Pleural Gas Analysis for Detection of Alveolopleural Fistulae

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Purpose. **Visual inspection (VI) of bubbles in the chest drainage unit does not differentiate a true leak of alveolopleural fistula (APF) from a false leak. We hypothesized that detection of elevated levels of carbon dioxide, increase in oxygen content, or both, in pleural gas upon the administration of supplemental oxygen would accurately identify APF.**

Description. **Prospective study comparing pleural gas analysis (GA) with VI to detect APF after surgical lobectomy (n = 50).**

Evaluation. **APF was found in 22 (44%) patients at the time of analysis. VI revealed air bubbles in 31 (62%) patients, indicating the presence of APF, of whom 12 (38.7%) were false leaks. VI failed to identify APF in 3 (6%) patients that resulted in post–tube removal pneumothorax. By contrast, GA accurately demonstrated APF in 21 patients, with only one false negative and no false positives. GA demonstrated better sensitivity (95.5% vs 86.4%), specificity (100% vs 57.1%), positive predictive value (100% vs 61.3%), and negative predictive value (96.6% vs 84.2%) compared to VI.**

Conclusions. **Pleural gas analysis is an effective technique to detect APF and can facilitate timely and safe chest tube removal.**

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Despite major advances in thoracic surgery, little improvement has been made in chest drainage since the inception of the water seal bottle system [1]. In this system, bubbles in the water column as detected by visual inspection (VI) are believed to represent the egress of air from an alveolopleural or bronchopleural fistula (true leak) [2]. However, VI is prone to error because the presence of air bubbles is dependent on patient effort, tube position, and the presence of fluid or clots in the tube, among other factors [3]. Bubbles may be observed even without an APF (false leak) in the setting of a large pleural space after lung resection [2], the introduction of air into the pleural cavity from the tube exit site, or reverse air flow in the chest tube [4]. Reverse air flow allows air in the tube to be sucked back into the pleural cavity during inspiration, and subsequent cough or forceful expiration produces bubbles that can be misinterpreted as an APF.

If no acid-base disorder is present, the partial pressure of alveolar carbon dioxide (CO_2) is ~40 mm Hg, equivalent to 5.6% CO_2 at sea level with atmospheric pressure of 760 mm Hg. In the presence of an alveolopleural communication, alveolar gas containing CO_2 escapes into the pleural cavity. Hence, elevated CO_2 in gas collected from the chest drainage system can indicate an APF. However, CO_2 can persist in the pleural cavity after resolution of an APF. In such circumstances, an increase in pleural O_2 with nasally administered supplemental O_2 ($SupO_2$) could differentiate an APF from high pleural CO_2 resulting from delayed diffusion out of the pleural cavity. Therefore, we hypothesized that pleural gas analysis (GA) would accurately identify APF and distinguish between true and false leaks. Accordingly, we determined the pleural CO_2 and O_2 levels that would indicate an APF and compared the efficacy of pleural gas analysis with the current standard of visual inspection.

Technology and Technique

Patient Population

We first determined the pleural CO_2 and O_2 levels in patients without APF (APF-negative) who had chest tubes for pleural effusion and those with APF observed in the operating room after lung decortication (APF-positive,

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n = 10 each). Then, we prospectively compared VI and GA in patients (n = 50) undergoing surgical lobectomy. The study was approved by the Institutional Review Board of Northwestern University.

Chest Tube Management and Visual Inspection for Air Leak

All patients had a single 24F or 28F chest tube that was kept on suction at −20cm after operation and switched to water seal drainage on day 1. For VI, the patient was asked to cough five times and then take five deep breaths. This sequence was repeated twice. The first sequence eliminated any trapped air in the pleural space and tubing. The result of VI was considered positive if air bubbles were detected during the second sequence.

Pleural Gas Analysis

The GA was performed by connecting a Datex analyzer (GE Healthcare, Inc, OK) to the sampling port of the chest draining system (Atrium, Inc, Hudson, NH). Measurements were performed while the tubes were on water seal drainage. Patients were breathing room air with SaO_2 above 92%. The analyzer was first connected to the chest drainage system and CO_2 and O_2 were recorded. $SupO_2$ was then administered nasally. Patients were allowed to take deep breaths for 1 minute, after which pleural CO_2 and O_2 levels were recorded.

End Point and Statistical Analysis

If pneumothorax developed after chest tube removal, APF was considered to be present. Patients were followed up for the development of pneumothorax until 3 weeks after operation. Statistical analysis was performed with Microsoft Excel 2011 (Microsoft Corp, Redmond, WA) and GraphPad Prism, version 6 (GraphPad Software, Inc, San Diego, CA). Two-tailed Student and Fisher exact *t* tests were used as appropriate. Statistical significance was defined at $p < 0.05$.

Clinical Experience

Pleural CO_2 and O_2 Levels in Patients With and Without APF

The mean CO_2 in the APF-negative patients was 0.9 ± 0.28%, and O_2 was 14.9 ± 1.8%. $SupO_2$ up to 10 L/min in APF-negative patients did not change the pleural O_2 composition (Fig 1) with the variation less than 2%. By contrast, APF-positive patients revealed a CO_2 of 4.9 ± 1.3%, O_2 17.0 ± 1.2%, and increase in pleural O_2 of 2% or more with $SupO_2$ ($p < 0.01$). Incremental levels of $SupO_2$ demonstrated that 5 L/min was adequate to achieve an increase in pleural O_2 of 2% or more for all APF-positive patients. We concluded that pleural CO_2 less than 1%, and increase in O_2 less than 2% with $SupO_2$ 5 L/min, or both, would indicate an absence of APF. Additionally, CO_2 above 1% with an increase in O_2 of 2% or more with $SupO_2$ 5 L/min would be consistent with APF, whereas CO_2 above 1% but an increase in O_2 below 2% would suggest recently resolved APF.

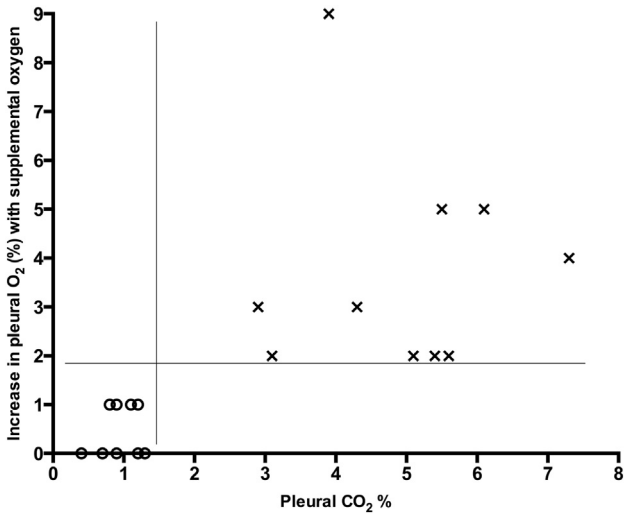

Fig 1. Pleural CO_2 and increase in O_2 with supplemental O_2 in patients with (APF-positive, cross mark) and without (APF-negative, circle) alveolopleural fistula.

Discordance Between VI and GA in Patients Undergoing Lobectomy

Next, we prospectively compared VI and GA in patients undergoing lobectomy (n = 50). The mean age of the study cohort was 53.1 ± 11.0 years, and the male to female ratio was 29:21. All patients had postresection predicted forced expiratory volume in first second and diffusion capacity of lung for carbon monoxide above 40%. Thirty patients (60%) underwent a right-sided procedure, and 20 (40%) underwent a left-sided procedure. Twenty-nine (58%) had upper, 19 (38%) had lower, and 2 (4%) had middle lobectomies. When the staff surgeon deemed that the fluid output had reached the removal threshold, a comparison between VI and GA was performed. The mean duration for the fluid output to fall below the individual surgeon's threshold from the day of operation was 1.8 ± 0.7 days. At this time, VI revealed bubbles suggesting APF in 31 (62%) patients. However, GA indicated APF in only 19 of these 31 patients (Table 1). Hence, 12 of 31 (38.7%) patients with bubbles on VI were deemed to have a false leak. The size of leak between those with false and true leak was not different (2.4 ± 1.1 vs 2.5 ± 0.8 chambers, $p = 0.8$). To confirm false leak, we clamped the tube in the first 4 patients, and their chest roentgenograms at 4 hours were normal. The tubes were removed

Table 1. Correlation Between Visual Inspection and Gas Analysis for Alveolopleural Fistula

	Visual Inspection	
Gas Analysis	Bubbles Present	Bubbles Absent
Positive for APF	19 (38%)	2 (4%)
Negative for APF	12 (24%)	17 (34%)

APF = alveolopleural fistula.