JCPR Journal of Clinical Physiotherapy Research Review Article

Diagnostic Ultrasound Imaging in Rehabilitation

Ali Bozorgmehr [a], Soheila Abbasi [b], Javad Sarrafzadeh [a*], Holakoo Mohsenifar [a], Mohammad Reza Pourahmadi [a]

a Department of Physical Therapy, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran; ***b*** Department of Physical Therapy, School of Rehabilitation Sciences, Tehran University of Medical Sciences, Tehran, Iran

***Corresponding Author:** Javad Sarrafzadeh, Department of Physical Therapy, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran. **Tel:** +98-21 22222059; **E mail:** j.sarrafzadeh@gmail.com

Submitted: 2016-09-24; **Accepted**: 2017-02-01

Abstract

Muscles that are attacked by neuromuscular disorders are integral parts of the musculoskeletal system, so the evaluation of this system is very important for therapists. Measurement of muscle morphology with rehabilitative ultrasound imaging has attracted much attention in recent years and researcher have demonstrated that it is a practical tool for physical therapists; however, far too little attention has been paid by therapists to it. This paper has tried to provide some relevant information about this method.

Keywords: Imaging, Musculoskeletal, Rehabilitation, Ultrasound

Please cite this paper as: Bozorgmehr A, Abbasi S, Sarrafzadeh J, Mohsenifar H, Pourahmadi MR. Diagnostic Ultrasound Imaging in Rehabilitation. J Clin Physio Res. 2017; 2(2): 51-54.

Introduction

Although the use of non-invasive and reproducible tools fitting the rehabilitation clinic space to assess neuromuscular impairments is rare, evidence for the application of ultrasound as a helpful tool in this field is growing.

In the past, ultrasound was used to measure muscle morphology, also it was applied along with exercise therapy by a group of the researchers at the University of Tokyo in 1960s to assess biceps brachii morphology (1), it was later on used to evaluate morphological features of many muscles such as the pelvic floor muscles (2), masseter (3), and lumbar multifidus (4, 5).

Nowadays, rehabilitative ultrasound imaging (RUSI) is a method used by physical therapists to evaluate the morphology of muscle, soft tissue and function during exercise and various movements to improve the design of rehabilitation programs (6). In 2005, a symposium was presented and use of ultrasound imaging in rehabilitation was defined for physical therapists (7). RUSI has two distinct fields. One of them is the evaluation of muscle structures (morphometry) including, muscle length, thickness, cross-sectional area, volume, and pennation angles, and the other field is assessing muscle function as a biofeedback mechanism (8) that is used in exercise programs to give high-quality feedback of muscle contraction to a patient (8).

Even though RUSI is a valuable tool in rehabilitation, physical therapists are not completely familiar with the rules and instrumentation underlying RUSI. It is, therefore, critical that they get acquainted with the basic physics of RUSI and other features of it as a safe, portable, objective, and relatively cheap tool.

In order to do so, we have tried to look briefly at the RUSI, to help the physical therapists learn more about it and choose proper rehabilitation program.

Ultrasound physics

RUSI uses sound waves with the frequency of 3.5 to 15 MHz which are created by the flow of an electric current into the crystal of probe (8).

The sound is the result of the passing mechanical energy through the materials. This energy can make the particles mover forward and apart. This behavior can be created by the principles of penetration and attenuation. Penetration is the

capability of sound to propagate into media and to lose energy until it completely disappears, this finally leads to the process of reflection, scattering, refraction and absorption. Three first processes are related to propagation of sound waves, but most of the energy is absorbed by the adjacent tissues which create heat (9-10).

Reflection is a phenomenon that takes place when the part of waves collide an interface then return to probe and they form the ultrasound image ,but the waves may change their direction when they pass through different media and its border (8). This phenomenon is refraction and it can be a disadvantage to image formation through creation of positional errors (8).

There is a general principle about attenuation and frequency of sound waves, it means that higher frequency of ultrasound waves is associated with greater attenuation and lesser penetration; therefore, for better resolution (ability to show detail) and more reflection, higher frequency of ultrasound waves is required. Structural depth is important to determine the frequency used. Higher frequencies (7.5-10.0 MHz) to create the image of surface tissues such as muscle, tendon, ligament, and lower frequency (3.5-5.0 MHz) for deeper tissue structures including deeper muscles, bladder, abdominal and pelvic contents are necessary to be used (11).

Hyperechoic is a term used to refer to a very true fact that the image will appear whiter from structures that are more densely organized collagen, like Bone which reflect sound better. Other tissues like fluids and muscle containing a small amount of collagen cannot reflect sound waves; therefore, they appear black within an ultrasound image that is referred to as "hypoechoic" or "anechoic" (12).

Types of display modes of ultrasound imaging

There are few available modes to display the electrical signals of the ultrasound echo that return from the tissues. The most common ones used in RUSI are "B" (brightness, brilliance) and "M" (motion, movement) modes (8).

B mode

Image that displayed by B-mode as a cross-sectional grey-scale can be used to display the structure morphology (nerve, muscle) (8) and the positional relationship of several structures with other structures. some of these relations include, positional relationship between pelvic floor muscle, bladder wall (13), bladder neck, symphysis pubic (14) and anorectal angle (15) during lower extremity movements, pelvic floor muscle contraction, increment of intra-abdominal pressure, and the influence of dynamic events such as muscle contraction on structures within the field of view. Additionally, it can be used as feedback to evaluate the behavior of muscles during the intervention (16). This technique can also be applied to investigate muscle atrophy among elderly patients and fatty infiltration of muscle in the various disease (8, 17).

B-Mode Ultrasound Assessment of Diaphragm Structure and Function

One of the assessments of the diaphragm is done by B- mode ultrasound technique as a diagnostic, conservative, reproducible and relatively cheap tool among patients with diaphragm dysfunction. The diaphragm can be examined in performance, structure, atrophy, range of motion, the thickness of the muscle and the contraction ratio during respiration (18).

In previous studies, linear transducer with 8-13 MHz was used to study the diaphragm muscle. In this method, the patient lies\ in supine position and the placement of the transducer is below the lower costal margin along the anterior axillary line of the chest. Diaphragm image on the monitor showed that when the probe was vertically placed between two ribs, it was surrounded by two hyperechoic layers of connective tissue (the parietal pleura and the peritoneum).

Diaphragm thickness is determined by measuring the distance between two layers by the cursor at the end of expiration or functional residual capacity, and maximal inspiration or total lung capacity. By dividing the average of these two values, the thickness ratio of the diaphragm is obtained. This value for average thickness of diaphragm at the end of the expiration is higher than 0.14 and for the ratio of the thickness is higher than 1.2 in healthy individuals.

M mode

The images displayed by m-mode have both the time axis (x) and the depth axis (y) that show the thickness change or depth of structure over the time that is why it has been called "time-motion" mode (8).

Research and clinical application of this technique can help therapists understand chronic dysfunction better. Investigation of the onset of lumbar multifidus contraction during various events such as, lower extremity movement (20), functional assessment of the lateral abdominal wall (21), paraspinal (22) and pelvic floor (13) muscles in the chronic disorders has been done by m-mode ultrasound imaging.

Instrumentations

An ultrasound machine generates a batch of short waves with regular intervals and it consists of 2 components: probe or transducer and imaging system (8). Probe is responsible for making ultrasound waves and converting them into electrical signals once they return from the tissue.

Crystal or piezoelectric transducer elements made of ceramic formulations, zirconium, and titanium change their shape because of the pressure by sound waves, and produce electrical energy. The arrangement, the frequency of the crystal elements and the width of the field of vision (in metric) produced are used to describe a transducer (10). The arrangement, or array of the elements within a transducer can be linear or curved (also referred to as "curvilinear"). The linear transducer is appropriate for imaging small superficial structures whereas the curvilinear transducer is valuable for deep structures (10). Imaging system receives electrical signals from probe as echo then analyzes them so that they can be seen as a digital image. Imaging system consists of 4 components: the beam former, signal processor, image processor and visual display (10). The beam former is responsible for the production of the electrical impulses which reach the probe. It also amplify and digitalize the electrical signals returning from the probe which are called echo ultrasound. The signal processor is responsible for filtering and compressing the electrical signal and the image processor converts them into the image then visual display shows them as the image (10).

Reliability of rehabilitative ultrasound imaging

Several investigations have been done to study the reliability of rehabilitative ultrasound imaging. In those studies, several muscles with various parameters were evaluated. (23-25 Generally, these investigations concluded that rehabilitative ultrasound imaging was reproducible tool for measuring muscle morphometry. Some of them reported that measuring thickness had moderate to high reliability, and its reliability to measure the thickness change, was poor to good (16, 26).

It should be noted that there are several factors, like reliability depends on tools, testing equipment, inclusion criteria of study, data analysis process and performer experience which can easily affect the reliability of the method; therefore, it is suggested that before data collecting, the reliability of ultrasound imaging be examined.

Conclusion

According to the available evidence, ultrasound imaging is a valuable tool in the field of rehabilitation which can provide reliable and repeatable information about muscle morphometry and function. There are questions that still remain unanswered and further research should be carried out have relevant information collected. The data taken by ultrasound imaging should be expounded with consideration, but as it was discussed previously ultrasound imaging as an efficient tool, has potential to be used as a needed tool in the rehabilitation.

Acknowledgments:
None

Conflict of interest:
None

Funding support:
This project had no external funding, and no financial or other relationships pose a conflict of interest

Authors' contributions:
All authors made substantial contributions to conception, design, acquisition, analysis and interpretation of data.

References

1. Ikai M, Fukunaga T. Calculation of muscle strength per unit cross-sectional area of human muscle by means of ultrasonic measurement. Internationale Zeitschrift für Angewandte Physiologie Einschliesslich Arbeitsphysiologie. 1968;26(1):26-32.
2. Bernstein I, Juul N, Grønvall S, Bonde B, Klarskov P. Pelvic floor muscle thickness measured by perineal ultrasonography. Scandinavian journal of urology and nephrology Supplementum. 1990;137:131-3.
3. Raadsheer M, Van Eijden T, Van Spronsen P, Van Ginkel F, Kiliaridis S, Prahl-Andersen B. A comparison of human masseter muscle thickness measured by ultrasonography and magnetic resonance imaging. Archives of oral biology. 1994;39(12):1079-84.
4. Hides JA, Cooper DH, Stokes MJ. Diagnostic ultrasound imaging for measurement of the lumbar multifidus muscle in normal young adults. Physiotherapy Theory and Practice. 1992;8(1):19-26.
5. Hides JA, Richardson CA, Jull GA. Magnetic Resonance Imaging and Ultrasonography of the Lumbar Multifidus Muscle: Comparison of Two Different Modalities. Spine. 1995;20(1):54-8.
6. Teyhen DS. Rehabilitative ultrasound imaging for assessment and treatment of musculoskeletal conditions. Manual therapy. 2011;16(1):44-5.
7. Teyhen D. Rehabilitative Ultrasound Imaging Symposium, May 8-10, 2006, San Antonio, Texas. Journal of Orthopaedic & Sports Physical Therapy. 2006;36(8):A-1-A-17.
8. Whittaker JL, Teyhen DS, Elliott JM, Cook K, Langevin HM, Dahl HH, et al. Rehabilitative ultrasound imaging: understanding the technology and its applications. journal of orthopaedic & sports physical therapy. 2007;37(8):434-49.
9. Kremkau F. Diagnostic ultrasound: Principles and instruments WB Saunders Company. Philadelphia, PA. 2002.

10. Kremkau FW. Diagnostic ultrasound: principles and instruments: WB Saunders Company; 2001.
11. Van Holsbeeck M, Introcaso J. Sonography of muscle. Musculoskeletal ultrasound. 2001;2:23-75.
12. Whittaker JL, Stokes M. Ultrasound imaging and muscle function. Journal of Orthopaedic & Sports Physical Therapy. 2011;41(8):572-80.
13. Thompson JA, O'Sullivan PB, Briffa K, Neumann P. Assessment of pelvic floor movement using transabdominal and transperineal ultrasound. International Urogynecology Journal. 2005;16(4):285-92.
14. Reddy AP, DeLancey JO, Zwica LM, Ashton-Miller JA. On-screen vector-based ultrasound assessment of vesical neck movement. American journal of obstetrics and gynecology. 2001;185(1):65-70.
15. Peng Q, Jones RC, Constantinou CE. 2D Ultrasound image processing in identifying responses of urogenital structures to pelvic floor muscle activity. Annals of biomedical engineering. 2006;34(3):477-93.
16. Hodges PW. Ultrasound imaging in rehabilitation: just a fad? Journal of Orthopaedic & Sports Physical Therapy. 2005;35(6):333-7.
17. Strobel K, Hodler J, Meyer DC, Pfirrmann CW, Pirkl C, Zanetti M. Fatty Atrophy of Supraspinatus and Infraspinatus Muscles: Accuracy of US 1. Radiology. 2005;237(2):584-9.
18. Baria MR, Shahgholi L, Sorenson EJ, Harper CJ, Lim KG, Strommen JA, et al. B-mode ultrasound assessment of diaphragm structure and function in patients with COPD. CHEST Journal. 2014;146(3):680-5.
19. Boon AJ, Harper CJ, Ghahfarokhi LS, Strommen JA, Watson JC, Sorenson EJ. Two-dimensional ultrasound imaging of the diaphragm: Quantitative values in normal subjects. Muscle & nerve. 2013;47(6):884-9.
20. Vasseljen O, Dahl HH, Mork PJ, Torp HG. Muscle activity onset in the lumbar multifidus muscle recorded simultaneously by ultrasound imaging and intramuscular electromyography. Clinical biomechanics. 2006;21(9):905-13.
21. Bunce SM, Hough AD, Moore AP. Measurement of abdominal muscle thickness using M-mode ultrasound imaging during functional activities. Manual therapy. 2004;9(1):41-4.
22. Campbell WW, Vasconcelos O, Laine FJ. Focal atrophy of the multifidus muscle in lumbosacral radiculopathy. Muscle & nerve. 1998;21(10):1350-3.
23. Jhu J-L, Chai H-M, Jan M-H, Wang C-L, Shau Y-W, Wang S-F. Reliability and relationship between 2 measurements of transversus abdominis dimension taken during an abdominal drawing-in maneuver using a novel approach of ultrasound imaging. journal of orthopaedic & sports physical therapy. 2010;40(12):826-32.
24. Koppenhaver SL, Hebert JJ, Fritz JM, Parent EC, Teyhen DS, Magel JS. Reliability of rehabilitative ultrasound imaging of the transversus abdominis and lumbar multifidus muscles. Archives of physical medicine and rehabilitation. 2009;90(1):87-94.
25. Liaw L, Liu S, Hsiao S. The reliability of measuring of inter-recti distance using real-time ultrasonography. Formosan J Phys Ther. 2006;31:213-8.
26. Sofka CM. A Systemic Review of the Reliability of Rehabilitative Ultrasound Imaging for the Quantitative Assessment of the Abdominal and Lumbar Trunk Muscles. Ultrasound Quarterly. 2010;26(2):115.