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A Partial Disconnection at the Main Stream CO_2 Transducer Mimics "Curare-cleft" Capnograph

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IN paralyzed and mechanically ventilated patients, normally, the expiratory phase of the capnogram consists of a period of increasing CO_2 followed by a plateau, which lasts until the next inspiration (fig. 1A). A brief inspiratory effort occurring during expiration will result in transient decrease in CO_2 during the plateau phase, an event popularly called a *curare-cleft* (fig. 1B).[1,2] This decrease may represent gasping caused by pain, hypoventilation, hiccups,[3] or an anesthetic machine malfunction.[4,5] We report here that a partial disconnect of a main stream capnometer also can present as a "cleft" on the expiratory CO_2 wave form during controlled ventilation.

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Key words: Breathing circuit disconnection; capnography.

Case Report

A healthy, 32-yr-old man weighing 64 kg was scheduled for right frontal craniotomy and the excision of meningioma. Anesthesia was induced with intravenous fentanyl (2 μg/kg) and sodium thiopental (5 mg/kg), and muscular relaxation was facilitated with vecuronium bromide (0.1 mg/kg). After tracheal tube placement, the lungs were ventilated with a Anespirator-1300 (ACOMA Inc., Japan) at a tidal volume of 500 ml and a respiratory rate 10 breaths/min using a semi-closed breathing system.

Standard monitors were used. Capnometer (Hewlett-Packard 47201 A; Hewlett-Packard Co., Waltham, MA) was also used, with the main-stream sensor placed between the endotracheal (ET) tube and breathing system. Because the transducer is heavy, adhesive tape was used to secure the connectors between the ET tube, the transducer, and the anesthetic circuit.

After induction of anesthesia, we noticed a "cleft" (a sudden dip in CO_2) during expiratory plateau phase on capnograph. Additional vecuronium (2 mg) was administered. There were no obvious inspiratory efforts by the patient nor did we see the typical negative deflection of the airway pressure gauge. We then noted that $ETCO_2$ (42 mmHg) had increased from control (33 mmHg), the peak airway pressure had decreased from 14 to 10 cmH_2O, and expired tidal volume had decreased to 280 ml (from the set 500 ml). A leak in breathing system was suspected and found between the capnograph transducer sensor assembly and the ET tube. Reconnection of the transducer eliminated the leak and restored the capnograph trace to normal in the next exhalation (fig. 1C).

After this incident, we found that it was possible to reliably reproduce the previously observed capnograph by creating a partial disconnect between the CO_2 transducer assembly and either the ET tube or the circuit, at least as long as the leak remained small enough to permit partial chest inhalation during inspiration.

Discussion

During controlled ventilation, the capnograph tracing has a characteristic shape. Expired CO_2 is typically zero during inspiration. With the onset of exhalation, CO_2 increases rapidly, followed by a plateau until the beginning of next breath. Any "cleft" in the exhalation phase represents entry of fresh gas near the transducer and the dilution of the exhaled CO_2.

In presence of the disconnection noted here, the inspiratory capnogram is unchanged. During the expiratory phase, the initial high expiratory flow rate will be sufficient to close the inspiratory valve and allow exhaled gas to flow through the CO_2 analyzer. After passing through the CO_2 analyzer, some exhaled gas will exit the circuit *via* the expiratory valve, whereas the remainder will exit *via* the partial disconnect (leak flow rate [LFR]). This will result in a normal initial expiratory capnogram, with a rapid increase in CO_2 followed by a plateau. As the expiratory flow rate decreases, leak flow will cause pressure to decrease in the circuit, allowing the expiratory valve to close prematurely and preventing the inspiratory valve to open. The resultant fresh gas flow through the CO_2 analyzer reduces the measured expired CO_2. As fresh gas flow causes pressure to rebuild in the circuit, the expiratory valve will reopen, allowing alveolar gas to again pass through the CO_2 analyzer. These events will appear as a cleft in the expiratory capnogram.

The transducer adapter in Hewlett-Packard 47201 capnometer (Hewlett-Packard) has connectors on both ends. Its heavy weight and longer length may increase the potential for disconnection. In this case, the adhesive top prevented complete separation and resulted in the partial disconnection, which resulted in the changes noted. Because the site of disconnect may be obscured under the drapes and remote to anesthetist, its detection may be difficult and delayed. Any delay in correction will result in hypoventilation, hypercapnia, and hypoxia.

In summary, occurrence of sudden clefts in the expiratory phase on the capnograph may result from a partial disconnection near the CO_2 analyzer.

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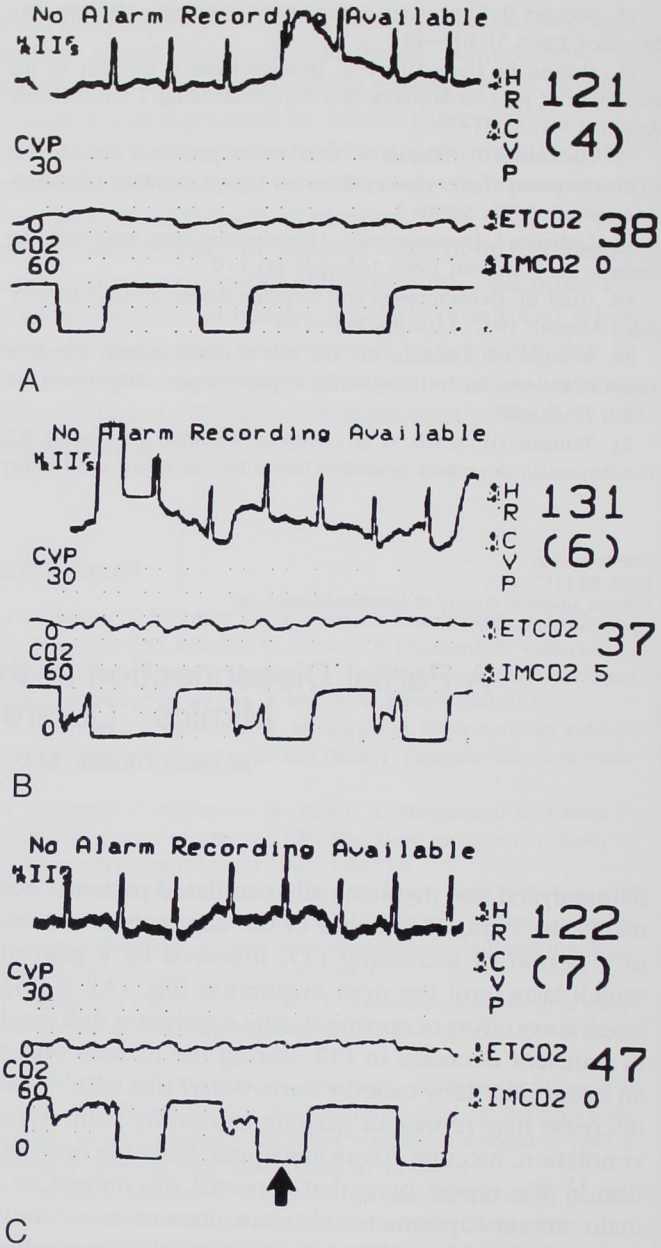

Fig. 1. ***(A)*** **Typical capnograph during positive pressure ventilation.** ***(B)*** **Typical expiratory "cleft" in capnograph with patient breathing due to wearing off effect of muscle relaxant (note the unchanged $ETCO_2$).** ***(C)*** **"Fish-mouth" disconnection capnograph mimics same that of** ***(B)*****, but the correction of leak "|" gives normal expiratory graph in the very next breath.**

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False-positive Diagnosis of Aortic Dissection Associated with Femoral Cardiopulmonary Bypass

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AORTIC dissection is a rare, catastrophic complication of cardiopulmonary bypass (CPB). In most reported cases of aortic dissection during cardiac surgery, the site of arterial cannulation is the origin of the dissection.[1] Experience with common femoral artery cannulation for standard CPB has demonstrated an incidence of retrograde ilioaortic dissection as high as 3% associated with significant morbidity and mortality.[1,2] Some recently introduced cardiac surgical systems (*e.g.*, PortAccess™, Heartport Inc., Palo Alto, CA) use femoral arterial cannulation for CPB and hence are at risk for retrograde ilioaortic dissection.[3] We describe a case in which transesophageal echocardiography (TEE) findings prompted the incorrect diagnosis of descending aortic dissection during initiation of femoral CPB for mitral valve surgery.

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Key words: Cardiac surgery; complications; transesophageal echocardiography.

Case Study

A 57-yr-old man with severe mitral regurgitation, congestive heart failure, and atrial fibrillation resulting from mitral valve prolapse was scheduled to undergo right thoracotomy for mitral valve repair. Preoperative cardiac catheterization confirmed mitral regurgitation and was otherwise unremarkable, including a normal ascending aorta. The patient had no other comorbidities and was noted on physical examination to have comparable blood pressures in both arms and normal femoral artery pulses bilaterally.

After uneventful induction of anesthesia and endotracheal intubation, a 5.0-MHz multiplanar TEE probe was inserted (Hewlett-Packard Sonos 2000, Hewlett-Packard Co., Palo Alto, CA). The pre-CPB TEE examination confirmed findings noted on the preoperative cardiac catheterization. In addition, the proximal ascending aortic and the descending thoracic aorta were well visualized showing no evidence of atherosclerotic disease.

After systemic heparin anticoagulation, a 24-French arterial cannula (Endoarterial Return Cannula, Heartport) was placed atraumatically in the right common femoral artery with direct surgical exposure, and a 28-French venous cannula was advanced into the right atrium from the right femoral vein. A centrifugal pump was placed between the venous cannula and the venous reservoir to increase venous drainage. The pump prime consisted of 1200 cc of Normosol (Abbott Laboratories, North Chicago, IL), 250 cc of 20% mannitol, 500 cc of 6% hydroxyethyl starch, 50 mEq of sodium bicarbonate, and 5000 U of heparin. As CPB was slowly initiated, TEE imaging at 45 cm from the teeth in the horizontal plane immediately demonstrated an echogenic region in the descending thoracic aorta apparently separated from the aortic lumen by a membrane. These TEE findings were believed to strongly suggest an evolving aortic dissection, and CPB was immediately discontinued. The observed TEE evidence of dissection rapidly disappeared, leaving a normal appearing descending aorta. No other clinical evidence during CPB initiation indicated aortic dissection. The in-line pump arterial pressures were normal throughout, as were the arterial pressure measured in the right radial artery, the pulse oximeter on the left thumb, and the bilateral middle cerebral artery transcranial doppler signals. CPB was cautiously reini-