Uses of ultrasound in anesthesia

Essays submitted for partial fulfillment for the requirements of master degree in *anesthesia*

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استخدامات الموجات فوق الصوتية في التخدير

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List of abbreviations

2 D	Two dimensions
3 D	Three dimensions
a	Attenuation coefficient
A mode	Amplitude mode
AP	Articular process
ASIS	Anterior superior iliac spine
B mode	Brightness mode
C	Cervical
CABG	Coronary artery bypass graft
Cm	Centimeter
CPB	Cardio pulmonary bypass
CT	Computerized tomography
CVC	Central venous catheter
CVP	Central venous pressure
DLT	Double lumen tube
ECG	Electrocardiography
ETT	Endotracheal tube
F	Maximum numbers of frames displayed per second
FV	Femoral vein
h	Hour
hg	Mercury
HZ	Hertz
I	Intensity
Ij	Internal jagular
IVC	Inferior venacava
J	Joules
KPa	Kilo Pascal
KH	Kilo Hertz
L	Lumbar
LA	Left atrium
LMA	Laryngeal mask airway

LV	Left ventricle
LVIDD	Left ventricle internal diastolic dimension
LVISD	Left ventricle internal systolic dimension
MHZ	Mega hertz
mm	Millimeter
MR	Mitral regurgitation
PCWP	Pulmonary capillary wedge pressure
PDT	Percutanous dilatational tracheostomy
PS	Paramedian sagittal
PRF	Pulse repetition frequency
PWV	Pulse wave frequency
PZT	Lead Zirconate Titanate
RF	Radio frequency
SC	Subclavian
SV	Stroke volume
SVC	Superior venacava
SWMA	Segmental wall motion abnormalities
T	Thoracic
TAP	Transverse abdominis plane
TEE	Transesophageal echocardiography
TGC	Time gain compensation
TP	Transverse process
US	Ultrasound
W	watts
Z	Acoustic impedance

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Introduction

Ultrasonography addresses a variety of concerns, such as patient safety, comfort, cost-effectiveness, time to complete a procedure, and success rates associated with invasive anesthesia procedures ***(*Jonathan P. Kline., *2011)*.**

Ultrasound guidance affords several advantages in comparison to traditional methods. The primary advantage of ultrasound is the direct visualization of neural and adjacent anatomical structures. This allows for visualization of the spread of local anesthetic during injection .In addition, sonographic imaging allows for detection of anatomical variants, one of the main reasons that conventionally administered blocks might fail. Other benefits of ultrasound technique include decreased pain with performance of blocks due to reduced number of needle passes, as well as increased patient satisfaction ***(Marhofer et al., 2010).***

Ultrasound guidance has also been suggested that its use during central line placement allows for a reduction in time-to-procedure completion and associated with a reduction in complication rates and an increase in success rates .The use of ultrasound for arterial cannulation has been associated with fewer attempts and increased success rate ***(Brzezinski et al., 2009).***

Echocardiography or cardiac ultrasound has long been established as an important cardiac imaging technique for acquiring real-time information about cardiac anatomy and function. The technological aspect of this cardiac ultrasound platform continues to evolve, recent developments such as real-time 3D scanning are currently being assimilated into clinical practice in transesophageal gninnacs ***(Fletcher., 2009).***

Ultrasound has several advantages for imaging of the airway – it is safe, quick, repeatable, portable and widely available. US can be used for direct observation of whether the tube enters the trachea or the esophagus. US can be applied before anesthesia induction and diagnose several conditions that affect airway management ***(Kristensen et al .,2011).***

Basic principles of ultrasound

Discovery of ultrasound:

The term ultrasound refers to sound with a frequency above that can be detected by the human ear. The audible frequency range lies between 20 Hz and 20 kHz (one hertz equals one cycle per second, one kilohertz equals one thousand cycles per second), whereas the frequencies of sound waves used for diagnostic applications in medicine are of the order of one thousand times higher than this, with a range between 1 and 10MHz (megahertz = one million hertz). Ultrasound imaging relies on the so-called pulse echo principle, which involves emitting a short burst of ultrasound and then listening for the returning ‘‘echo’’ after the sound has been reflected off appropriate surfaces. This is exactly the mechanism which has been employed by bats for millions of years to navigate their way around dark caves and to catch flying insects. ***(*Lawrence JP.,*2007)***.

Nature of sound:

Acoustic (sound) waves are merely organized vibrations of the molecules or atoms of a medium that is able to support the propagation of these waves. Usually the vibrations are organized in a sinusoidal fashion. A sinusoidal sound wave is actually a series of areas of compression and rarefactions. Such changes are frequently described as a sine wave with the peak of the “hill” representing the pressure maximum, and the nadir of the “valley” representing the pressure minimum. The combination of one compression and one rarefaction represents one cycle. **(David Lieu., 2010*)*.**

Longitudinal and transverse sound waves:

When a sound wave travels through a medium, the particles in that medium are displaced in a direction that is parallel to the direction of travel of sound wave. This is called longitudinal wave. It is possible in some media such as quartz that the direction of vibration of particles is perpendicular to the direction of travel of the wave. These are called transverse waves. Diagnostic ultrasound transducers are designed to produce longitudinal sound waves, because only longitudinal waves can be transmitted through soft tissues ***(*****George Kossoff.,2000*****)***.

Ultrasound waves:

Diagnostic ultrasound uses a device known as a transducer, which can both emit and detect ultrasound waves. Transducers are made from a material known as a piezoelectric crystal, which vibrates millions of times per second when a short burst of electric current is applied to it. These crystals also have the property of detecting ultrasound by converting vibrations back into electrical energy. Piezoelectric properties occur in some naturally occurring crystals such as quartz, although most clinical transducers are based on a synthetic piezoelectric substance known as lead zirconate titanate (PZT) **(David Lieu., 2010*****).***

Ultrasound energy spreads by means of rapid alternate compression and expansion of the matter through which it travels, and therefore it cannot pass through a vacuum. Ultrasound passes through most biological tissues with a roughly constant speed (c) of 1540 meters per second. The distance between two consecutive peaks in an ultrasound wave is known as the wavelength, and each pulse typically consists of a few wavelengths. The wavelength depends on the frequency (f) and speed of sound (c) and wavelengh (**λ)**according to the following equation:

$$c = \lambda f$$

Attenuation in soft tissue is proportional to the frequency of the ultrasound beam and path length. If the scan frequency is doubled, the attenuation is also doubled. High-frequency sound penetrates much less than low frequency sound due to attenuation. This explains why superficial structures, such as the breast and thyroid, can be scanned at high frequencies but deep organs in the abdomen or pelvis must be scanned at lower frequencies **(David Lieu., 2010*).***

***Time-gain compensation*:**

The attenuation of ultrasound as it passes through tissues means that echoes obtained from deep structures are much weaker than those obtained from more superficial tissues. To compensate for this effect, the amplitudes of returning echoes are therefore multiplied by a number that increases exponentially with time. This has the effect of amplifying the echoes that originate at increasing depth. This is known as ‘‘time-gain compensation’’ (TGC), and allows similar features at different depths to give a similar appearance in the ultrasound image. The degree of compensation required (known as the ‘‘gain’’) depends on the attenuation coefficient (a) of the tissue. Since (a) can vary depending on the tissue type, most ultrasound systems allow the operator to adjust the gain at different depths to give the best possible image. Some systems allow TGC to be estimated automatically according to the strength of the returning echoes. Very weak echoes can be rejected entirely by setting an appropriate intensity threshold (before or after TGC is applied). This helps to suppress noise in the image. **(David Lieu., 2010*).***

INTERACTION OF SOUND AND TISSUE:

As sound travels through a medium, it essentially travels in a straight line. When the beam reaches an interface between