Focused ultrasound for airway management

Philips tutorial

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1 Introduction

Point-of-care ultrasound is a rapid, affordable, and dynamic modality for the evaluation of airway anatomy and the facilitation of endotracheal intubation when performed by trained clinicians in the emergent or elective setting.[1–3]

The sonographic assessment of the airway may be performed before, during, and after securing the airway.[4] In anticipation of a predicted difficult airway, the cricothyroid membrane should be identified, marked, and prepared for a potential surgical airway.

Confirmation of endotracheal tube placement relies primarily on the exclusion of esophageal intubation while directly visualizing the appropriate landmarks during endotracheal tube advancement. [5–7]

Further ultrasound applications including evaluation for pneumothorax and recognition of inadvertent mainstem bronchial intubation are discussed in the Philips Ultrasound Tutorial on Lung Ultrasound.

Please **click here** to view "Point-of-care lung ultrasound" by Dr. Mike Stone

2 Clinical case

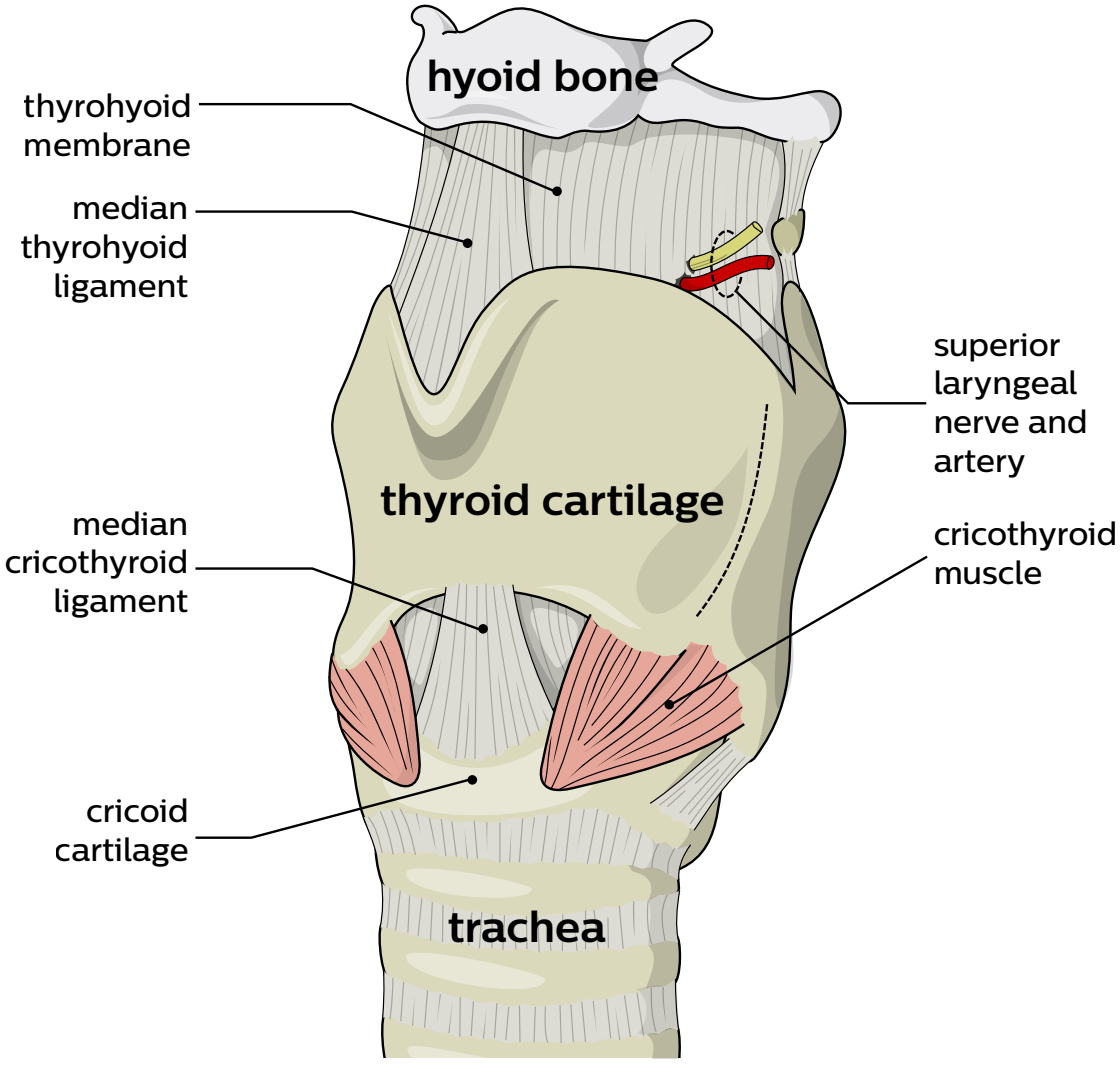
An 88-year-old male is transferred from a community hospital to a tertiary care Emergency Department for neurosurgical evaluation due to an unstable cervical spine fracture sustained after a mechanical fall from a ladder. On arrival the patient is immobilized with a cervical collar, appears confused, and is moving all extremities and trying to climb out of the gurney. During initial attempts to verbally reassure the patient, he becomes acutely unresponsive and hypoxic, his oxygen saturation dropping to 78% on room air.

3 Fundamentals of the exam

Point-of-care ultrasound evaluation of the airway consists of two steps.

- Preparation for a potential surgical airway
- Confirmation of tracheal tube placement (via exclusion of esophageal intubation)

Upon identification of a predicted difficult airway, the clinician locates and subsequently marks the cricothyroid membrane prior to attempts at non-surgical airway management. This preparation may facilitate emergent cricothyrotomy by localizing the cricothyroid membrane when it is difficult to identify landmarks by inspection and/or palpation.



[Figure 1] **Relevant anatomy of the upper airway.**

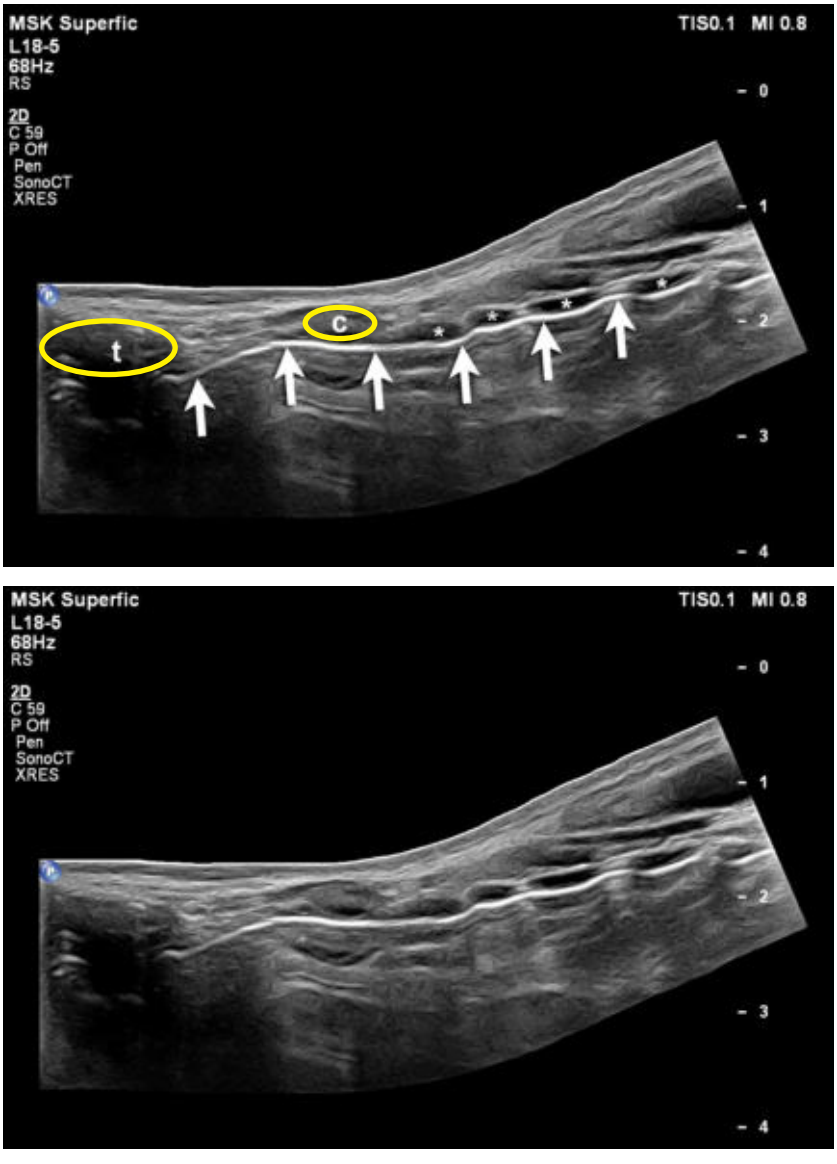
Wikipedia: The free encyclopedia. (2014, June 5). FL: Wikimedia Foundation, Inc. Retrieved June 12, 2014, from http://www.wikipedia.org

Confirmation of tracheal tube placement is performed indirectly by visualizing the esophagus during advancement of an endotracheal tube. Due to the sonographic appearance of the cartilaginous air-filled trachea, it is often difficult to identify a correctly placed endotracheal tube. In contrast, recognition of an endotracheal tube as it passes left and posterolateral to the trachea is indicative of an esophageal intubation. If a tube is not visualized in the esophagus, correct endotracheal placement is thereby confirmed indirectly.

Nomenclature and definition of the terms

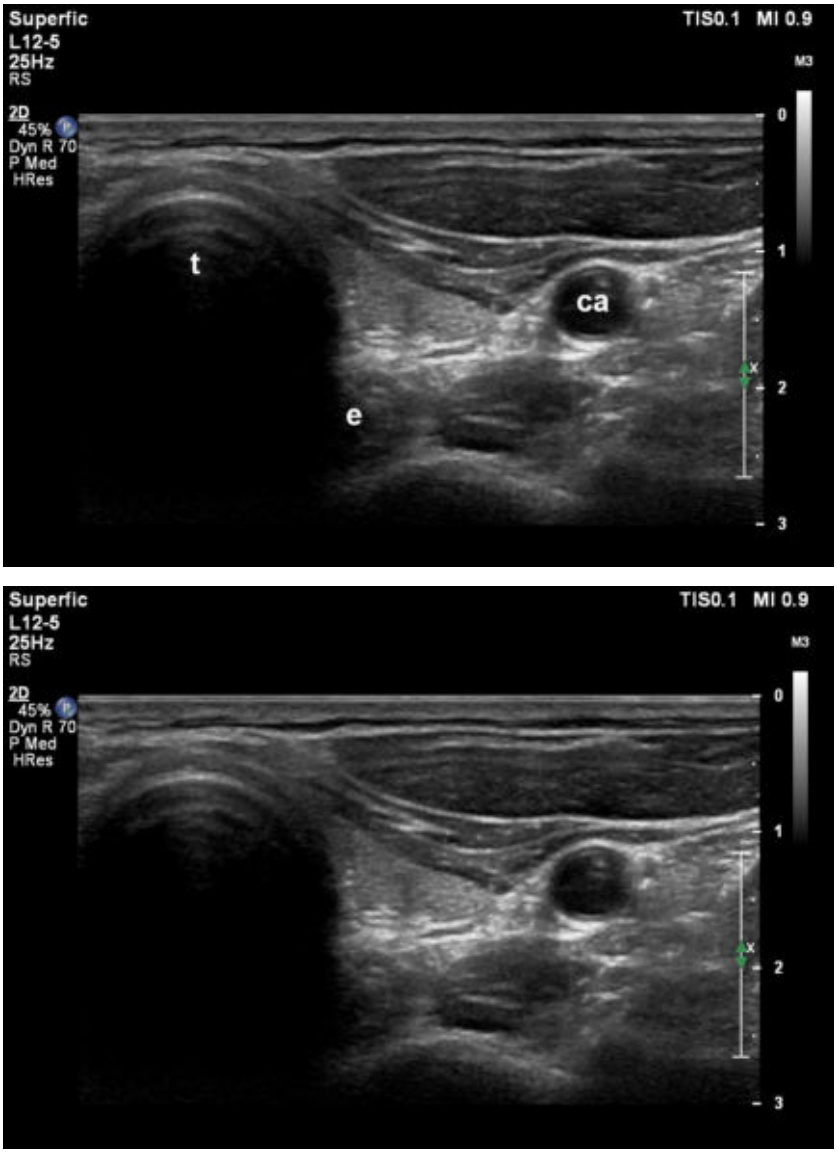
The relevant tissues visualized in the upper airway using ultrasound include the thyroid cartilage, the cricoid cartilage, the tracheal rings, and the interface of the tracheal mucosa and the air within the trachea. The esophagus, thyroid gland, and common carotid arteries represent the relevant surrounding anatomic structures.

- Cartilage has a **hypoechoic** (dark) sonographic appearance
- Due to the significant difference in acoustic impedance between soft tissue and air, sound waves are strongly reflected resulting in a **hyperechoic** or bright appearance at the air-mucosal interface (**A-M interface**) along the anterior border of the airway. In **Figure 2**, note the hyperechoic thin line just deep to the tracheal rings, cricoid cartilage and thyroid cartilage.[6,8,9] The air within the tracheal lumen does not permit transmission and return of ultrasound, and the lumen and posterior wall are therefore not visualized.



[Figure 2]
Longitudinal view of the relevant upper airway anatomy. Note the thyroid cartilage (t), cricoid cartilage (c), tracheal rings (asterisks) with their characteristic "string of pearls appearance," and the air-mucosal interface (arrows).

- Due to the reflective properties of the A-M interface, a characteristic **reverberation** artifact is generated, and appears as a series of parallel hyperechoic lines that occur at regularly spaced intervals deep to the A-M interface **[Figure 3]**. These have a similar appearance to the A-lines encountered during lung sonography, and are artifacts generated due to a similar interface between soft-tissue to air.[6,8]
- The thyroid gland has a characteristic homogenous echo-texture, and is identified both laterally (the main lobes) and anteriorly (the isthmus) to the trachea.



[Figure 3]
Transverse view of the relevant upper airway anatomy. Note the trachea (t), esophagus (e), and left common carotid artery (ca).

Transducer selection

The anatomic structures of interest are superficial and therefore best evaluated with a linear-array, high-frequency transducer.

Due to its smaller transducer footprint, a high-frequency curvilinear transducer may be required in patients with particularly short necks or those in cervical immobilization.

Other aspects of airway assessment (such as evaluation of the posterior tongue, oropharynx, and lung) may be performed with a curvilinear, low-frequency transducer,[4] and will not be discussed further in this module.

Image optimization

The gain, depth, and focal zone(s) should be set appropriately to optimize the visualization of relevant structures. Excessive depth may make identification of the superficial anatomy difficult.

4 Ultrasound technique

Identification of the cricothyroid membrane

Ensure that the patient's neck is in full extension unless spinal immobilization is indicated. Apply the linear transducer to the caudal midline of the anterior neck with the directional indicator oriented towards the patient's head.

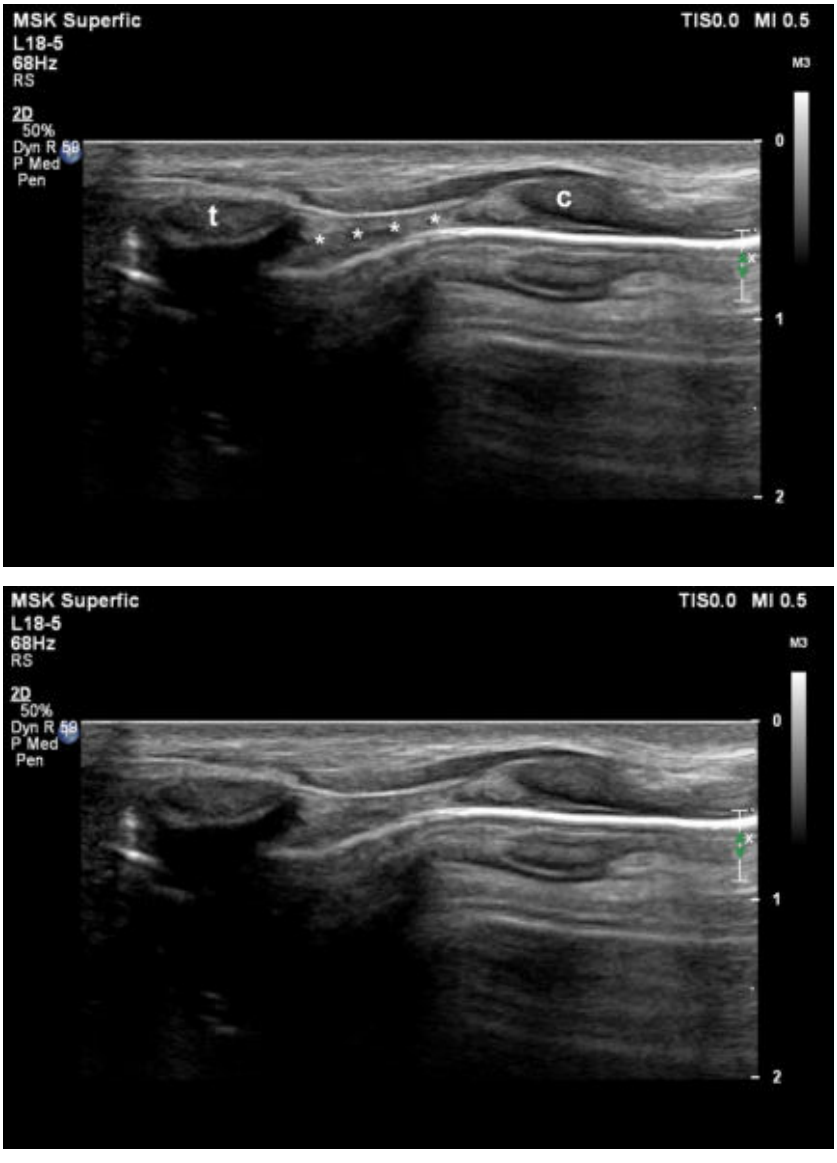
[Figure 4] Appropriate transducer placement for obtaining the longitudinal view of the airway anatomy.

The tracheal rings are visualized as a series of hypoechoic "beads on a string" that terminate cephalad with the larger, ovoid-shaped hypoechoic cricoid cartilage. As noted previously, the hyperechoic line deep to the string of beads represents the air-mucosal (A-M) interface.

As the transducer is moved cephalad, the cricothyroid membrane is identified, bounded cephalad and caudad by the edges of the thyroid and cricoid cartilages, respectively **[Figure 5]**.

Note that the membrane itself may not be clearly visualized and should therefore be identified by its cartilaginous boundaries.

Adjust the depth of the image so that the trachea and cricoid cartilage are optimally visualized. A surgical marking pen is used to mark the midline of the cricothyroid membrane in both transverse and sagittal planes.



[Figure 5]
The cricothyroid membrane (asterisks) is bordered by the thyroid cartilage (t) cephalad and the cricoid cartilage (c) caudad.

[Video 1]

Identification and marking of the cricothyroid membrane.

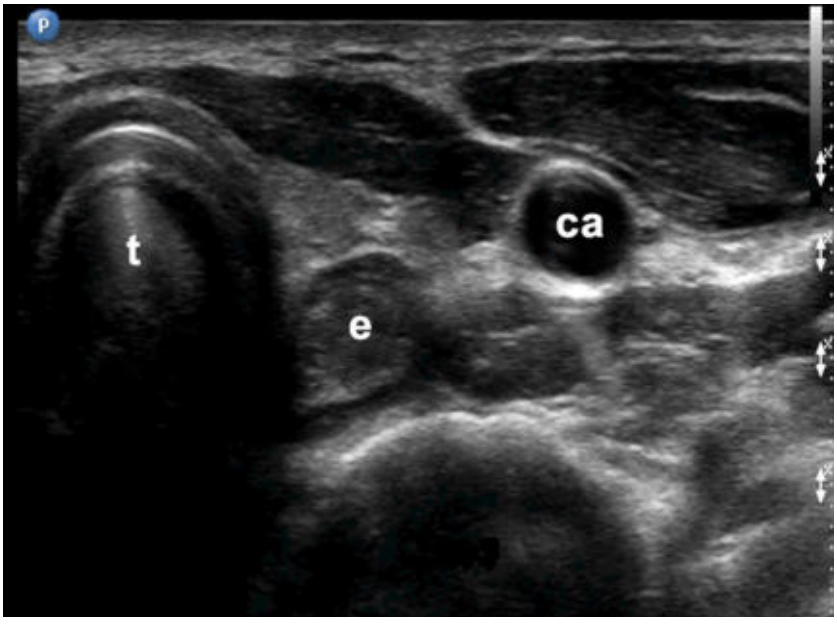
Endotracheal intubation

Apply the linear transducer to the trachea in a transverse plane just cephalad to the suprasternal notch, with the directional indicator oriented to the patient's right **[Figure 6a]**.

The curved trachea can be easily recognized due to its location and characteristic reverberations from the A-M interface. The esophagus is identified by its concentric layers[8,9] and its position left and posterolateral to the trachea **[Figure 6b]**.

Proper identification of the esophagus is essential to ensure accurate sonographic assessment during endotracheal intubation.

[Figure 6a]
Appropriate transducer placement for observation during orotracheal intubation.



[Figure 6b]
Transverse view of the upper airway anatomy. Note the characteristic reverbations in the trachea (t) and the concentric layers esophagus (e).

As a different operator advances the endotracheal tube, the clinician should continuously observe the esophagus for the appearance of an A-M interface and/or a curved hyperechoic structure being manipulated through the esophageal lumen. Absence of these signs indirectly confirms tracheal placement of the tube. The clinician should slide the transducer slightly to the patient's left and optimize the image depth to ensure that the posterior position of the esophagus is well visualized.

[Video 2]

Demonstration of esophageal intubation.

[Video 3]

Demonstration of successful tracheal intubation and a video recorded after placement of an endotracheal tube and an orogastric tube.

Real-time imaging with continuous observation during tube advancement optimizes this application for airway management.[4,8,9] Difficult-to-identify landmarks, unsteady or static views, and intermittent observation will not allow accurate use of ultrasound to confirm tracheal intubation.

This technique (as opposed to traditional methods to confirm endotracheal tube placement such as capnography and auscultation) enables clinicians to identify inadvertent esophageal intubation prior to delivering ventilatory breaths through the endotracheal tube, potentially decreasing the risk of gastric insufflation and subsequent aspiration.

5 Case resolution

This patient has an unstable cervical spine injury and cervical immobilization lends for a predictable airway challenge. Pre-intubation identification and preparation of the cricothyroid membrane in anticipation of a surgical airway is indicated. The clinician may access the appropriate anatomy through the pre-formed opening on most commercially available cervical collars without having to remove the collar or move the patient.

Using ultrasound, the cricothyroid membrane is identified as the space bordered by the thyroid cartilage and cricoid cartilage. A mark on the skin is placed midline and lateral to the level of this surgical landmark while the patient is ventilated by bag-valve-mask and intubation equipment and medications are prepared. Ultrasound is used to confirm real-time placement of the endotracheal tube without the need for a surgical airway.

14 Bibliography

1. Muslu B, Sert H, Kaya A, et al. Use of sonography for rapid identification of esophageal and tracheal intubations in adult patients. J. Ultrasound Med. 2011;30(5):671–6. Available at: http://www.ncbi.nlm.nih.gov/pubmed/21527615.
2. Uya A, Spear D, Patel K, Okada P, Sheeran P, McCreight A. Can novice sonographers accurately locate an endotracheal tube with a saline-filled cuff in a cadaver model? A pilot study. Acad. Emerg. Med. 2012;19(3):361–4. Available at: http://www.ncbi.nlm.nih.gov/pubmed/22435870.
3. Stuntz R, Kochert E, Kehrl T, Schrading W. The effect of sonologist experience on the ability to determine endotracheal tube location using transtracheal ultrasound. Am. J. Emerg. Med. 2013:10–12. Available at: http://www.ncbi.nlm.nih.gov/pubmed/24360314. Accessed December 31, 2013.
4. Kristensen MS. Ultrasonography in the management of the airway. Acta Anaesthesiol. Scand. 2011;55(10):1155–73. Available at: http://www.ncbi.nlm.nih.gov/pubmed/22092121. Accessed December 25, 2013.
5. Miss J, Nagdev A, Fahimi J. Real time ultrasound guided endotracheal intubation should strive for identification of esophageal intubation. Resuscitation. 2013;(July):9572. Available at: http://www.ncbi.nlm.nih.gov/pubmed/24128797. Accessed December 31, 2013.
6. Chou HC, Tseng WP, Wang CH, et al. Tracheal rapid ultrasound exam (T.R.U.E.) for confirming endotracheal tube placement during emergency intubation. Resuscitation. 2011;82(10):1279–1284.
7. Werner SL, Smith CE, Goldstein JR, Jones RA, Cydulka RK. Pilot study to evaluate the accuracy of ultrasonography in confirming endotracheal tube placement. Ann. Emerg. Med. 2007;49(1):75–80. Available at: http://www.ncbi.nlm.nih.gov/pubmed/17014927. Accessed December 31, 2013.
8. Singh M, Chin KJ, Chan VW, Wong DT, Prasad GA YE. Use of Sonography for Airway Assessment. J Ultrasound Med. 2010;(2):79–85.
9. Chou HC, Chong KM, Sim SS, et al. Real-time tracheal ultrasonography for confirmation of endotracheal tube placement during cardiopulmonary resuscitation. Resuscitation. 2013;84(12):1708–12. Available at: http://www.ncbi.nlm.nih.gov/pubmed/23851048. Accessed December 31, 2013.

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