Interventional Ultrasound in Adult Critically Ill Patient in Surgical ICU

An Essay

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بسم الله الرحمن الرحيم

قالوا

سبحانك لا علم لنا
إلا ما علمتنا إنك أنت
العليم الحكيم

صدق الله العظيم

سورة البقرة الآية: ٣٢

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List of Contents

Title	Page No.

List of Figures

List of Figures cont...

Fig. No.	Title	Page No.

List of Figures cont...

Fig. No.	Title	Page No.

ABSTRACT

Ultrasonography in the intensive care unit (ICU) has become a valuable tool for expeditiously, safely and effectively diagnosing and treating a myriad of conditions commonly encountered in this setting. Most intensivists are familiar with focused assessment with sonography in trauma (FAST) and can readily grasp the fundamentals of a limited or directed ultrasonographic exam. Thus, with appropriate training and practice, intensivists can utilize this tool in visualizing, characterizing and treating life-threatening conditions in their role as intensivists in the surgical ICU (SICU). In this review we will discuss the different uses of ultrasonography in general critical care for assessing as well as intervention in the thoracic, abdominal and vascular systems. Vascular ultrasonography for central venous line placement has been shown to significantly increase the overall chances for successful placement on the first attempt and to reduce the rate of complications. The data were most compelling for internal jugular vein central venous line placement over subclavian vein cannulations. Thus, this technique has been recommended in the United States by the Agency for Healthcare Research and Quality for all central venous line insertions and in the United Kingdom by the National Institute for Clinical Excellence (NICE).

Keywords: Interventional Ultrasound, Surgical ICU

Introduction

Ultrasonography in the intensive care unit (ICU) has become a valuable tool for expeditiously, safely and effectively diagnosing and treating a myriad of conditions commonly encountered in this setting. Most intensivists are familiar with focused assessment with sonography in trauma (FAST) and can readily grasp the fundamentals of a limited or directed ultrasonographic exam ***(Galvan et al., 2011)***.

Thus, with appropriate training and practice, intensivists can utilize this tool in visualizing, characterizing and treating life-threatening conditions in their role as intensivists in the surgical ICU (SICU). ***(Galvan et al., 2011).***

Vascular ultrasonography for central venous line placement has been shown to significantly increase the overall chances for successful placement on the first attempt and to reduce the rate of complications. The data were most compelling for internal jugular vein central venous line placement over subclavian vein cannulations. Thus, this technique has been recommended in the United States by the Agency for Healthcare Research and Quality for all central venous line insertions and in the United Kingdom by the National Institute for Clinical Excellence (NICE) ***(Hind et al., 2003).***

Also Ultrasound-guided thoracentesis offers a potentially safer alternative to thoracentesis without direct imaging guidance. The physical examination finding of dullness to percussion or the presence of a density on a chest radiograph can sometimes be misleading. Ultrasound allows documentation of the pleural fluid and rules out other etiologies such as atelectasis, consolidation, mass, or an elevated hemidiaphragm. Currently, most clinicians reserve ultrasound-guided thoracentesis for more difficult cases, such as patients (1) receiving mechanical ventilation, (2) with less-than-ideal body habitus, or (3) with small fluid collections ***(Mayo, 2006).***

The post-operative transversus abdominis plane (TAP) block is a relatively new regional anesthesia technique that provides analgesia to the parietal peritoneum as well as the skin and muscles of the anterior abdominal wall. It has a high margin of safety and is technically simple to perform, especially under ultrasound guidance ***(Young, 2012).***

AIM OF THE ESSAY

The aim of this essay is to Identify and simplify how to use the ultrasound in surgical ICU, benefits of its usage, prospective and its limitations.

PRINCIPLES & USES OF ULTRASOUND

1. Ultrasound Imaging:

Ultrasound imaging utilizes high-frequency sound waves (3–17 MHz). The speed of sound in soft tissue is fairly constant (1540 m/sec), so the position of objects can be inferred from the time of flight of their received echoes. The product of wavelength and frequency is the speed of sound, so high-frequency sound waves have shorter wavelengths, and therefore provide better axial resolution. Attenuation of sound waves is frequency-dependent (approximately 0.75 dB/cm/MHz), so penetration of high-frequency sound waves into deep tissue is limited. For interventional guidance, one of the biggest advantages of ultrasound over other imaging modalities is the real-time acquisition of images ***(Gray, 2013).***

Theoretically, ultrasound imaging can cause warming of tissue through absorption of sound waves (quantified by the thermal index). Transmission of sound waves also can cause cavitation (gas body formation, quantified by the mechanical index). However, no adverse biological effects have been confirmed for diagnostic ultrasound. Nevertheless, it is prudent to limit scanning to that necessary for clinical care and related education ***(Bianchi, 2007).***

The most common artifact associated with ultrasound imaging is contact artifact. Contact artifact is defined as loss of acoustic coupling between transducer and skin. Scanning gel is normally applied to exclude air from the transducer–skin interface. This interface can be disrupted simply because the transducer does not touch the skin. Another common cause is trapping of air bubbles under the sterile cover of the transducer. If the block needle is inserted too close to the transducer, the skin contact will be disturbed. Firm, even pressure with the transducer (like holding a mask to ventilate an anesthetized patient) is required to produce optimal scans. Manual compression exerted with the transducer is usually optimal for regional block when sufficient to just cause coaptation of the walls of superficial veins within the field of imaging ***(Soong et al., 2005).***

2. Doppler:

In 1842, Christian Johann Doppler described the frequency shift that occurs when a wave source or receiver moves. Doppler's stellar observation has been applied to estimate the velocity of moving reflectors in the body (typically red blood cells) by measuring the frequency shift of sound waves. Modern color Doppler velocity imaging maps the mean velocity to a color scale. Specifically, color flow mapping systems overlay a pseudocolor velocity map on a gray-scale, two-dimensional image (fig. 1) ***(McNally, 2011).***

A new color Doppler technology has been developed. It estimates the mean Doppler frequency shift, as well as estimating the integrated Doppler power spectrum. The advantage of power Doppler is that it is more sensitive at detecting blood flow than velocity imaging (by a factor of 3 to 5 in some cases). In addition, the integrated power Doppler signal is almost independent of the angle between the vessel and the transducer beam. Finally, power Doppler is not subject to aliasing artifacts. The disadvantages of power Doppler are the high motion sensitivity (flash artifact) and the lack of directional information ***(Pinzon and Moore, 2009).***

When performing regional blocks, it is important to distinguish small arteries from small monofascicular nerves because these two anatomic structures often run together. For the reasons cited earlier, power Doppler is the best tool for this purpose. In addition, visible pulsations with probe compression also can be useful in identifying small arteries. Nerve vasculature can be demonstrated with color Doppler in some normal subjects. Longitudinal vessels within the epineurium or microvasculature within nerves can occasionally be detected, However, a robust Doppler signal clearly distinguishes small arteries from nerves ***(Gassner et al., 2002).***

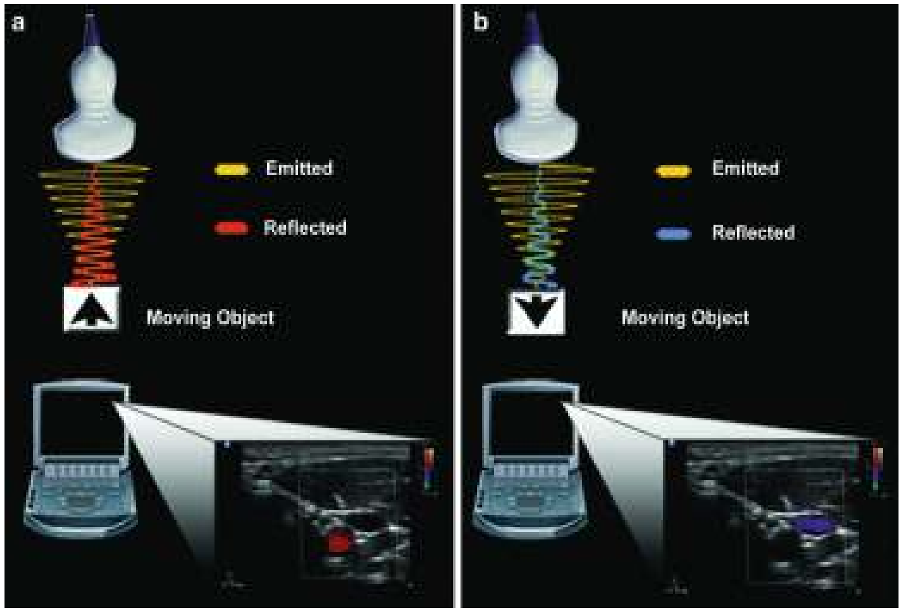

Figure (1): Doppler. (a) When a sound wave is emitted from the transducer and reflected from a target object moving toward the transducer, the returning frequency will be higher than the original emitted sound wave. The corresponding image on the ultrasound machine is represented by a red color. (b) Conversely, if the target object is moving away from the transducer, the returning frequency will be lower than the original emitted sound wave. The corresponding image on the ultrasound machine is represented by a blue color ***(Pinzo, 2009)***.

3. Generation of Ultrasound Pulses:

Ultrasound transducers contain multiple piezoelectric crystals which are interconnected electronically and vibrate in response to an applied electric current. This phenomenon called the piezoelectric effect was originally described by the Curie brothers in 1880 when they subjected a cut piece of quartz to mechanical stress generating an electric charge on the surface ***(Lawrence, 2007).***