Case Report

Positive end-expiratory pressure as a novel method to thwart CO_2 leakage from capnothorax in robotic-assisted thoracoscopic surgery

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ABSTRACT

Capnography and end tidal CO2 (EtCO2) aids the anaesthesiologist in diagnosing problems during all phases of general anaesthesia. Negative arterial to end-tidal carbon-dioxide gradient during anaesthesia has been reported in various conditions including pregnancy, infants and inadvertent exogenous addition of carbon dioxide (CO2) to the expired gas in case of thoracoscopic procedures with iatrogenic injury to lung parenchyma/bronchial tree. Thus, airway injury or intentional opening of airway as a part of surgical step can be diagnosed using a negative arterial and end tidal CO2 gradient. Higher optimal PEEP can be used as a splint across the bronchial cuff in one-lung ventilation which prevents leak from capnothorax and decrease inadvertent entry of CO2 in to the expired gases which erroneously increase arteriolar to end tidal CO2 gradient.

Key words: Capnothorax, positive end-expiratory pressure, thoracoscopic surgery

INTRODUCTION

Negative arterial to end-tidal carbon-dioxide gradient during anaesthesia is reported in various conditions including pregnancy, infants, and inadvertent exogenous addition of carbon dioxide (CO_2) to the expired gas in thoracoscopic procedures with iatrogenic injury to lung parenchyma.[1-3] We discuss a case of robotic-assisted thoracoscopic surgery with negative arterial-$EtCO_2$ gradient, its intraoperative concern, and a novel management technique.

CASE REPORT

A 59-year-old female of height 156 cm with carcinoma of lung left lower lobe was posted for left lower lobectomy. Her preoperative assessment revealed adequate cardiopulmonary reserve and had predicted postoperative Forced Expiratory Volume (FEV_1) of 58%. Anaesthetic plan included thoracic epidural analgesia and general anaesthesia. During intubation there was difficulty in negotiation of tracheal cuff of 35- French left sided double lumen tube (DLT) through the glottis. Hence a 7-French bronchial blocker (Arndt- Cook® Medical) was chosen for lung isolation. A 7.5 mm endotracheal tube was placed through which bronchial blocker was placed in left main bronchus guided by a fibreootic bronchoscope (FOB). Position of the bronchial blocker and isolation of left lung was ensured by FOB in right-lateral position.

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After docking of the Robotic da Vinci Xi® surgical system, capnothorax was created in left pleural cavity with pressure of 8 mmHg. Commencement of dissection of left lower bronchus resulted in sudden increase in $EtCO_2$ with intermittent normal range of $EtCO_2$. Patient's heart rate, saturation (SpO_2), blood pressure, temperature, and airway pressure were stable throughout the procedure. Arterial blood gas revealed partial pressure of CO_2 ($PaCO_2$) of 45 mmHg. Suspecting increased systemic absorption of CO_2 from capnothorax, respiratory rate was increased to increase minute-ventilation [tidal volume-300 ml, respiratory rate – 18.min^{-1}, positive end-expiratory pressure (PEEP) 4 cm H_2O]. Few minutes later, $EtCO_2$ continued to rise up to 114 mmHg [Figure 1a] with $PaCO_2$ of 42 mmHg. At this point, the left lung remained collapsed and bronchial cuff position was confirmed by FOB. On inspection, open left lower lobe bronchus communicating with capnothorax was suspected to be the cause for negative arteriolar to $EtCO_2$ gradient [Figure 1b]. The surgeon was notified regarding the same and the capnothorax pressure was reduced to 5 mmHg (6.5 cmH_2O). PEEP was increased to 8 cmH_2O thereby reversing the pressure gradient across the open bronchus and proximal bronchial cuff. These manoeuvres led to the reduction in efflux of capnothorax CO_2 into the airway which was reflected in $EtCO_2$. Thoracoscopic lobectomy was continued and rest of the procedure was uneventful.

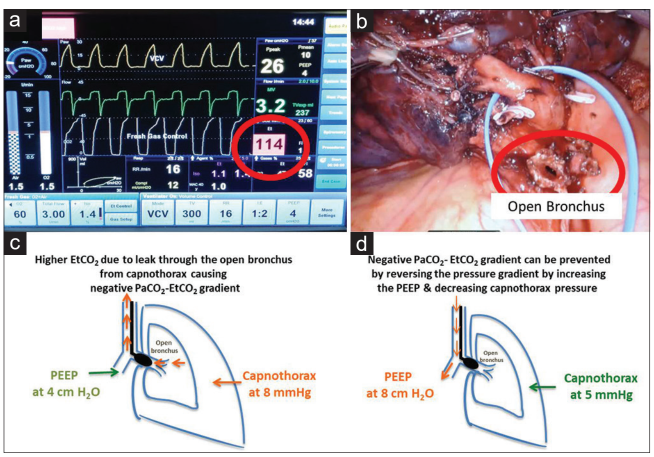

Figure 1: Intraoperative rise in $EtCO_2$ due to leak from capnothorax and its management. (a) Rise in $EtCO_2$. (b) Open bronchus communicating with capnothorax. (c and d) PEEP as a technique to prevent CO_2 leak from capnothorax

DISCUSSION

Capnography along with electrocardiogram (ECG), blood pressure, SpO_2, temperature, peak airway pressure, plateau airway pressure, arterial partial pressure of oxygen (PaO_2), and $PaCO_2$ are generally used in arriving at a specific diagnosis for intraoperative rise in $EtCO_2$ under general anaesthesia [Table 1]. A sudden rise in $EtCO_2$ in patients undergoing robotic-assisted thoracoscopic lobectomy with OLV can be associated with CO_2 embolism and lung/airway injury.[2,4,5] CO_2 embolism, though rare, can be seen commonly at the time of CO_2 insufflation into the pleural cavity. It is diagnosed with the help of clinical features secondary to abnormalities in gas exchange and increased right ventricular afterload. However, it is also possible that CO_2 embolism may present with decreased $EtCO_2$ due to the "gas lock" effect. Although CO_2 embolism is seen commonly during initial period of insufflation, a sudden rise in $EtCO_2$ due to lung/airway injury can occur during the middle of the surgery during dissection. The insufflation CO_2 can escape through the injured open airway (bronchial tree) and reaches capnometer with the expired gases causing rise in $EtCO_2$. This differs from CO_2 embolism in that the $PaCO_2$ in embolism remains higher and the gradient between the $PaCO_2$ and $EtCO_2$ remains the same or only slightly increased.[5] Whereas in "lung/airway injury" there is a significant rise in $EtCO_2$ with near normal $PaCO_2$.[2] A negative $PaCO_2$ to $EtCO_2$ gradient associated with a sudden rise in $EtCO_2$ in a thoracoscopic

Table 1: Differential diagnosis for a sudden rise in $EtCO_2$ in a case of thoracoscopic/laparoscopic procedures

ECG/heart rate and blood pressure	Capnography	Airway pressure	$PaCO_2$	PaO_2	Temperature	Diagnosis
Arrhythmia, tachycardia, and higher systolic blood pressure	Normal plateau or longer plateau with a higher $EtCO_2$	No change	Higher than normal	No change or reduced	No change	Hypoventilation e.g., lower tidal volume or respiratory rate not eliminating the normal CO_2 production
Arrhythmia, tachycardia, and higher systolic blood pressure	Normal plateau with a higher $EtCO_2$	Increased in case of laparoscopy or thoracoscopy and No change in case of malignant hyperthermia	Higher than normal	No change or reduced	Significantly higher in case of malignant hyperthermia	Increased CO_2 production/ absorption e.g., CO_2 pneumoperitoneum, thoracoscopy and malignant hyperthermia
No change	Significantly higher $EtCO_2$	No change	No change	No change	No change	Airway injury/intentional opening airway as part of surgical step

lobectomy points toward a possible airway injury and rules out other differential diagnosis such as CO_2 embolism and malignant hyperthermia wherein the gradient remains positive. Other possible causes for a negative arteriolar to end-tidal CO_2 gradient can be seen in infants and patients with decreased functional residual capacity especially when they are ventilated with higher tidal volume at lower respiratory rate.[6] In our case, the insufflation CO_2 entered through the damaged bronchial tree [Figure 1b], causing the $EtCO_2$ level reaching a peak of 114 mmHg with arterial CO_2 tension of 41 mmHg at that point of time. The primary issue with CO_2 leak into the bronchial tree was that the capnothorax pressure was inadequate for the surgeon to operate with ease. This made them to increase the CO_2 flow and capnothorax pressure which further increased the leak around the bronchial cuff causing a further rise in $EtCO_2$. Therefore, encountering negative arteriolar to end-tidal CO_2 gradient in a thoracoscopic procedure should act as a clue toward possible airway damage which should be communicated to the surgeon promptly for early repair. More often the damage goes unnoticed and the thoracoscopic procedure gets converted to an open procedure as the cause for a sudden rise in $EtCO_2$ cannot be found. A simple way to avoid this scenario would be to quickly rule out other possible treatable causes and once diagnosis of airway injury is made, we suggest to increase the PEEP,[7] which can act as a splint, preventing CO_2 leak around the bronchial cuff [Figure 1b]. In our case, to prevent the inadvertent leak around the bronchial cuff, we reversed the pressure gradient by increasing the PEEP to 8 cmH_2O and reducing the capnothorax pressure to 5 mmHg [Figure 1c and 1d].[8] It was immediately followed by a steady decrease in $EtCO_2$ to 45 mmHg. Similarly, in case of DLT and a leak around bronchial cuff through an injured bronchial tree, the PEEP at the tracheal lumen can be increased to prevent the leak. Therefore, diagnosing airway injury or intentional opening of airway as a part of surgical step using a negative arterial-$EtCO_2$ gradient and managing the leak using optimally higher than normal PEEP can be used to prevent unnecessary conversion of thoracoscopic procedures to an open surgery.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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