BRIEF COMMUNICATIONS

CARBON DIOXIDE EMBOLISM DURING ENDOSCOPIC SAPHENECTOMY FOR CORONARY ARTERY BYPASS SURGERY

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A 74-year-old woman (43 kg, 139 cm) was admitted to the Montreal Heart Institute for unstable angina. She had had left carotid endarterectomy 4 years earlier and was awaiting surgery for right carotid occlusive disease in another hospital. An unstable angina syndrome developed for which she was referred to our center. A coronary angiogram revealed a proximal occlusion of the left anterior descending artery, severe stenosis of the left circumflex artery with poor runoff, and a 70% stenosis of the dominant right coronary artery. Left ventricular contraction was within normal limits at echocardiography. She was scheduled for a double coronary artery bypass of the left anterior descending and right coronary arteries without extracorporeal bypass to minimize the risk of stroke. Anesthesia was induced with sufentanil, midazolam, and pancuronium. The blood pressure was 180/75 mm Hg and the central venous pressure, 5 mm Hg. Catheterization (Swan-Ganz catheter, Baxter Healthcare Corp, Edwards Division, Santa Ana, Calif) showed a normal pulmonary artery pressure (19/9 mm Hg) and cardiac output was 2.4 L/min (cardiac index: $1.9 \text{ L} \cdot \text{min}^{-1} \cdot \text{m}^{-2}$). The initial blood gas values were within normal limits. Concomitantly to sternotomy and the beginning of the internal thoracic artery dissection, a right lower thigh incision was performed for endoscopic saphenectomy (Vasoview, Uniport Endoscopic Vessel Harvesting System, Origin Medsystems, Inc, a subsidiary of Eli Lilly and Company, Indianapolis, Ind). After identification of the internal saphenous vein and insertion of a port, a seal was achieved at the level of the knee incision and carbon dioxide insufflation was initiated at a flow of 2 L/min to obtain a pressure of 15 mm Hg. The saphenous vein was dissected up to the level of the femoral crux. During isolation of branches, 1 small collateral vein was torn off near the crux, 8 minutes after the start of the endoscopic dissection. Simultaneously, systemic blood pressure suddenly fell to 55 mm Hg systolic (Fig 1, A), followed by ischemic changes (depression of the ST segment in leads

DII and V₅, Fig 1, B). Capnography showed an immediate rise of end-tidal carbon dioxide to 48 mmHg (Fig 1, D). Carbon dioxide insufflation was immediately discontinued and the internal thoracic artery retractor was taken down to rule out any cardiac compression, but there was no improvement in the hemodynamic status. A sternal retractor was put in and cardiac dissection was begun as the extracorporeal circuit was primed. One hundred micrograms of phenylephrine hydrochloride (Neo-Syneprine) was administered and a perfusion of norepinephrine was started. The blood gas sample drawn during the hypotensive episode showed respiratory acidosis with a pH of 7.27 and a PCO₂ level of 64 mm Hg. There were no changes in ventilation pressures and the arterial oxygen saturation was 100%. Pulmonary artery pressure rose to a level of 60 mmHg systolic with a central venous pressure of 19 mm Hg (Fig 1, C). Ventilatory rate and tidal volume were increased with an inspired oxygen fraction of 100%. Ischemic changes regressed as the blood pressure was restored. The total duration of hypotension was 4 minutes. After hemodynamic stabilization without further need for inotropic support, the harvesting of the left internal thoracic artery was resumed and the saphenous vein was taken out by the bridging technique. The 2 bypasses were completed uneventfully off-pump with mechanical stabilization. The patient was extubated 12 hours after the operation with no evidence of neurologic deficit or elevation of serum creatine kinase MB levels. The patient was discharged on postoperative day 6 without complications.

Comment. The internal saphenous vein used for coronary artery bypass is usually harvested by the open technique, allowing direct visualization. Many potential complications may occur with the traditional technique, including dehiscence, skin necrosis, or wound infection. These complications are increased in the case of obesity, diabetes mellitus, and peripheral vascular disease. To reduce these complications and to improve the functional result and, to a lesser degree, the cosmetic appearance, new techniques are now available with the current trend of minimally invasive coronary surgery. These include the classic bridging technique, the tunneling technique, and endoscopic harvesting with or without gas insufflation.

Serious venous gas embolism, a rare complication of endoscopic procedures with an incidence of about 1 in 7500 cases in laparoscopic surgery,¹ has not yet been reported in endoscopic saphenectomy. The mechanisms of carbon dioxide embolism usually involve absorption into the circulation, carbon dioxide being highly soluble in blood, or, more seriously, direct entry of

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Fig 1. C, Hemodynamic recording showing sudden drop in mean arterial pressure (PAM) at 9:20 with a progressive rise in mean pulmonary artery pressure (APM) from 9:15 to 9:30. B, Recording of the ST-segment trend during the acute hypotensive episode with a 0.2 mV lowering of the segment concomitant to the hypotension. D, Capnographic recording showing acute elevation of end-tidal carbon dioxide at the time of carbon dioxide embolism.

gas into the vascular bed generally via an injury to a vessel. This is dependent on the gradient between the central venous pressure and the pressure of insufflation, as demonstrated by Bazin and colleagues² during laparoscopy in a porcine model. By extrapolation, one can assume that the mechanism is similar in case of injury to the saphenous vein and in the presence of relative hypovolemia, as in our patient. Similarly, gas embolism has been reported during hysteroscopy with patients in the Trendelenburg position.³ This important yet simple factor should be taken into consideration and the operating table should be set in the Fowler position, which facilitates the harvesting of the internal thoracic artery pedicle.

Manifestations of carbon dioxide embolism are "gas lock" in the right atrium, pulmonary gas embolism, paradoxical embolism with or without patent foramen ovale with coronary embolism or neurologic disturbances, bradycardia or arrhythmia, cardiovascular collapse resulting from acute reduction in the peripheral resistance, and cardiopulmonary arrest.⁴ The detection of carbon dioxide embolism is based on the widely established end-tidal carbon dioxide monitoring. Indeed, carbon dioxide embolization causes a biphasic change in end-tidal carbon dioxide.⁴ The decrease in end-tidal carbon dioxide is usually encountered in case of embolism, being preceded by an initial increase resulting from pulmonary excretion of carbon dioxide, as in our patient (Fig 1, D). Transesophageal echocardiography, increasingly used in modern cardiac surgery, is a more sensitive tool for detecting gas bubbles during laparoscopy⁵ and could be used routinely in this clinical setting, allowing in addition the evaluation of regional contraction. Furthermore, clinical evaluation using transesophageal echocardiography is in progress in our center to assess the precise incidence of this phenomenon. We are aware that the majority of episodes are not clinically significant, as demonstrated in a series of laparoscopic cholecystectomies.⁶ If hypercapnia occurs, the endoscopic procedure insufflation should be immediately suspended and simultaneous compression of the proximal venous axis at the

groin should be instituted. Trendelenburg position with tilting of the patient to the left, pharmacologic manipulations, and central venous pressure elevation by volume repletion to restore the hemodynamic status should be implemented promptly and the operation resumed with conversion to the open or bridging technique. In case of a major embolism, aspiration of gas from the right ventricle via the thermodilution catheter or via a direct puncture using a needle may relieve a gas lock in the right ventricle.¹ In refractory cases, cardiopulmonary bypass may be required.

In the case reported here, the conjunction of multiple factors, that is, injury to the vein in an elderly woman with low weight and friable tissues, with concomitant hypovolemia in the supine position, enabled gas embolism to occur. No untoward consequences occurred because of vigilant intraoperative monitoring and prompt intervention. Knowledge of the predisposing factors and preventive measures should keep the rate of this complication low and enable patients to have the full benefits of this advance in coronary artery bypass surgery.

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