ULTRASONOCALLY GUIDED RENAL PUNCTURE

THESIS

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The ability to introduce a needle into the collecting system, puncture a cyst, obtain a core of renal tissue or renal mass for biopsy, insert a nephrostomy tube and inject a dye material through this tube, or enlarge the needle track by dilatation thus gaining good access to that system and allowing the introduction of endoscopes down that track into the kidney to deal with stones either by direct extraction if small or by non mechanical disintegration followed by extraction when large, all this has revolutionized the whole field of renal surgery.

A sound knowledge of renal anatomy is essential to master all percutaneous manoeuvers. The advance in radiological and imaging techniques namely fluoroscopy and ultrasonography has been central to advent and evolution of percutaneous kidney puncture, any safe access to the collecting system must be guided by these radiological and imaging techniques, and not depending on the old formerly used hit or miss method.

Both sonography and fluoroscopy have been recommended for renal localisation and needle guidance for purcutaneous renal puncture.

Currently, fluoroscopic guidance with or without a biplane option, seems to be the most frequently used method of guidance. Contrast material has been used to opacify the pelvicalyceal system, but the administration of contrast material to patients in renal failure is thought to be accompanied with some risk. Single plane fluoroscopic localization may require several punctures before the collecting system is entered, thus the potential risk of damage to the kidney or internal structures is incsreased, thus biplane fluoroscopy is essential. However, with sonographic and specially with the use of sonographic aspiration transducers, the risk of complications is reduced because not only the need of intravenous contrast material is eliminated, but localization of the kidny can be established in three planes, with more accurate guidance of the needle towards its target. Also sonography carries no irradition hazards specially in pregnant females. Yet punctures with ultrasound alone needs vast experience with ultrasonically guided puncture techniques.

The role ultrasonography and fluoroscopy in performing a percutaneous renal puncture are not competitive but synergistic.

CHAPTER I

BASIC PHYSICAL AND BIOLOGICAL EFFECTS OF ULTRASOUND.

BASIC PHYSICAL PRINCIPLES OF ULTRASOUND

Sound is a mechanical vibration of particles in a medium around an equilibrium position. Sonic waves requires a medium of a molecular nature in order to propagate (Hassani, 1976).

Ultrasound has characteristics that enable it to provide a means of displaying internal body structures, this is accomplished by sending short bursts of ultrasound into the body and displaying the reflections received from tissue interfaces

The main advantage of ultrasound for diagnostic purposes is that it can be directed in a beam which obeys, like light , the laws of reflection and refraction.
The principal disadvantage of ultrasound is that it propagates poorly through a gaseous medium such as air. As a result the ultrasound producing element (transducer) must have airless contact with the body during examination, acoustic gel or mineral oil can be used for this purpose. In addition it is difficult to examine parts of the body that contain air e.g. the intestines (Feigenbaum, 1981).

Ultrasound is like the ordinary sound that we hear except that it has a pitch or frequency above the human hearing range.

Sound is a travelling variation or wave of quantities called acoustic variables. Each acoustic variable experiences a repeating variation of compressions rarefactions.

The combination of one compression and one rarefaction is one cycle

The frequency (F) is the number of cycles per second, is normally specified in megahertz

The period is the amount of time required for one cycle to occur, where frequency and period are reciprocals of each other,

i.e. period = 1 / frequency (MHz.)

Ultrasound is a sound with a frequency greater than the upper limit of normal human hearing i.e. 20,000 hertz (cycles per second). For diagnostic purposes, frequencies above 1 megahertz (MHz) are used (Nomeir et al 1975).
The wave length ( ) is the amount of distance taken up by a cycle or better the distance between the onset of one cycle to the next.

The velocity (V) equals the frequency (F) times the wavelength (_)

V = F x

The velocity depends upon the density and elastic properties of the medium. Sound travels faster through a dense medium. The velocity also depends upon temperature (Normeir et al, 1975)

Diagnostic ultrasound is usually in the form of short bursts consisting of a small number of cycles. Spatial burst length is the distance from the start to the end of the burst, it is equal to the wavelength times the number of cycles in the burst

The acoustic impedance (Z) of a medium is equal to a product of the density (D) and the velocity (V),

Z = D x V

When the sound beam reaches an interface between two media of different acoustic impedances, part of the beam is refracted and part is reflected.

Almost all diagnostic ultrasound methods are based on the principal that ultrasound is reflected by an interface between media of different acoustic impedances

The amount of sound reflected depend upon the degree of difference between the two media, i.e., the greater the difference, the greater the amount reflected. The amount of ultrasound reflected depends also upon the angle of the incidence of the ultrasonic beam (Feigenbaum, 1981)

Refraction is a change of direction of the sound path upon passing from one medium to another. It occurs when the two media have different propagation speeds.

Attenuation of the sound waves is the amplitude or intensity reduction of the waves as it passes through a medium.

The half value layer is a term used to express the amount of absorption and attenuation of ultrasound in tissues. This term refers to the distance that ultrasound will travel in a particular tissue before its energy is attenuated to one half its original value. The half value for blood is extremely long and indicate that it is an excellent conductor for ultrasound. On the other hand bone has a low half value layer and this explains the difficulty of ultrasound examination through bone (Feigenbaum, 1976)

Ultrasonic transducers :

The transducer is a device for converting electrical energy to acoustic energy and for converting acoustic energy to electrical energy.

The transduction between electrical and acoustic energy is accomplished using materials that exhibit the piezoelectric effect

Piezoelectric means "Pressure electric". Such substances change shape under the influence of an electric field

Quartz was one of the first elements noticed to have this property. If an electric current is allowed to pass through a quartz crystal, the crystal will expand and contract producing compressions and rarefactions or sound waves. The reverse is also true, when a crystal is struck by a sound wave, it produces an electrical impulse. Such a piezoelectric element is the primary component of an ultrasonic transducer (Nomein, 1975).

The piezoelectric crystal of the transducer is a small cylindrical in shape and is generally 1-2 cm. wide and 1 mm thick. Two electrodes are connected to its sides and are connected to an electrical source. Behind the piezoelectric element is some packing material, which

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absorbs sound energy directed backwards and improves the shape of the forward energy.

A case of durable plastic is used to protect the unit. The transducers used in clinical work have different frequency ranges, from 1 to 15 MHz. approximately, 0.1 percent of the time, the transducer acts as a transmitter and 99.9 percent of the time it acts as a receiver. The characteristics of the system depend on the frequency of the trasducer and the choice of frequency depends on the region to be studied. High frequency offers high resolution which provides optimal definition of small objects, but the depth of penetration is limited (Hassani,1976).

Ultrasound instrumentation :

The instrument used to create an image using ultrasound is known as an echograph. The essential components include :

1. <u>The transducer</u> :

   Which lies in contact with the tissues being examined and which sends and receives ultrasound. The rate at which the bursts of ultrasound energy are emitted from the transducer is the repetition rate of the echograph, and varies between 200 and 2000 pulses per second (Hassani, 1976).

2. The transmitter :

It regulates the sending of ultrasound by the transducers. A time is present in the transmitter to control the duration and frequency of the ultrasonic impulses emitted by the transducer

3. The receiver :

The transducer converts the returning echoes to electrical impulses which are picked by the receiver and signal amplifier

4. Signal amplifier :

Is located between the receiver and cathode ray tube, it increases the voltage of the signal cathode tube.

5. Cathode ray tube :

It receives the amplified impulses of the returning echoes, and displays them on a screen.

The display modes may be A-mode, Time motion (TM), B-mode, Real time, Doppler and Gray scale imaging.

A-mode (amplitude mode) :

In this type the probe is kept stationary. The echoes are represented as vertical deflections from the horizontal base line. The hight of the deflection is proportional to the amplitude of the reflected echoes.

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