueous solubility and lack of support of combustion. The magnitude of physiologic derangement attributable to carbon dioxide is 6.5 times less than that of air.[13] Neither helium nor argon support combustion, but argon has been associated with myocardial depression, and helium has been associated with subcutaneous emphysema.

This intraoperative endoscopic approach to the multifocal vascular malformations of blue rubber bleb nevus syndrome has rarely been described,[3,14,15] although in 10 previous cases at our institution by the same surgeon and gastroenterologist, VAE did not occur. However, this case raises an intriguing question. Because transoral and transrectal flexible endoscopy is so commonly performed and intraoperative enteroscopy is rarely used, it is likely that technical aspects of the latter technique contributed to the occurrence of VAE. Continuous insufflation through the endoscope while maintaining manual compression of the distal bowel optimizes visualization and the likelihood of identifying small lesions. However, this technique may increase the intraluminal pressure beyond that caused by standard closed-abdomen endoscopy. As collaborations in the operating room continue to develop between surgeons and procedurally trained medical colleagues, consideration should be given to how techniques developed outside the operating room should be modified, such as conversion to carbon dioxide rather than air for gastrointestinal insufflation. VAE is rare in current clinical practice,[16,17] but as practice and new collaborations evolve, previous practices should be a cause for reflection if not active, prospective study.

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Remifentanil in the Intensive Care Unit: Tolerance and Acute Withdrawal Syndrome after Prolonged Sedation

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SEDATION in the intensive care unit should be minimized to reduce the duration of mechanical ventilation and its related complications.[1] The drug regimen would ideally allow rapid awakening, to perform neurologic and respiratory evaluation on a daily basis.[2,3] In this context, remifentanil, with its unique pharmacokinetic profile, should be considered an agent of choice.[4,5] However, acute tolerance and even hyperalgesic response have been observed after opioid administration.[6–8] In addition, withdrawal syndrome after cessation of opioid-based sedation has been seen in the intensive care unit setting.[9–11] We report three cases of severe and fast-onset withdrawal syndrome, with signs of acute tolerance, after remifentanil-based sedation of between 2 and 30 days' duration, requiring reintroduction of remifentanil and then tapering over 24–48 h.

Case Reports

Case 1

A 69-yr-old man was admitted to the hospital for facial and hip trauma after a bike accident. He underwent intubation on day 3 for respiratory failure. He was sedated with propofol at 200 mg/h and remifentanil at 0.1 $\mu g \cdot kg^{-1} \cdot min^{-1}$ and then 0.16 $\mu g \cdot kg^{-1} \cdot min^{-1}$ to maintain a Ramsay score of 3. On day 5, the propofol was stopped, and the remifentanil infusion was decreased to 0.08 $\mu g \cdot kg^{-1} \cdot min^{-1}$ for 1 h. The patient then safely underwent extubation, and the remifentanil was stopped 1 h later. Within 10 min, the patient became very anxious, reporting vague discomfort but no pain. He had myoclonus and uncontrollable shaking of all four limbs, and was noted to be sweating, hypertensive, and tachycardic. We suspected an opioid withdrawal syndrome, which was treated with 20 mg intravenous morphine, 150 μg clonidine, and 10 mg haloperidol. Despite this treatment, the symptomatology persisted. We restarted remifentanil at 0.1 $\mu g \cdot kg^{-1} \cdot min^{-1}$, and the symptoms disappeared within 5 min. Subsequently, we started a morphine infusion at 40 mg/day and then progressively tapered remifentanil over the next 48 h.

Case 2

A 52-yr-old man was admitted to the hospital for head trauma after a motorbike accident. He underwent intubation and received remifentanil at 0.1 $\mu g \cdot kg^{-1} \cdot min^{-1}$ and midazolam at 15 mg/h. After 24 h, the midazolam was stopped. During the ensuing 30 days, we had to increase the infusion rate of remifentanil to 0.725 $\mu g \cdot kg^{-1} \cdot min^{-1}$ to maintain a Ramsay score of 3. On day 33, after neurologic improvement, we were able to decrease the infusion rate to 0.325 $\mu g \cdot kg^{-1} \cdot min^{-1}$, and the patient underwent extubation after further tapering over a 2-h period. Ten minutes after discontinuation, we observed severe agitation with tachycardia, hypertension, tachypnea, mydriasis, sweating, and myoclonus. The patient was given 10 mg morphine and 150 μg clonidine intravenously, without any change. We restarted remifentanil infusion at a rate of 0.1 $\mu g \cdot kg^{-1} \cdot min^{-1}$, and the symptoms improved dramatically. An intravenous infusion of morphine was started, followed by tapering of the remifentanil over 24 h.

Case 3

A 32-yr-old woman was admitted to the hospital after an automobile accident with head trauma, myocardial contusion, and fracture of the wrist and ankle. She underwent intubation and was sedated for the next 4 days to maintain a Ramsay score of 4, with propofol at 120 mg/h and remifentanil at 0.12 $\mu g \cdot kg^{-1} \cdot min^{-1}$. The remifentanil infusion rate had to be increased to 0.72 $\mu g \cdot kg^{-1} \cdot min^{-1}$ and the propofol rate had to be increased to 200 mg/h because of pneumonia. After resolution of the pneumonia, the remifentanil infusion rate was decreased to 0.48 $\mu g \cdot kg^{-1} \cdot min^{-1}$, and propofol was stopped and replaced by midazolam at 10 mg/h because of signs of major anxiety. On day 15, midazolam and remifentanil were discontinued, and 10 mg morphine was injected intravenously. The patient became extremely agitated, although not confused, with associated tachycardia, hypertension, tachypnea, and mydriasis. She received 150 μg intravenous clonidine and 20 mg ketamine, without any improvement. She improved immediately after reintroduction of remifentanil. The patient underwent extubation 2 days later, after remifentanil was tapered in conjunction with an intravenous infusion of morphine and clonidine.

Discussion

We use remifentanil-based sedation to facilitate frequent awakening for neurologic and respiratory evaluation of our patients.[4,5,12,13] During a 6-month period, 4 of 40 patients receiving a similar sedation regimen in our department presented the same acute-onset withdrawal syndrome, in addition to development of acute tolerance to remifentanil.

Initial infusion rates complied with the manufacturer's recommendations (0.10–0.15 $\mu g \cdot kg^{-1} \cdot min^{-1}$). Subsequently, they were adjusted, following an established protocol, to maintain a predefined Ramsay score. When sedation was no longer needed, the infusions were ta-

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pered and stopped over a 2-h period. This protocol was similar to protocols in place in other intensive care units in France.

We think that the observed symptoms are those of withdrawal syndrome because, first, the clinical presentation was typical of an opioid withdrawal syndrome, and the onset was approximately 10 min after discontinuation of remifentanil; second, the patients were not in pain at the time of symptoms; third, the patients had regained consciousness and did not show any confusion; and finally, the patients did not have any significant preexisting medical conditions or history of substance abuse (*e.g.*, alcohol) that could explain the symptoms.

We did not find any similar cases of acute-onset withdrawal syndrome in studies with adult patients[9,10] or children.[14–17] In adult studies, withdrawal syndrome occurs when there is a sudden discontinuation of an opioid drug (usually fentanyl).[9,10] We postulate that in our series of patients, the same phenomenon occurred after discontinuation of the short-acting remifentanil over a short period of time (2 h).

Acute tolerance to the analgesic effects of opioids has been shown to occur within a few hours after commencing administration of opioids,[6,7] including remifentanil,[6,8] but acute tolerance to their sedative properties has been studied little.[16,17]

Our patients had no history of alcohol or substance abuse. However, other patients who received the same drug regimen, including some who were alcohol abusers, did not present such a withdrawal syndrome. We believe there may be a genetic component to these observations.[18,19] Pharmacogenetics is a gene-by-gene approach, and pharmacogenomics is an approach to the genome focusing on its expression.[20] The latter approach seems more appropriate in evaluating a genetic basis for tolerance and withdrawal, because these processes are complex and likely involve many pathways (*e.g.*, the cyclic adenosine monophosphate signal transduction pathway and its distal effectors).[20] However, much research remains to be done in this field before we can accurately evaluate the potential importance of these various mechanisms.[21]

In conclusion, we hypothesize that remifentanil-based sedation may result in acute tolerance and a unique withdrawal syndrome, in that it can only be treated by remifentanil. The obvious precipitating factor seems to be the rate of infusion discontinuation. Because there were no medical risk factors identified, we postulate that this difference could be due to yet unknown genetic factors. Current guidelines recommend a systematic prevention of opioid withdrawal syndrome by gradually tapering the infusion rate.[22] However, further studies are necessary to prospectively evaluate the clinical importance of this phenomenon in relation to remifentanil. In the meantime, we recommend tapering a remifentanil-based sedation over 24–48 h, in conjunction with a concurrently running morphine infusion (evidence-based recommendation grade C).

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