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General Guidelines for Optimizing the Outcome in Routine Abdominal Ultrasound Examination: A Quick Review

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Abstract: **Medical ultrasound imaging can support physicians with valuable information that can help in the diagnosis of diversity of diseases, and subsequently a successful treatment. The image formation in ultrasound imaging comprises the use acoustic waves through the transmission and receiving of the applied signal through the ultrasound transducer. This received signal initially contributes to the formation of the final ultrasound image. Advantages of medical ultrasound relate to the relatively low cost beside the safety compared to the other radiology imaging techniques that uses ionizing radiation. Improving the image quality will increase the diagnostic outcome. However, the ultrasound image quality may degrade due to many reasons which may varies from the ultrasound machine performance, the applied technique, beside the operator competency. This paper reviews the guidelines and techniques that help to improve the ultrasound image quality and diagnostic outcome in abdominal ultrasonography. This paper covers some of the most important methods for better abdominal ultrasound outcome through reviewing the accessible globally published literature relating ultrasound-imaging technology with summarizing the essential methods to improve the outcome for better interpretation and diagnosis of the suspected pathology.**

Keywords: **Abdominal Ultrasound, Image quality, Optimization, Quality control, Artifacts.**

1. INTRODUCTION

Ultrasound imaging comprises the use of acoustic waves transmitted and received by a hand-held transducer. This imaging technology is cost-effective, flexible, and with no ionizing radiation hazard [1].The sound wave travels through the tissues of the body in a way, which makes it promising to form useful images using relatively simple procedures to form images of internal body organs. Ultrasonography can used to visualize solid structures and organs within the human body. The vasculature within these organs can be evaluated by color Doppler, power Doppler, or spectral modes along with the recent advances in the reconstruction, and rendering techniques which support the outcomes of the diagnosis [2]. Medical applications includes; general abdominal imaging, vascular imaging, urology, cardiology, obstetrics and gynecology, along with guided surgical procedures [1].

This paper provides general guidelines for optimizing the outcome in routine abdominal ultrasound examination. Detailed topics were not included in this review and further information can be found in the included references. The paper is

organized as follows: Section 2 provides a background and discusses the image formation, the ultrasound imaging modes and the main abdominal applications.

Sections 3 review some of the most common factors that may affect the ultrasound examination outcome. Sections 4 summarize some of the basic techniques and methods to improve the procedure outcome. Section 5 outlines safety considerations associated with ultrasound imaging and Section 6 concludes the paper.

2. BACKGROUND

2.1 Ultrasound Image Formation:

Medical ultrasound scanners generate images by using pulsed acoustic waves with frequencies ranging from one to 20 MHz transmitted into the body through a hand-held transducer. After interacting with tissues, some of the transmitted energy returns and detected by the transducer to form the ultrasound image [1]. The transducer is a device that when it placed in direct contact with the patient's body it performs several functions. Its first function is to produce the ultrasound pulses when electrical pulses are applied to it. A short time later, when echo pulses return to the body surface, they captured up by the transducer and, converted back into electrical pulses that processed by the system and form into an image. When a beam of ultrasound pulses is passes into a body, most of the ultrasound energy is absorbed and the beam is attenuated, while some of these pulses will be reflected by the internal body structures and send echoes back to the surface where they are collected by the same transducer and used to form the image. Therefore, the general ultrasound image is a display of structures or reflecting surfaces in the body that produce signal echoes [3]. The signal of echoes is initially amplified and filtered in an analogue chain and next, digitally processed using ADC (Analog-Digital Converter) ,with 8-14 bit of resolution [4]. The received high frequency signal (called RF – radio frequency) of the echoes is amplitude- and phase modulated carrier frequency signal. The signal is demodulated in the device to obtain baseband frequency. The demodulated echo signal is further processed, depending on the application [5].

2.2 Ultrasound Imaging Modes:

The standard imaging modes are all from the same initial information taken from the acoustic echoes. The basic modes are A mode, B mode, M mode, Doppler, and duplex imaging. A mode, refer to amplitude modulation, which represents the amplitude of an acoustic waveform over time [6]. It is the simplest form of ultrasound imaging, and only gives one-dimensional information. It is useful to measure distances and for echo applications.

B mode, refer to brightness modulation, shows echoes as different shades of gray according to their intensity. The B mode image is a two- dimensional reconstruction of the obtained A mode information over a given space at a given time point, where the amplitude of the points on the A mode image is now pixels whose brightness is dictated by the amplitude of the received signal. The horizontal and vertical directions represent real distances in tissue, whereas the intensity of the gray scale indicates echo strength [7]. B mode can provide cross sectional images through the area of interest.

M mode or TM mode (time-motion) shows motion over time, and used often in echocardiography, this allows a real-time analysis of velocities, to outline abnormalities in valvular motion. M mode applied also to areas such as assessment of diaphragmatic movement, or deformation of vascular structures. Doppler imaging enables quantification of flow velocities, such as fetal heartbeat or arterial pulse [6]. These technology advances, followed by widespread acceptance and use of ultrasound in medical diagnosis from simple measurements of anatomical dimensions, to screening and detection of subtle changes in tissue texture and study of blood flow in arteries. Ultrasound is considered now as the first line of investigation, before alternative imaging techniques [7].

2.3 Ultrasound Abdominal Applications:

The application of ultrasound to medical diagnosis has seen continuous development and growth over several decades [7].Abdominal ultrasound is a particularly useful diagnostic procedure in the evaluation of wide abdominal abnormalities. Its advantages include its being noninvasive, portable, and not requiring the use of radiographic contrast material [8].Sonography has wide value in the diagnosis of abdominal pathologies such as vascular abnormalities, hepatobiliary and pancreatic diseases. With respect to the Urinary system, ultrasound can help for demonstrating urinary tract obstructions, possible cysts, abscesses, tumors or fluid collections. Ultrasound also is a commonly employed imaging modality in

obstetrics and is generally consider as safe to the fetus. Current ultrasound technology involves the use of Doppler, 3-dimensional (D) and 4-D ultrasound [9].

3. FACTORS AFFETING THE ULTRASOUND EXAM OUTCOME

The inability to make a sonographic diagnosis or making an error in the diagnosis may occurs for several reasons, these include; the inability of the scanner to resolve the pathological changes due to scanner malfunction or incorrect gain setting. On the other hand patient related factors such as improper patient preparation in addition to poor examination technique, failure to recognize sonographic image findings by the operator or failure to correctly interrupt the sonographic findings also may affect the outcome of the exam [10]. Therefore, accurate selection and calibration of the ultrasound scanner with optimizing the various factors that affect the image formation and interpretation is a challenge in ultrasonography.

4. GUIDLEINES FOR BETTER EXAMINATION OUTCOME

4.1 Ultrasound Machine Quality Control:

In medical imaging, many quality control techniques are developed and used to evaluate the general quality of the imaging equipment. Many quality control tests are used to ensure the quality of the instruments performance and the quality of the final images. The purpose of a quality assurance (QA) program in ultrasonography is to outline and follow steps to evaluate the performance of medical ultrasound machines. Sonologists and sonographers aim to guarantee that the image information obtained in ultrasound procedures are accurate to meet the diagnostic purposes with determining that equipment and clinical practices are safe. The ultrasound image quality depends initially on the ability of a machine to detect echoes [11]. A machine capable of producing a high-quality image is likely to remain operational for much longer than one capable of only poor quality, which will need replacement. A poor-quality image is a false economy in abdominal scanning [12]. For that, the implementation of a comprehensive quality control program is necessary to ensure that an instrument is operating consistently at its expected performance level.

4.2 Clinical justification/ Guidelines:

Unlike most imaging modality, ultrasound diagnosis is most commonly provides real-time images. A study conducted by Landry, B.A., et al., reveals that more than 5% of the abdominal, thyroid, and carotid ultrasound scans requested by family physicians were not clearly indicated based on the clinical history provided. Common trends in requesting these examinations reinforce the need to improve guidelines for requesting scans and for managing many presenting complaints in family practice [13]. Therefore a justifiable and clear ultrasound requisition with adequate clinical history about the problem play a major role in the final outcome of the procedure and help the operator to reach the correct diagnosis.

4.3 Patient preparation, education and care:

Adequate patient preparation as required along with communication and effective education by giving briefing about the procedure as well as clear instructions before the starting and during the procedures minimizes the possibility of errors and contributes positively to better outcome.

4.4 Optimization of the scanning protocol:

As ultrasound is operator dependent, skills are required for effective scanning to obtain the needed information while scanning with coupling the image findings to clinical information, for accurate diagnosis. In clinical practice, correct choices regarding the transducer, the setting of the technical equipment, and the amount of sonographic gel are fundamental to obtain usable diagnostic images [14]. A constant minor adjustment in the equipment settings while scanning different body parts is essential to get best results. One should try to use a low frame rate and as high a frequency as possible to allow for better image quality. Changing patient position and angle of the transducer is vital. Understanding the clinical setting and ultrasound limitations is also important in making the correct diagnosis. On the other hand there can be multiple sources of error that can arise between the physical interactions of the ultrasound beam with the patient's viscera. Interpretation of the echoes is important, as errors can creep in at any stage. The following pointers serve to make the most of the ultrasound machine [12].

- Interact with machine (adjust settings)
- Use the highest frequency possible—try increasing the frequency when examining the pancreas or anterior gallbladder.
- Use the lowest frame rate and highest line density possible. Restless or breathless patients will require a higher frame rate.
- Use the focal zone at relevant correct depth.
- Use tissue harmonic imaging to increase the signal to noise ratio and reduce artifact..
- Try different processing curves to highlight subtle abnormalities and increase contrast resolution.

On the other hand there are, many general approaches, which help to get the best from the scanning procedure. The following pointers serve to improve the outcomes on abdominal ultrasound scanning [15].

- Scan in a systematic way to ensure the whole of the upper abdomen has been thoroughly questioned. The use of a worksheet, which indicates the structures to be scanned, is advisable.
- Always scan any organ in at least two planes, preferably at right angles to each other. This reduces the risk of missing pathology and helps to differentiate artifact from true pathology.
- Where possible, scan in at least two patient positions. It is surprising how the available ultrasound information can enhance by turning your patient oblique, decubitus or erect. Inaccessible organs flop into better view and bowel moves away from the area of interest.
- Use a combination of sub- and intercostal scanning for all upper-abdominal scanning. The different angles can reveal pathology and eliminate artifact.
- Use a variety of planes and angulations and do not limit the scanning to longitudinal and transverse sections.
- Deep inspiration is useful in a proportion of patients, but not all. Sometimes it can make matters worse by filling the stomach with air and obscuring large areas. An intercostal approach with the patient breathing gently often has far more success.
- Positioning patients supine, particularly if elderly or very ill, can make them breathless and uncomfortable. Raise the patient's head as much as necessary; a comfortable patient is much easier to scan.
- Images are a useful record of the scan and how it has been performed, but do not make these your primary task. Scan first, sweeping smoothly from one aspect of the organ to the other in two planes, and then take the relevant images to support your findings.

4.5 Use of imaging enhancement techniques:

Modern ultrasound machines offer an array of pre and post-processing options; these should be well understood and utilized. Image enhancement techniques comprise two types: preprocessing and post-processing techniques. Preprocessing techniques used to enhance image degradations associated to physical properties of the ultrasound signals such as propagation, attenuation, absorption, etc., and comprise modifications in the signal generation and/or image acquisition phases. Examples of this technique include harmonic imaging, spatial and frequency compounding, and pulse inversion. Post-processing methods, on the other hand, deals with the signal-processing techniques to enhance the images after they generated. Deconvolution and filtering are two examples of these techniques. These techniques help to decrease noise, enhance image edges and improve the required contrast, what helps the interpretation of the images [1].

4.6 Recognition and correction of artifacts:

Ultrasound image artifacts commonly occur during routine ultrasonography and contribute to image inaccuracies. These artifacts are categorized into artifacts arising from factors manageable prior to imaging or from sound beam interactions within the patient which may result in clinically useful or confusing artifacts[16].The reader can refer to the published in-depth review of ultrasound artifacts for further reading[17],[18],[19],[18].

4.7 Operator Training:

Ultrasound Image misinterpretation is a major issue in diagnosis ultrasonography because ultrasound scanning is operator-dependent. The skill of effective scanning lies in the operator's ability to maximize the diagnostic information available and in being able to interpret the appearances properly. This is dependent upon [20]:

- Clinical knowledge—knowing what to look for and why, knowing how to interpret the appearances on the image and an understanding of physiological and pathological processes.
- Technical skill to obtain the most useful and appropriate images along with knowledge of artifacts with avoiding the pitfalls during scanning.
- Knowledge of the equipment being used—i.e. making the most of your machine.

It is important that sonographers and ultrasound physicians should have proper training in order to accomplish the expected diagnostic efficiencies of the procedure. The skill of effective scanning lies in the operator's capability to maximize the diagnostic information obtainable and in being able to interpret the appearances correctly.

5. SAFETY CONSIDERATIONS

Ultrasonography is a safe and effective form of imaging that has been used by physicians for more than half a century to aid in diagnosis and guide procedures [21].Although there is no confirmation that diagnostic ultrasound has produced any risk to patients in the past decades, attention should be paid to clinical safety. Harmful effects from ultrasound have been documented in laboratory conditions. These include thermal and mechanical effects. Thermal effects, are demonstrated as a slight rise in temperature particularly in close proximity to the transducer face, during ultrasound scanning, while mechanical effects, refer to cavitation radiation pressure caused by stresses in the tissues and depend on the amplitude of the ultrasound pulse [22]. The acoustic output of up to date equipment is generally much greater than that of the early equipment and, in view of the continuing improvement in equipment design and applications, outputs are expected to continue subject to change. Furthermore, investigations into the possibility of subtle or transient effects are under investigations. Diagnostic ultrasound is considering safe if used correctly. Recommendations related to ultrasound safety suppose that the equipment's are manufactured to international safety requirements and that; well-trained expert operates it. It is the responsibility of the operator to be aware of, and able to apply the current safety standards and regulations besides undertaking the risk/benefit assessment for each examination. The World Federation for Ultrasound in Medicine and Biology (WFUMB) has announced recommendations for the safe use of diagnostic ultrasound [23]. Generally, patient scanning with ultrasound should use the lowest possible acoustic output setting to obtain the necessary diagnostic information under the ALARA principle [24]. The Journal of Ultrasound in Medicine published many articles, which provides an in-depth review of ultrasound bio effects for further reading [25] [26, 27].

6. CONCLUSION

Ultrasound image quality is affected by many factors, making it challenging an operator to obtain and interpret the images for diagnostic information. Abdominal ultrasound is classified as the safest and cost-effective imaging modality in many applications; so many efforts have been done to make the images more valuable. Many factors may degrade the obtained image and affect the procedure outcome. These factors vary from system related factors or patient related factors to operator's errors as well as clinical referral issues. Providing an organized ultrasound machine quality control to assure its performance is the base line to improve the ultrasound exam outcome. On the other hand, justification of the need for the specific ultrasound examination with sufficient clinical history that provided by the referring physician is the key success to reach the required outcome. Optimization of the scanning protocol by the operator as well as the ability to use the system features to enhance the quality of the obtained image is a challenge. In addition, adequate patient preparation with clear instruction contributes positively in improving the outcome. Finally, training and supervision in the provision of ultrasound imaging are most important, improving the skills of Sonologists and sonographers can achieved through continues training with performance monitoring in the workplace for better outcome.

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