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Pneumothorax: Clearing the Air on the Pressure-Dependent Airleak Hypothesis

Pneumothorax research, a long-neglected subject, has recently attracted unprecedented, and much overdue, interest sparked by several landmark randomized clinical trials (1, 2). Debates on optimal management of pneumothorax consistently lead to the fundamental gaps in our understanding of the disease pathophysiology (3, 4). For example, through endobronchial valve studies, we now understand the conventional concept that one airway leading to one leak site is over-simplistic (5). Most patient do not have an obvious site of leak on CT or even when surgeons submerge the lung underwater intraoperatively, rekindling arguments about how air passes through visceral pleura (e.g., hypothesis of pleural pores) (6).

In this issue of the *Journal*, Walker and colleagues (pp. 145–149) proposed a new hypothesis that chest tubes inserted for pneumothorax drainage create a negative pressure outlet, exacerbating the pressure gradient across the visceral pleural defect, and cause prolonged airleak (7). They stated that "ongoing visceral airleak is largely dependent on an induced pressure gradient." This hypothesis is thought-provoking and has merits. However, it is difficult (if not impossible) to test and lacks empiric evidence, and, most importantly, its clinical application can potentially cause harm.

Confirming the hypothesis is difficult because measurement of pleural pressure gradient requires intrapleural placement of a catheter with a pressure-measuring device (e.g., manometer), which inevitably provides an escape route and disturbs the pressure gradient. Corroborative evidence is also lacking. The majority of pneumothoraces treated with tube drainage do heal with time despite this potential pressure gradient. All clinicians have encountered patients whose pneumothorax enlarges without drainage; conversely, removing the pressure gradient (e.g., when chest tubes dislodge or are prematurely removed) does not stop the leak but generates surgical emphysema or recurrence of pneumothorax. These observations argue against tube drainage being the key driving force for ongoing airleaks. Interestingly, Walker and colleagues have published data showing that a sizeable number of traumatic pneumothoraces did not enlarge even when patients were subjected to positive pressure ventilation (which would induce a much larger pressure gradient across visceral pleural defects than chest tube insertion in patients breathing spontaneously [8]).

The authors provided three "rationales" to support their hypothesis. All evidence was indirect and the interpretation contestable. First, the result of the PSP (Primary Spontaneous Pneumothorax) trial (1) was used to support this hypothesis. The PSP study was a randomized clinical trial that investigated the noninferiority of conservative management (no drainage) of pneumothorax against conventional smallbore tube drainage. The trial found that 85% of patients were successfully managed without drainage. Radiographic lung reexpansion was, as expected, slower with conservative management, although by 8 weeks, there were no significant intergroup differences. However, the study did not (and could not) measure if airleak resolves faster with or without a chest tube and should not be used as evidence of such. Not draining the pneumothorax allows the lung to remain deflated and brings the edges of any defect to closest proximity and enhances healing—an alternative explanation (to the pressure gradient hypothesis) for the benefits of conservative management.

In their second rationale, the authors interpreted that patients with an ongoing airleak (shown by tracer gas) whose pneumothorax air was aspirated but had a "recurrence" the next day as a consequence of exacerbation/reopening the airleak from the negative pressure gradient generated during evacuation (9). A more plausible explanation would be that those airleaks never stopped. Aspiration temporarily cleared the air, and sufficient air accumulated over the following hours to become appreciable radiologically. The third rationale centered on a study of post–lung-resection patients (10) whose pleural pressure changes (including possible trapped lung space) would be very different from spontaneous pneumothorax.

If the authors' hypothesis is accepted, patients with a chest tube and ongoing leak should have their tubes clamped/removed—an

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intervention that can potentially cost lives! There are no simple clinical studies that can be designed to test (or refute) this hypothesis. If it stands, then applying suction to patients with chest tubes for pneumothorax would further exaggerate the induced gradient and worsen the outcome, a potentially testable scenario in a clinical trial, albeit an indirect evaluation of their hypothesis.

We strongly agree with the authors that for patients with pneumothorax with sufficient respiratory reserves (e.g., most with PSP), drainage is not necessary (11). For those who suffer from symptomatic breathlessness (e.g., many with secondary spontaneous pneumothorax), drainage is needed for symptomatic relief, regardless of any effect of the pressure changes on the healing of pleural defects. Pleurodesis should be considered for secondary spontaneous pneumothorax owing to its high recurrence rate and associated potential life-threatening risks (12). Given their limited lung reserve, the most suitable approach for many patients is bedside chemical pleurodesis, which needs a chest tube.

Literature on the pathophysiology (especially pleural pressure changes) during pneumothorax is outrageously scarce compared with its high incidences. Caution must be executed for extrapolation from studies in animals (with their different pleural anatomy) or those using artificially induced pneumothorax, in which the anatomical defects are likely different from spontaneous ones. In health, pleural pressures are largely governed by the opposing elastic recoils of the lung and the chest wall and are slightly below atmospheric pressure. During inspiration, pleural pressure decreases over the lung surface but increases in the zone of apposition. The pressure rises during active expiration. In case of an ongoing airleak, pleural pressure should decrease during inspiration, drawing air into the lungs and pleural space. The converse should hold true during expiration. A chest drain with underwater seal should lead to an increase in pressure within the pneumothorax to an amount approximating the height of water in the underwater seal. Pleural air will escape via the drain when pleural pressure exceeds the hydrostatic pressure of the underwater seal (e.g., during expiration or cough).

However, pleural pressures are also likely to be influenced by the condition of the lung (e.g., atelectasis or gas trapping). There is also a vertical gradient of pleural pressure, proposed to arise from various forces including hydrostatic pressure, compression by the heart and abdomen, and viscous flow of pleural fluid (13). Air in the pleural space is actively absorbed, which could significantly alter the intrapleural pressures, a factor not included in most literature. Any physiologic model will need to incorporate the complex interactions of these (and other) forces.

Once a "dry" academic topic, the physiology of pneumothorax is now a vibrant and clinically relevant subject given new clinical approaches. Our current understanding of the pathophysiology is sketchy, and the hypothesis put forward by Walker and colleagues (7) provides excellent focal points for debate and hopefully a platform for further studies and deliberation that lead to clearer understanding of the disease process. ■

Author disclosures are available with the text of this article at www.atsjournals.org.

Y. C. Gary Lee, M.B. Ch.B., Ph.D.
Respiratory Medicine
Sir Charles Gairdner Hospital
Western Australia, Australia

Medical School
University of Western Australia,
Western Australia, Australia

and

Pleural Medicine Unit
Institute for Respiratory Health
Perth, Western Australia, Australia

Bhajan Singh, M.B. B.S., Ph.D.
Pulmonary Physiology and Sleep Medicine
Sir Charles Gairdner Hospital
Western Australia, Australia

West Australian Sleep Disorders Research Institute
Queen Elizabeth II Medical Centre
Western Australia, Australia

and

Faculty of Human Sciences
University of Western Australia
Western Australia, Australia

ORCID ID: 0000-0002-0036-511X (Y.C.G.L.).

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