DIFFICULT WEANING FROM MECHANICAL VENTILATION IN ICU PATIENTS

ESSAY

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By

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Abstract

Weaning from mechanical ventilation is a critical component of ICU care. Early weaning is important to avoid complications of prolonged mechanical ventilation, such as ventilator induced lung injury, ventilator associated pneumonia, increased duration and cost of ICU stay. Difficult weaning is caused by disease factors (*e.g.* respiratory, cardiac, metabolic, and neuromuscular) and clinician management factors (*e.g.* failing to recognize readiness to wean and inappropriate ventilator settings).

Key word:

Mechanical
Icu
anesthesiology

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List of Acronyms Used

A/C	Assist control
APRV	Airway pressure release ventilation
ARDS	Acute respiratory distress syndrome
ARF	Acute respiratory failure
ASV	Adaptive support ventilation
ATC	Automatic tube compensation
BiPAP	Biphasic positive airway pressure
CINMA	Critical illness neuromuscular abnormalities
CMV	Controlled mandatory ventilation
COPD	Chronic obstructive pulmonary disease
CROP	integrative index of compliance, rate, oxygenation, pressure
FiO_2	Fraction of inspired oxygen
fR	Respiratory frequency
GI	Gastrointestinal
H_2O	water
HCPs	Health care professionals
HFOV	High frequency oscillatory ventilation
ICU	Intensive Care Unit
IPPV	Intermittent positive pressure ventilation
KPa	Kilo Pascal
MRSA	methicillin-resistant staphylococcus aureus
NAVA	Neurally adjusted ventilator assist
NIV	Non-invasive ventilation
P0.1	Ratio of airway occlusion pressure 0.1 seconds after the onset of inspiratory effort

$PaCO_2$	Partial pressure of arterial carbon dioxide
PAO_2	Partial pressure of alveolar oxygen
PaO_2	Partial pressure of arterial oxygen
PAV	Proportional assist ventilation
PB	barometric pressure
PCV	Pressure controlled ventilation
PEEP	Positive end expiratory pressure
PEEP*i*	Intrinsic positive end expiratory pressure
pH	Negative log of hydrogen ion concentration
PImax	maximal inspiratory pressure
PMV	Prolonged mechanical ventilation
PPS	Prospective payment system
PRVC	Pressure regulated volume control
PSV	Pressure support ventilation
RSBI	Rapid shallow breathing index
SaO_2	Arterial oxygen saturation
SBT	Spontaneous breathing trial
SIMV	Synchronized intermittent mandatory ventilation
SvO_2	Mixed venous oxygen saturation
SWUs	Specialized weaning units
VAP	Ventilator-associated pneumonia
VE	Minute ventilation
VILI	Ventilator-induced lung injury
VSV	Volume support ventilation
VT	Tidal volume
WOB	Work of breathing

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Introduction

Mechanical ventilation remains to be one of the most challenging tasks facing physicians in the ICU. Ventilator discontinuation process is a critical component of ICU care. [1] Patients are generally intubated and placed on mechanical ventilators when their ventilatory or gas exchange capabilities are exceeded by the demands placed on them from a variety of diseases. Mechanical ventilation also is required when the respiratory drive is incapable of initiating ventilatory activity, either because of disease processes or drugs. [2]

Weaning from mechanical ventilation could be defined as the gradual process of transferring the respiratory work of breathing from the ventilator to the patient. Discontinuation of mechanical ventilation and removal of artificial airway are easily obtained in about 70-80% of the patients. [3]

However about 20–30% of the patients present a difficult weaning. This difficulty can be the result of impairment between the load imposed on the respiratory system and the capacity of the respiratory muscle to perform this increased work of breathing. [4] The factors that limit the weaning process can be summarized as follows: (1) oxygenation, (2) respiratory load and capacity of the respiratory muscle to accomplish this load, (3) cardiovascular performance, and (4) psychological factors. [5]

Ongoing ventilator dependency is caused by both disease factors (*e.g.*, respiratory, cardiac, metabolic, and neuromuscular) and clinician management factors (*e.g.*, failing to recognize discontinuation potential and inappropriate ventilator settings/management). [1]

Although mechanical ventilation is a life saving intervention in patients with acute respiratory failure and other disease entities, a major goal of critical care clinicians should be to liberate patients from mechanical ventilation as early as possible to avoid the multitude of complications and risks associated with prolonged unnecessary mechanical ventilation. These complications include ventilator induced lung injury; ventilator associated pneumonia, increased length of ICU and hospital stay, and increased cost of care delivery. [6]

The daily wean screen and subsequent SBT in those patients passing the screen is now the "gold standard" for ventilator withdrawal assessment and should be performed in virtually all patients who are recovering from respiratory failure. The decision to remove the artificial airway in those patients successfully passing an SBT requires further assessments of the patient's ability to protect the airway. [1]

Successful liberation from mechanical ventilation in the ICU depends on the application of skilled judgment, decision making, and medical and nursing interventions. [6]

Managing the patient who fails the SBT is one of the biggest challenges facing ICU clinicians. In general, stable forms of assisted/supported ventilation are what is required between the daily wean screens/ SBTs. Finally, in the patient requiring prolonged mechanical ventilatory support, specialized multidisciplinary units may offer value. [1]

Anatomical & Physiological Considerations

The Respiratory System

The respiratory organs may be divided into ventilatory organs (upper and lower air passages) and those subserving the exchange of gases between air and blood (alveoli).

Oxygen, with the generation of carbon dioxide, is needed for the oxidative breakdown of nutrients in every cell of the organism (internal respiration). Oxygen is taken up from the surrounding atmosphere into the lungs, while carbon dioxide is released (external respiration).

After gas is exchanged between air and blood in the alveoli, the oxygen is transported by the bloodstream to the cells of the body. Here oxygen is given up in exchange for carbon dioxide, which is then transported in the reverse pathway. (7)

Organs of the Air Passages

The upper air passages include nasal and oral cavity with paranasal sinuses, pharynx, and larynx. The lower air passages include trachea, and bronchial tree. With the exception of the oral cavity, the mesopharynx, and the hypopharynx, the mucosa of the ventilatory respiratory passages is lined with respiratory ciliated epithelium with numerous goblet cells.

There are two nasal cavities separated by the nasal septum. They have an external opening: nostrils (nares), and a pharyngeal opening: choanae. The floor is formed by hard and soft palate. Surface of side-walls is increased by bones (nasal conchae) lined with mucosa. On

each side there is a superior concha (olfactory region, line with olfactory mucosa), a middle concha, and an inferior concha (respiratory region, warms and cleans the inspired air). They form the boundary of the nasal passage.

The paranasal sinuses are lined with mucous membrane; they prewarm the inspired air and form a cavity for resonance. They include one frontal sinus, two maxillary sinuses, two ethmoid sinuses with ethmoid air cells, two sphenoid sinuses, all draining into the nasal cavity.

The pharynx is divided into 3 spaces. Superior pharyngeal space: nasopharynx (transition from the nasal cavities through the choanae). Middle pharynx: oropharynx (crossing of the digestive tract). Inferior pharynx: hypopharynx (next to the larynx).

The larynx closes the trachea to the pharynx, separating the respiratory and digestive passages, enabling increase in pressure in the thorax and abdomen, allowing straining, coughing and voice production.

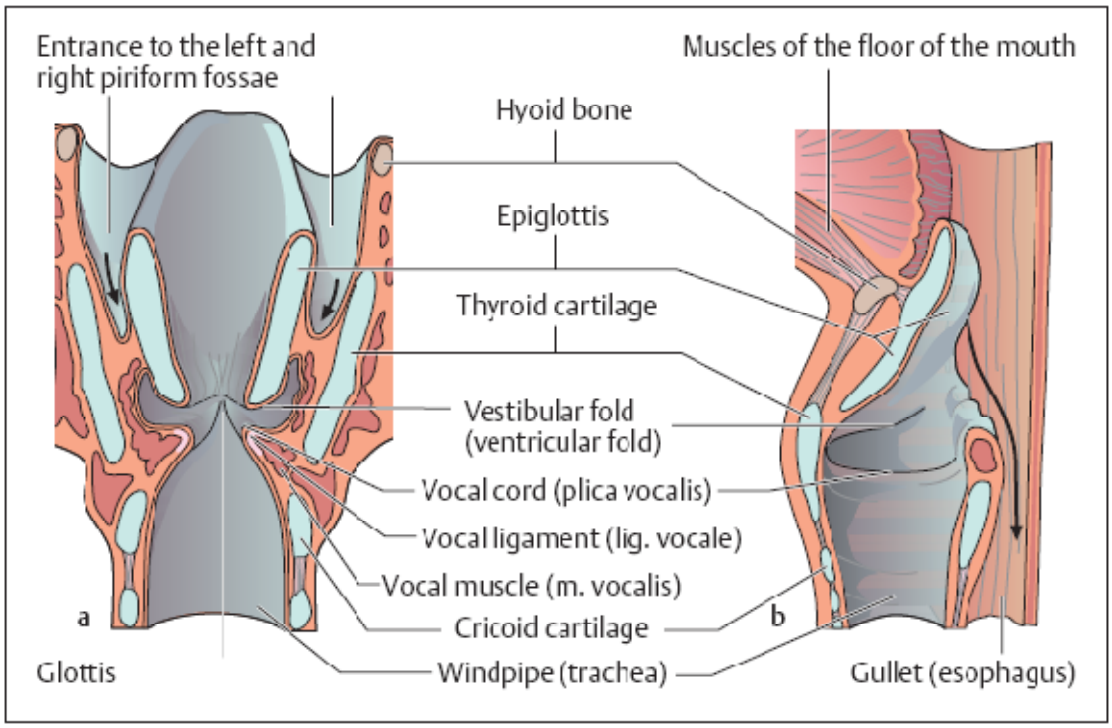

Figure 1: Larynx viewed from the inside [7]

- **a** Coronal section (anterior view)
- **b** sagittal section through the larynx

The larynx consists of cartilaginous skeletal elements covered with mucous membrane (hyaline cartilage: thyroid cartilage, cricoid cartilage, two arytenoid cartilages; elastic cartilage: epiglottis).

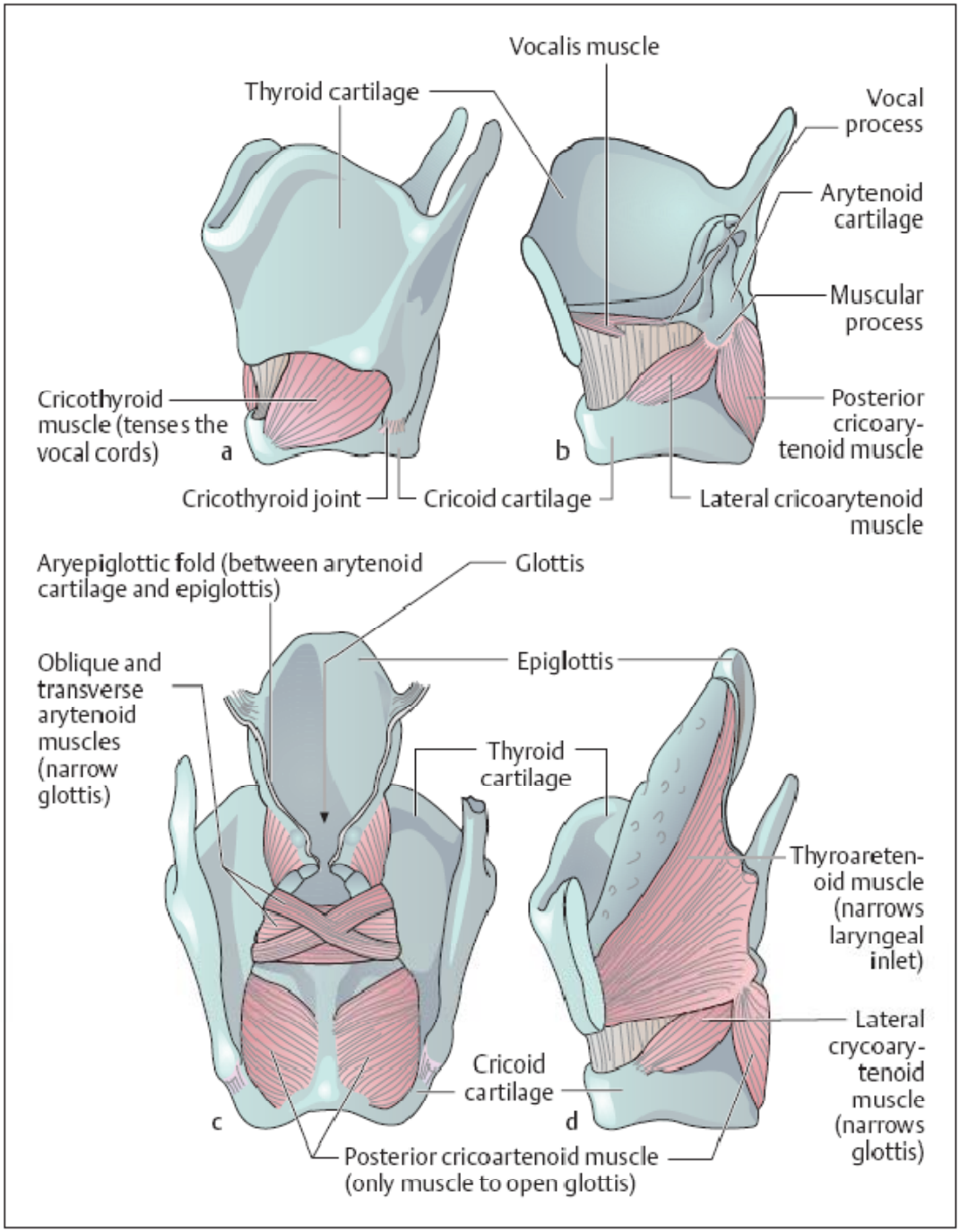

Figure 2: The laryngeal muscles and their functions [7]

- **a** Lateral view
- **b** Lateral view with epiglottis and epiglottic muscles removed
- **c** Posterior view
- **d** Lateral view with left side of the thyroid cartilage removed

Externally it is connected to the hyoid bone and the trachea, and internally it is connected to skeletal elements, laryngeal ligaments and muscles.

Thyroid cartilage is open posteriorly, anteriorly forms the Adam's apple; posterior border with two processes, one superior, one inferior; the inferior share a joint with the cricoid cartilage.

Cricoid cartilage consists of a ring in front, posteriorly a lamina (plate) sharing a joint with the arytenoids.

Arytenoid cartilages include the vocal processes, from which the vocal cords run to the posterior side of the thyroid cartilage. The vocal cords and the vocal muscles form the vocal folds; the space between the vocal folds is the glottis.

Epiglottis is attached to the posterior side of the thyroid cartilage by an elastic membrane. It closes the laryngeal opening during swallowing.

Muscles include superior and inferior hyoid muscles which elevate and depress the larynx; striated laryngeal muscles which move the parts of the larynx on each other, and produce the voice by opening (one muscle only) and closing of the glottis and changes in the tension of the vocal cords.

The trachea is a tube formed by about 20 cartilaginous rings lined by a mucous membrane, about 10−12 cm in length and 2 cm in diameter; at the bifurcation divides into left and right bronchi.

The bronchial tree consists of left and right main bronchi which divide into lobar bronchi (three right, two left): each divides into 10 segmental bronchi supplying the segments of the lung, each continuing to divide until they reach the terminal bronchi, which no longer have cartilaginous reinforcements in their walls.

Serous cavities and of the chest and abdomen include pleural cavity (contains the lungs). Its serous membranes: visceral pleura and