

LUNG RECRUITMENT MANEUVERS IN ICU

An Essay
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ABSTRACT

The plateau pressure (PP) is the pressure applied to small airways and alveoli. It is measured during an inspiratory pause on the ventilator. The goal plateau pressure is <30 cm H₂O to prevent volutrauma. Without lung disease, peak inspiratory pressure (PIP) is only slightly above the plateau pressure.

KEY WORDS

Recruitment]

Maneuvers

icu

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List of abbreviations

ALEC: Artificial Lung Expanding Compound

ALI: Acute lung injury

APACHEII : Acute Physiology and Chronic Health Evaluation

APRV: Airway pressure release ventilation

ARDS: Acute respiratory distress syndrome

ARDSNet: ARDS Clinical Network

CPAP: Continuous Positive Airway Pressure

Cstat: Static compliance of the lung

CT: Computed tomography

DPPC: Dipalmitoylphosphatidylcholine

ECMO: Extracorporeal membrane oxygenation

EPA: Eicosapentaenoic acid

e-sigh: Extended sigh

ET: Endotracheal tube

FIO₂: Fraction of inspired oxygen

FRC: Functional residual capacity

GLA: Gamma-linoleic acid

HFOV: High frequency oscillatory ventilation

i PEEP: intrinsic PEEP

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ICU: Intensive care unit

INO: Inhaled nitric oxide

LFPPVECCO₂R: Low- frequency positive-pressure ventilation with extracorporeal carbon dioxide removal

LIP: Lower inflection point

LPV: Lung protective ventilation

NIH: National Institute of Health

NO: Nitric oxide

P₁: Transpulmonary pressure

PAO₂: Alveolar partial oxygen tension

PCO₂: Arterial pressure of carbon dioxide

PCWP: Pulmonary capillary wedge pressure

PEEP: Positive end expiratory pressure

PG: Phosphatidylglycerol

PIP: Peak inspiratory pressure

PO₂: Arterial partial oxygen tension

PP: Plateau pressure

P_{plat}: end-inspiratory plateau pressure

RCTs: Randomized control study

RDS: Respiratory distress syndrome

RM: Recruitment maneuver

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SFTPA1: apoproteins plasma protein A

SFTPB: apoproteins plasma protein B

SFTPC: apoproteins plasma protein C

SFTPD: apoproteins plasma protein D

SIRS: Systemic inflammatory response syndrome

SP: Plasma proteins

SPO₂: Pulse oximetry

UIP: Upper inflection point

VILI: Ventilator-induced lung injury

V_t: Tidal volume

WOB: Work of breathing

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Introduction:

ARDS, or acute respiratory distress syndrome, is a lung condition that leads to low oxygen levels in the blood. ARDS can be life threatening. ARDS usually occurs in people who are very ill with another disease or who have major injuries. Most people are already in the hospital when they develop ARDS.

Mechanical ventilation is a supportive and life saving therapy in patients with acute lung injury (ALI)/acute respiratory distress syndrome (ARDS). Despite advances in critical care, mortality remains high. During the last decade, the fact that mechanical ventilation can produce morphologic and physiologic alterations in the lungs has been recognized.

Recruitment is a strategy aimed at re-expanding collapsed lung tissue, and then maintaining high PEEP to prevent subsequent 'de-recruitment'. In order to recruit collapsed lung tissue, sufficient pressure must be imposed to exceed the critical opening pressure of the affected lung.

The use of low tidal volumes (V_T) and limited inspiratory plateau pressure (P_{plat}) has been proposed when mechanically ventilating the lungs of patients with ALI/ARDS, to prevent lung as well as distal organ injury. However, the reduction in V_T may result in alveolar derecruitment, cyclic opening and closing of atelectatic alveoli and distal small airways leading to ventilator-induced lung injury (VILI) if inadequate low positive end-expiratory pressure (PEEP) is applied.

On the other hand, high PEEP levels may be associated with excessive lung parenchyma stress and strain and negative hemodynamic effects, resulting in systemic organ injury. Therefore, lung recruitment

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maneuvers have been proposed and used to open up collapsed lung, while PEEP counteracts alveolar derecruitment due to low V_T ventilation. Nevertheless, the beneficial effects of recruitment maneuvers in ALI/ARDS have been questioned. Although there is no evidence that recruitment maneuvers reduce mortality or the duration of mechanical ventilation in patients with ALI/ARDS, such maneuvers may be useful to reverse life-threatening hypoxemia and to avoid derecruitment resulting from disconnection and/or airway suctioning procedures.

Anatomy of the lungs

The lungs are the essential organs of respiration; they are two in number, placed one on either side within the thorax, and separated from each other by the heart and other contents of the mediastinum. Each lung is conical in shape, and presents for examination an apex, a base, three borders, and two surfaces. The apex is rounded, and extends into the root of the neck, reaching from 2.5 to 4 cm above the level of the sternal end of the first rib. The base is broad, concave, and rests upon the convex surface of the diaphragm. ⁽¹⁾

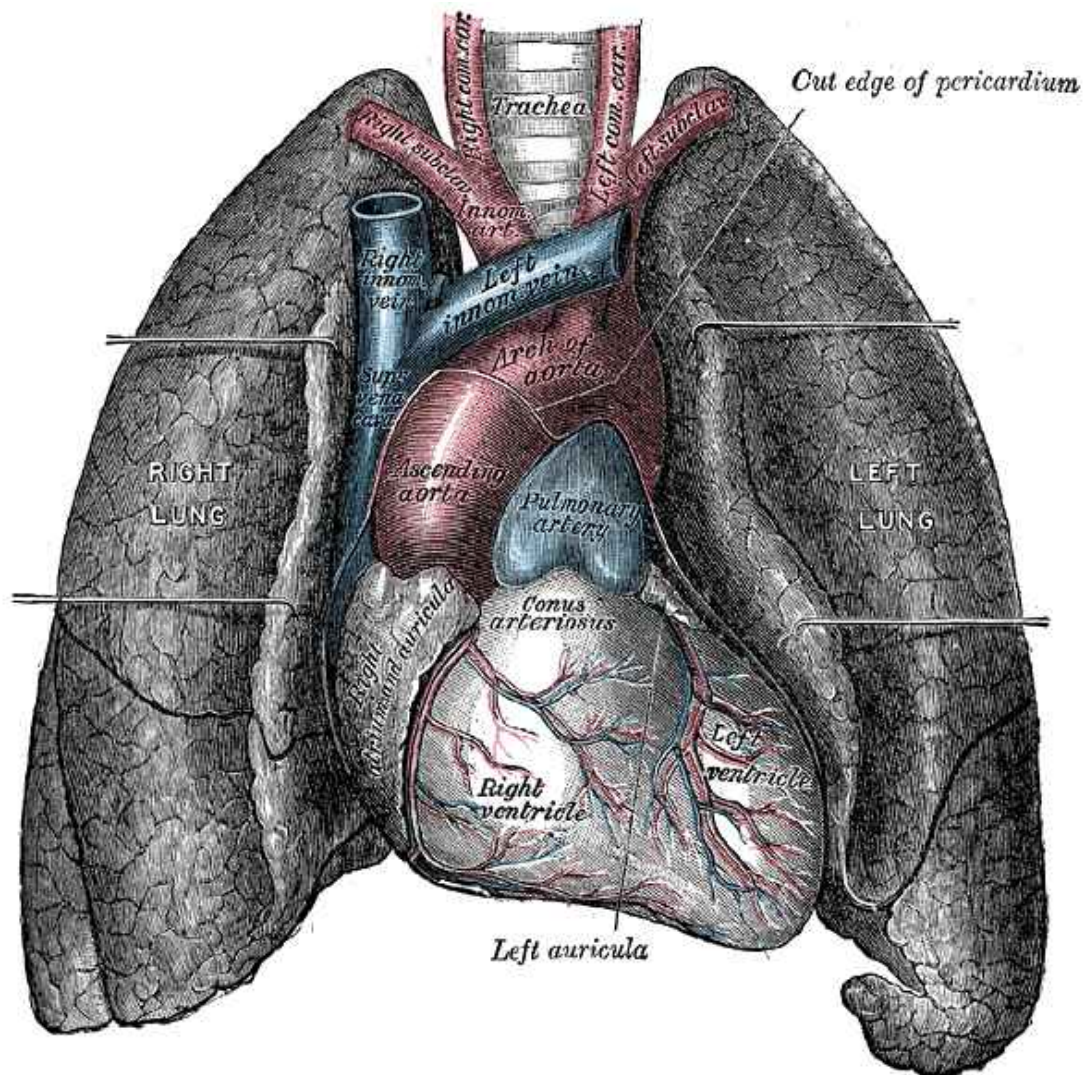


Figure (1): Anatomy of the lungs. ⁽¹⁾

Surfaces:

- a) The **costal surface** is smooth, convex and corresponds to the form of the cavity of the chest. It is in contact with the costal pleura.
- b) The **mediastinal surface** is in contact with the mediastinal pleura. The **cardiac impression**, which accommodates the pericardium. Above and behind this concavity is a triangular depression named the **hilum**, where the structures which form the root of the lung enter and leave the viscous. These structures are invested by pleura, which, below the hilus and behind the pericardial impression, form the pulmonary ligament. ⁽¹⁾

Borders:

- a) The **inferior border** is thin and sharp, it separates the base from the costal surface and extends into the phrenicocostal sinus; medially where it divides the base from the mediastinal surface it is blunt and rounded.
- b) The **posterior border** is broad and rounded, longer than the anterior border, and projects, below, into the phrenicocostal sinus.
- c) The **anterior border** is thin and sharp, and overlaps the front of the pericardium. The anterior border of the *right* lung is almost vertical, and projects into the costomediastinal sinus; that of the *left* presents, below, an angular notch, the **cardiac notch**, in which the pericardium is exposed. ⁽¹⁾

Fissures and lobes of the lungs:

The **left lung** is divided into two lobes, an upper and a lower, by an interlobular fissure, which extends from the costal to the mediastinal surface of the lung both above and below the hilus. This fissure begins on the mediastinal surface of the lung and runs backward and upward to

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the posterior border, which it crosses at a point about 6 cm. below the apex. It then extends downward and forward over the costal surface, and reaches the lower border a little behind its anterior extremity.

The **right lung** is divided into three lobes, superior, middle, and inferior, by two interlobular fissures. One of these separates the inferior from the middle and superior lobes. Its direction is more vertical, and cuts the lower border about 7.5 cm. behind its anterior extremity. The other fissure separates the superior from the middle lobe. It begins in the previous fissure near the posterior border of the lung, running horizontally forward, cuts the anterior border on a level with the sternal end of the fourth costal cartilage. ⁽¹⁾

The root of the lung:

It is a little above the middle of the mediastinal surface of each lung, and nearer its posterior than its anterior border by which the lung is connected to the heart and the trachea. The structures are arranged in a similar manner from before backward on both sides, the upper of the two pulmonary veins in front; the pulmonary artery in the middle; and the bronchus, together with the bronchial vessels, behind. From above downward, on the two sides, their arrangement differs. ⁽¹⁾

On the right side their position is—eparterial bronchus, pulmonary artery, hyparterial bronchus, pulmonary veins, but on the left side their position is—pulmonary artery, bronchus, pulmonary veins. The lower of the two pulmonary veins, is situated below the bronchus, at the apex or lowest part of the hilus. ⁽¹⁾

Divisions of the bronchi:

- a) The **right bronchus** gives off; about 2.5 cm. from the bifurcation of the trachea, a branch for the superior lobe arises above the level of the pulmonary artery (**eparterial bronchus**). All the other divisions of the main stem come off below the pulmonary artery (**hyarterial bronchi**).
- b) The **left bronchus** passes below the level of the pulmonary artery before it divides; all its branches are hyarterial. The first branch of
- c) The left bronchus arises about 5 cm from the bifurcation of the trachea, and is distributed to the superior lobe. The main stem then enters the inferior lobe, where it divides into ventral and dorsal branches. ⁽¹⁾

Vessels:

The **pulmonary artery** it divides into branches which accompany the bronchial tubes and end in a dense capillary net-work in the walls of the alveoli. The **pulmonary capillaries** form plexuses which lie immediately beneath the lining epithelium, in the walls and septa of the alveoli and of the infundibula. The **pulmonary veins** commence in the pulmonary capillaries, the radicles coalescing into larger branches which run through the substance of the lung, independently of the pulmonary arteries and bronchi. After freely communicating with other branches they form large vessels, which come into relation with the arteries and bronchial tubes, and accompany them to the hilus of the organ. Finally they open into the left atrium of the heart, conveying oxygenated blood to be distributed to all parts of the body by the aorta. ⁽¹⁾

The **bronchial arteries** supply blood for the nutrition of the lung; they are derived from the thoracic aorta or from the upper aortic intercostal arteries, and, accompanying the bronchial tubes. The

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bronchial vein is formed at the root of the lung, receiving superficial and deep veins corresponding to branches of the bronchial artery. It does not receive all the blood supplied by the artery, as some of it passes into the pulmonary veins. It ends on the right side in the azygos vein, and on the left side in the highest intercostal or in the accessory hemiazygos vein. ⁽¹⁾

Nerves:

The lungs are supplied from the anterior and posterior pulmonary plexuses, formed chiefly by branches from the sympathetic and vagus. ⁽¹⁾