# Updates in Critical Care Ultrasound Usage

An Essay

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By

**Seif El-deen Ali Ahmed Abel-Rahman**

*M.B.B.CH Faculty of Medicine, Assuit University*

Supervised by

**Prof. Dr. Hazem Mohamed Abdel-Rahman Fawzi**

*Professor of Anesthesia, Intensive Care and Pain Management*
*Faculty of Medicine, Ain Shams University*

**Dr. Mayar Hasan El Sersi**

*Associate Professor of Anesthesia, Intensive Care and Pain Management*
*Faculty of Medicine, Ain Shams University*

Faculty of Medicine
Ain Shams University
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# Abstract

Vascular ultrasound is used for diagnosis of DVT which is a very common finding in the ICU, and it carries high risk of pulmonary embolism which is potentially fatal. Another important use of vascular ultrasound is the placement of vascular access without complications.

Ocular ultrasound is useful in trauma patients for diagnosis of rupture globe and in non-trauma patients for measurement of intracranial pressure. Ultrasound uses in urethral catheterization and endotracheal intubation potentially decrease the complications of these procedures.

**Keywords:** Magnetic Resonance- Magnetic Resonance Imaging - Optic Nerve Diameter - Optic Nerve Sheath Diameter

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 Abbreviations

| Abb. | Full term |
|---|---|
| *2D* | *Two Dimensional* |
| *A mode* | *Amplitude Mode* |
| *A* | *Amplitude* |
| *AO* | *Aorta* |
| *ARDS* | *Acute Respiratory Distress Syndrome* |
| *AV* | *Aortic Valve* |
| *B mode* | *Brightness mode* |
| *CCE* | *Critical Care Echocardiography* |
| *Cm* | *Centimeter* |
| *CO* | *Cardiac Output* |
| *CSF* | *Cerebrospinal Fluid* |
| *CT* | *Computed Tomography* |
| *CUS* | *Compression Ultrasound* |
| *CXR* | *Chest X Ray* |
| *dB* | *Decibel* |
| *DIVC* | *Distensibility Index of Inferior Vena Cava* |
| *DVT* | *Deep Venous Thrombosis* |
| *ECG* | *Electrocardiography* |
| *EPSS* | *Enhanced Peritoneal Stripe Sign* |
| *F* | *Frequency* |
| *FAC* | *Fractional Area Change* |
| *FAST* | *Focused Assessment with Sonography for Trauma* |
| *FV* | *Flow Velocity* |
| *HZ* | *Hertz* |
| *IAS* | *Inter-Atrial Septum* |
| *ICP* | *Intracranial Pressure* |
| *ICU* | *Intensive Care Unit* |
| *IV* | *Intravenous* |

# *List of Abbreviations (Cont...)*

| Abb. | Full term |
|---|---|
| *IVC* | *Inferior Vena Cava* |
| *KHZ* | *Kilo Hertz* |
| *LA* | *Left Atrium* |
| *LUS* | *Lung Ultrasound* |
| *LV* | *Left Ventricle* |
| *LVOT* | *Left Ventricle Outflow Tract* |
| *M mode* | *Motion Mode* |
| *M* | *Meter* |
| *M/s* | *Meter per Second* |
| *MHZ* | *Mega Hertz* |
| *mm* | *Millimeter* |
| *MR* | *Magnetic Resonance* |
| *MRI* | *Magnetic Resonance Imaging* |
| *OND* | *Optic Nerve Diameter* |
| *ONSD* | *Optic Nerve Sheath Diameter* |
| *P* | *Period is the Time of One Complete Wave Cycle* |
| *P.E* | *Pulmonary Embolism* |
| *PAcT* | *Acceleration Time of the Pulmonary Ejection Signal* |
| *PC* | *Pericardial Collection* |
| *PE* | *Pericardial Effusion* |
| *PI* | *pulsatility index* |
| *PICCs* | *peripherally inserted central catheters* |
| *PSAX* | *parasternal short axis* |
| *RA* | *right atrium* |
| *RACE* | *Rapid Assessment by Cardiac Echo* |
| *RV* | *right ventricle* |
| *SV* | *stroke volume* |
| *SVC* | *superior vena Cava* |

# List of Abbreviations (Cont…)

| Abb. | Full term |
|---|---|
| *TAPSE* | *Tricuspid annulus plane systolic excursion* |
| *TCD* | *transcranial Doppler* |
| *TDI* | *Tissue Doppler Imaging* |
| *TEE* | *Trans-esophageal echocardiography* |
| *TTE* | *Trans-thoracic echocardiography* |
| *TVUS* | *transvaginal ultrasonography* |
| *VTE* | *Venous thromboembolism* |

# INTRODUCTION

Ultrasound was first used medically by ***Dr Karl -Dussik in 1942,*** this was for the diagnosis of brain tumors and location of cerebral ventricles. Since that date, the scientists added many diagnostic and therapeutic applications for ultrasound in medicine ***(Lichtenstein et al., 2014).***

In fact, there were advances in ultrasound technology over the last years including smaller and portable machines, decreased cost of ultrasound technology as well as improved probes achieving better interpretation of images. Simultaneously there is a revolution in the use of ultrasound in the intensive care units which includes diagnosis and therapy ***(Wilson and MacKay, 2012).***

Focused Echocardiography in critically ill patients has a short duration and it helps interpretation with clinical examination to provide better diagnosis and management such as assessment of left and right ventricular functions, pericardial space and volume status ***(Wilson and MacKay, 2012).***

Thoracic ultrasound in the ICU can be done bedside easily in comparison to CT scan and can be repeated when needed. It is very useful in detection of pneumothorax, lung consolidation, and pleural effusion and for the diagnosis of alveolar interstitial syndrome. Early detection and management of such abnormalities will be very useful for improving the prognosis of the diseases ***(Chacko and Brar, 2014).***

Ultrasound guided venous and arterial cannulation can be used in the ICU for decreasing complications and the numbers of trials especially in patients with thrombocytopenia or coagulopathy. Here the course of the needle is visualized through the soft tissues reaching the vein or the artery ***(Lichtenstein et al., 2014).***

Abdominal Ultrasonography in the ICU has many uses, in the Surgical ICU for example it can be used for detection of the cause of deterioration of trauma patients of intra-abdominal etiology though having several limitations such as open wounds, tubes, drains, rib shadows or bowel gases but Focused Assessment with Sonography for Trauma (FAST) examination is very useful in detection of free peritoneal fluid collection which changes the approach to such a patient. Other findings such as pneumoperitoneum can be a sign of ruptured viscus. Diagnosis of liver abscess and acute cholecystitis can help detection of the cause of fever in ICU patients ***(Guillory and Gunter, 2008).***

# Aim of the Work

The goal of this work is to focus the light on the different types of ultrasonography and the updates in its usage in the ICU and its importance in relation to the traditional methods which help making the management of critically ill patients easier and better.

# Chapter 1
# PRINCIPLES OF ULTRASONOGRAPHY

To understand the nature of ultrasound we have to know some principles; Wave length, Velocity, Amplitude, Period, Frequency. Sound is a form of energy which passes through a medium by vibrating particles. Sound is a medium vibration which propagates a sine wave creating areas of compression and rarefaction. There are two types of waves; longitudinal and transverse, Sound waves are longitudinal ***(Fagley et al., 2015).***

Wave length is the distance between two consecutive corresponding points at the same phase (the distance where the wave shape repeated). It is measured in the units of length (m, cm, mm, etc). It is known by the symbol ($\lambda$). Amplitude refers to the particle displacement. Amplitude is a measure of the maximum height of the wave. It is known as (A) and expressed as decibels (dB). Period is the time of one complete wave cycle. It is known as (P) ***(Macgregor et al., 2010).***

Frequency (f) means the number of sound waves per second, where the frequency of one hertz means one wave per second (hertz is the unit of measurement of frequency). The sound waves audible the human ear ranges from 20 – 20000 hertz (20 HZ to 20 KHZ). Ultrasound has a frequency above 20 KHZ, while clinical ultrasound has a frequency of 1MHZ (1000000 HZ) ***(Fagley et al., 2015).***

Velocity is the wave speed while passing through a certain medium; it depends on the physical properties of the medium. It is measured by m/s (meter per second). The velocity of sound waves differs from one medium to another; it is 330 m/s through the air. While clinical ultrasound passes through the soft tissues be average velocity of 1540 m/s as follows: liver 1580 m/s, muscle 155 m/s, blood 150 m/s, bone 4080 m/s, fat 1430 m/s (figure 1) ***(Macgregor et al., 2010).***

## Generating ultrasound and image production:

The ultrasound probe is composed of large number of transducers which are arranged in lines called array. The transducer emits ultrasound wave and stay silent until it detects the waves returning after hitting something ***(Lisciandro, 2014).***

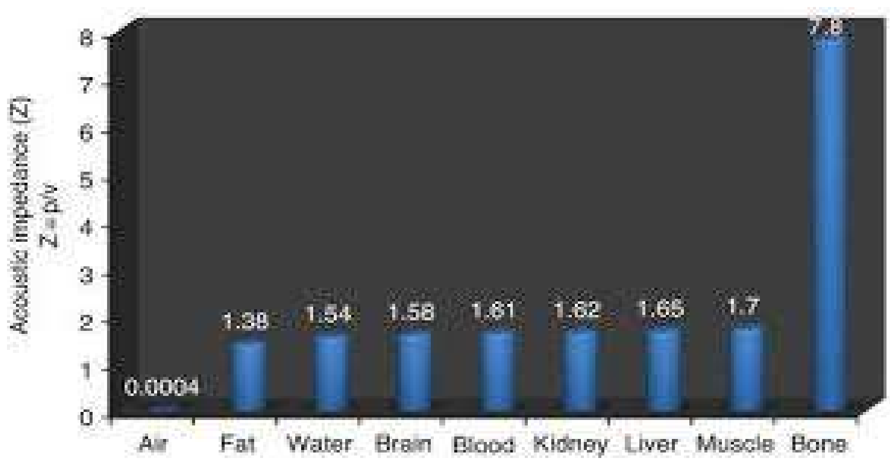


**Figure (1): Velocity (m/sec) of sound through common body tissues or substances.** Note the similar velocity through most soft tissues. This is the basis for using 1,540 m/sec as the number in depth calculations by the ultrasound processor ***(Lisciandro, 2014).***

The piezo-electric effect is the phenomenon where some materials; like ceramics crystals change their shape when an electrical charge applied to them and also can emit electrical charge when some thing distorts its shape, so the act as sound transmitter and receiver. The generated sound waves pass into tissues, some waves are reflected and others are propagated, the reflected waves are used to generate the ultrasound image ***(Berry and Mauragis, 2015***).

The ultrasound beams are sweeped across the imaging plane to form one line at a time, these lines are used to form a frame for the image, and these frames are repeated to form a real time image. The amplitude of the returning echo from tissues determines the brightness of the image. The density and the velocity of the tissues determine the position ***(Sofferman and Ahuja, 2012).***

## Interaction of ultrasound with tissues:

The probes of high frequency (between 5 and 13 HZ) can not penetrate tissues deeply but provide images with greater resolution, while probes with low frequency (between 2 and 5 HZ) can penetrate tissues deeply (up to 30 cm) but the resolution of the images is less than probes with higher frequency. This is due to the fact that the resolution relates to the distance between two points in the path-line of the beam, which depends on the pulse duration; so the higher the frequency of the probes the lower the pulse duration which