Electronic Physician (ISSN: 2008-5842) http://www.ephysician.ir
July 2018, Volume: 10, Issue: 7, Pages: 7095-7100, DOI: http://dx.doi.org/10.19082/7095

Comparing the image quality of tissue harmonic and conventional B-mode ultrasound of kidney in over-obese individuals

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Type of article: Original

Abstract

Background: Increased subcutaneous fat thickness and depth of target organs in over-obese patients, results in weak signals and inadequate images. Tissue harmonic imaging has been used widely in obese patients and is believed to result in higher quality images. This superiority is not proved in modern machines with improved image quality in conventional mode.
Objective: To compare the image quality between conventional and tissue harmonic ultrasound images.
Methods: This cross-sectional study was carried out from March 2015 to June 2016. Seventy-six over-obese patients referred to Ghaem Hospital (Mashhad, Iran) for weight-correction surgeries, were enrolled into the study. Conventional and tissue harmonic images of their kidneys were blinded and compared back-to-back by four expert radiologists. Data were analyzed by SPSS version 16, using Cochrane's Q test.
Results: All raters reported image quality to be better in tissue harmonic compared to fundamental frequency ultrasound (p=0.000, Cochrane's Q test). Although better image quality in tissue harmonic mode was reported by the four raters, there was weak inter-observer agreement (p=0.081 for right kidney and p=0.21 for left kidney).
Conclusion: Advances in ultrasound equipment and the introduction of tissue harmonic imaging can improve the diagnostic performance in over-obese patients and this mode of imaging should be used whenever evaluating over-obese subjects.
Keywords: Ultrasonography, Image enhancement, Diagnostic imaging

1. Introduction

1.1. Obesity

The mounting wave of obesity in the world has imposed a great burden on population health issues and healthcare costs (1, 2). The Islamic Republic of Iran has not been an exception and we have seen considerable increase in the prevalence of obesity in recent years (3). Obesity is defined as body mass index (BMI) equal or greater than 30. It is classified into three classes; Class I is defined as BMI 30-34.9, class II is defined as BMI 35-39.9 and class III is defined as BMI equal or greater than 40 (4). Degree of accumulated body fat is proportionally related to the BMI and obesity class, and so is the thickness of subcutaneous fat.

1.2. Obesity and ultrasound

Acquiring high-quality ultrasound images has always been a matter of importance for sonographers. Many factors including operators' experience, device quality and patient body habitus are involved in obtaining optimal images. Obesity is one of the great obstacles in obtaining optimal images, and the increased prevalence of obesity has

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Received: April 28, 2017, Accepted: February 16, 2018, Published: July 2018
iThenticate screening: February 17, 2018, English editing: March 11, 2018, Quality control: May 14, 2018
This article has been reviewed / commented by three experts

exaggerated this problem. It is a rising concern for radiologists to be familiar with the most suitable methods of imaging in obese patients and provide the most accurate diagnostic evaluation.

1.3. Tissue harmonic imaging

Sound beam attenuation in fatty tissue is directly proportional to the product of transducer frequency by subcutaneous fat thickness (5). For example, sound beam is approximately 94% attenuated while imaging through a 7-cm subcutaneous tissue using a 7 MHz transducer (5). Tissue harmonic imaging (THI) was introduced into radiology in 1998 and soon found its credit as an adjunct technique that increased image quality and provided better tissue differentiation. The fundamental of this imaging technique is to receive ultrasound beams with frequencies which are integer multiples of the frequency of the transmitted beams that are called harmonics (6). For example, when an ultrasound device emits sound beams with the frequency of 2 MHz, the harmonics are beams with frequencies of 4 MHz, 6 MHz, 8 MHz, etc. Harmonics are produced by the tissue itself as the result of slight beam distortions that occur when the sound propagates in the tissue. In fundamental frequency ultrasound (FFU), beams received by the transducer have the same frequency as the emitted beams, while in the THI, the first harmonics (4 MHz beams in the example) are used to produce tissue harmonic images (7). Tissue harmonics are virtually absent at the skin surface and their production increases in deeper tissues (7). This increase in harmonics in deeper tissues is confronted by the fact that ultrasound beams with higher frequencies have less penetration, so harmonics from very deep tissues may not reach the transducer. So, the tissue harmonic effect increases to a certain depth and then starts to decrease gradually. This is a completely different behavior in comparison to FFU in which the beam energy decreased linearly with increased depth (8, 9). THI is an ultrasound innovation that prevents such noise in deep tissues (6). This mode of imaging was discovered accidentally while scientists were producing microbubbles as contrast material for echocardiography. They noticed that there were ultrasound beams reflected from the tissue whose frequencies were multiples of the frequency of the emitted beam. This phenomenon has since been called tissue harmonic, and harmonic beams refer to those with frequencies multiples of the frequency of the emitted beams (10). Sound beam has a higher propagation speed while passing compressed tissues. A transducer that is emitting 3 MHz ultrasound beam, actually emits a spectrum of beams with frequencies that are slightly different and located in near 3MHz of frequency. Harmonic beams are integer multiples of fundamental beam, in this case, centered at 6 MHz, 9 MHz, 12 MHz, etc., and are produced while the emitted beam passes various body tissues. In modern ultrasound machines, the receiver transducer can be set as to receive only harmonic beams (11) and this mode of imaging is called tissue harmonic imaging. Since its introduction to radiology, tissue harmonic imaging has been known to improve ultrasound quality in various conditions. Theoretical benefits of this imaging mode include better axial resolution, better lateral resolution and decreased noise (8). The advent of modern ultrasound utilities provides the radiologists with higher frequencies, deeper penetrations, better image resolutions and improved overall image qualities. As there are shortcomings in THI - the most significant of them being decreased depth of imaging, as explained earlier - diagnostic ultrasound may have reached a point in which the costs outweigh the benefits and there is no significant image improvement. This is particularly important in over-obese patients in whom the increased tissue depth may cause a significant decrease in image quality and the costs may finally outweigh the benefits of tissue harmonic imaging. This raises a dilemma about routine use of tissue harmonic imaging in this population. Although it has been suggested to decrease phase aberration and improve visualization of deep tissues in obese patients, the limited penetration may cause image degradation in deep tissues in over-obese patients and mask possible pathologies. And so comes the question of “whether THI in modern ultrasound equipment still increases the image quality in over-obese patients“. We designed a study to compare the image quality of THI with FFU in over-obese patients.

2. Material and Methods

2.1. Study design

This was a cross-sectional study performed on 76 over-obese patients referred for bariatric surgery from March 2015 to June 2016 (a 15-month period) to Ghaem Hospital, Mashhad, Iran, which is a tertiary and educational hospital affiliated with Mashhad University of Medical Sciences. The ultrasound images of both kidneys were acquired and optimized in both modes and from the same anatomic areas and same plane and orientation for each kidney. They were then blinded and compared side by side by four expert radiologists in the research team. The radiologists were asked to choose which of the two images had the best overall quality. Ultrasound examinations were performed using Medison™ V8 Device (curve 2-7 MHz transducer). In the FFU, 3.5 MHz beams were transmitted and received, while in THI, 2 MHZ beams were transmitted and 4 MHz beams were received. While performing the examination, our colleague operator chose the best possible setting for each patient and saved the images on the device. The research team spent two weeks on preparing, optimizing and blinding the images. The images were processed to have the same exposure levels. We did not change the contrast level of the images in order to avoid affecting the image quality inherent to the mode of imaging. All the images were recorded with the following standards: The sagittal image of each kidney was recorded so that the largest possible long axis diameter of the kidney is in the image and constitutes at least 70% of the all-field diameter. The echogenic renal sinus was visible in all images.

2.2. Patient selection

The over-obese patients who were candidates for bariatric surgeries referred to Ghaem Hospital, (Mashhad, Iran) for the routine preoperative ultrasound examination were evaluated with conventional and tissue harmonic imaging. The over-obesity was defined as body mass index of 35 or more. Before entering the study, the process was explained to the patients. We explained to the patients that ultrasound examination did not involve any ionization radiation and if they consented to the study, they would spend on average, fifteen extra minutes in the radiology department. Written consent was obtained before enrolling respective patients on the study.

2.3. Data collection

Four national board-certificate radiologists, each with at least fifteen years of experience in ultrasonography performed image comparison. We asked them to compare two blinded images obtained from the same anatomic location and with same angle and orientation side by side, and determine the better image regarding overall quality. Figure 1 shows a sample of coronal sonographic image of right kidney.

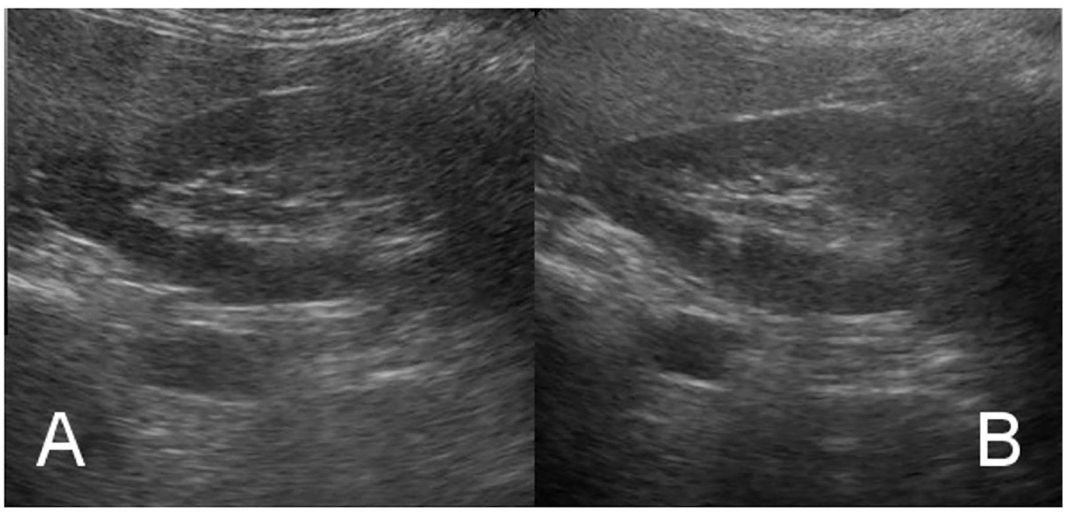

Figure 1. A sample of coronal sonographic image of right kidney paired in two boxes. As the image shows, all the markers were removed and the image parameters were adjusted.

2.4. Statistical analysis

The statistical software SPSS version 16 (SPSS Inc., Chicago, Illinois, USA) was used for data analysis. Cochrane's Q test was used to evaluate rater's opinion about the better mode of imaging. Krippendorff's Alpha and Fleiss' Kappa tests were used to determine inter-observer agreement between the raters in subjective evaluation of overall image quality.

3. Results

3.1. Demography

We evaluated 76 over-obese and otherwise healthy subjects that were candidates for bariatric surgery. As right and left kidneys were evaluated separately, we had 152 pairs of images that were compared subjectively. The mean weight of the patients was 117.60 kg (±23.16) and the mean body mass index was 43.34 (±6.22). Fourteen (18.4%) males and 62 (81.6%) females were enrolled in the study.

3.2. Raters' evaluation of the images

In total, 152 pairs of images were evaluated by four readers. All raters rated tissue harmonic imaging as the modality with better overall image quality (p=0.000, Cochrane's Q test). The level of agreement between each pair of readers was evaluated using Cohen's Kappa test. For this purpose, the rater's opinion about the tissue harmonic imaging was first categorized into a dichotomous variable with the mutually exclusive categories of "tissue harmonic had better image quality" or "tissue harmonic did not have better quality". The one by one comparison of raters' opinions is summarized in Table 1. Krippendorff's Alpha and Fleiss' Kappa tests were used to evaluate inter-observer agreement. The alpha value for inter-observer agreement was 0.081 for right kidney, which is a slight agreement and 0.2 for left kidney, which is a fair agreement. The results are summarized in Table 2.

Table 1. Average pairwise inter-reader agreement in image quality of THI and FFU images of left and right kidneys

Variables		Right kidney (n=76)	Left kidney (n=76)
Average pairwise agreement (%)	Rater 1 & 4	64.47	51.30
	Rater 1 & 3	60.50	60.52
	Rater 1 & 2	68.40	63.15
	Rater 2 & 4	82.89	80.26
	Rater 2 & 3	86.84	76.30
	Rater 3 & 4	82.89	75.00

Table 2. Comparison between THI and FFU for overall image quality in renal ultrasound of over-obese patients.

Location	Observers' opinion (% of THI images chosen as better quality images)				Observers' agreement	
	Observer #1	Observer #2	Observer #3	Observer #4	Krippendorff's Alpha	Fleiss' Kappa
Right kidney	64.50	90.80	88.10	73.70	0.084	0.081
Left kidney	61.8	65.8	57.9	72.4	0.202	0.200

4. Discussion

4.1. Effect of obesity on image quality

The mounting wave of obesity in the world has imposed a great burden on the population health of imaging. Increased subcutaneous fat increases patient's radiation dose in both radiography and CT scan (5). MRI image quality is also impaired in obese patients. Obesity is a great barrier against ultrasound image quality, which decreases significantly in deep tissues and thick subcutaneous fat in over-obese patients and hampers proper evaluation of deeply located organs like kidneys. Thus, having a tool to enhance visualization of the kidneys and other deeply located structures must be considered as great importance. THI is a modality that is suggested as a probable solution to improve image quality in over-obese patients (5).

4.2. Tissue harmonic imaging

There is a slight difference of sound propagation speed in different body tissues. This difference results in a phenomenon called phase aberration that causes sound beam distortion and noise. The slight distortion of noise creates harmonic frequencies not present in the initial wave (12) and is the basis for THI. THI is believed to reduce the adverse effect of fatty tissue on image quality, and has been proposed to yield higher quality images in obese patients (5). Many modern ultrasound machines are now equipped with tissue harmonic enabled transducers and this mode of imaging is now automatically activated in some company-defined ultrasound programs. It is suggested that this imaging mode can increase image quality in patients with a body mass index over 30. There are also some limitations in this imaging mode, the most important of them being less penetration and more tissue shadowing. Both these shortcomings can have a bad influence on visibility of deeply located tissues in obese patients (8). Many studies have reported better performance of tissue harmonic ultrasound on image quality and lesion conspicuity in comparison to conventional ultrasound in both adult and pediatric patients (6, 8, 13-15), but there are only a few studies that have evaluated image quality of tissue harmonic imaging in comparison to conventional ultrasound in obese patients (6, 7, 13, 16), all of which suggested better image quality in THI. THI has been suggested to be used in obese pregnant women for fetal echocardiography (7), evaluating abdominal disease in obese patients (6), breast ultrasound (13) and trauma patients (16). According to the tremendous rate of improvement in ultrasound devices and with introduction of modern high-tech, high-quality machines, it seems necessary to re-evaluate the visibility of real lesions on tissue harmonic imaging in comparison with conventional high-tech B-mode ultrasound images. The results of the present study showed the better overall image quality of THI than FFU ultrasound. THI overall image quality was preferred to FFU image quality in most (61.3%) over-obese patients. More intense tissue harmonic beams are generated in body tissues containing higher proportions of fat. This is due to the highest nonlinearity coefficient in fat tissue and may explain the better image quality of THI in over-obese patients in comparison to

FFU. Generation of tissue harmonic beams results in beams that are less attenuated or distorted in the fat containing body wall of over-obese subjects. This demonstrates that THI can be useful in evaluating over-obese patients.

4.3. Study limitations
Although all raters assessed the THI as the superior imaging mode, the inter-raters' agreement was poor. This may be due to complex interaction of multiple factors that are collectively interpreted by one's mind. Although the purpose of the study was to evaluate the overall image quality in THI, the lack of individual objective items might be considered as a study limitation. We should also mention that although the raters were blind to the imaging mode, they were all experienced radiologists and although we equalized the pairs in terms of background brightness, they may have been able to guess the rougher texture of THI in comparison to FFU.

5. Conclusions
This study showed that although there was not inter-rater agreement, the overall image quality of kidney ultrasound images was evaluated to be better with THI in comparison to FFU in over-obese patients. We conclude that advance in ultrasound equipment and the introduction of tissue harmonic imaging can improve the diagnostic performance in over-obese patients, and this mode of imaging should be used whenever evaluating over-obese subjects. Conducting a study for objective evaluation of image resolution in different depths of tissue in over-obese patients can be helpful in delineating the exact reliability of THI in this population.

Acknowledgments:
This research was supported by the Chancellor for Research of Mashhad University of Medical Sciences, Mashhad, Iran.

Conflict of Interest:
There is no conflict of interest to be declared.

Authors' contributions:
All authors contributed to this project and article equally. All authors read and approved the final manuscript.

References:
1) WHO. Obesity and overweight. WHO. 2018. Available from: www.who.int/mediacentre/factsheets/fs311/en/.
2) Choi YS, Berry-Caban C, Stratman R, Fleming JH. Prevalence of high body mass index among children and adolescents at a US military treatment facility, 2008-2009. Prev Chronic Dis. 2012; 9: E166. doi: 10.5888/pcd9.120051. PMID: 23153773, PMCID: PMC3505115.
3) Bahrami H, Sadatsafavi M, Pourshams A, Kamangar F, Nouraei M, Semnani S, et al. Obesity and hypertension in an Iranian cohort study; Iranian women experience higher rates of obesity and hypertension than American women. BMC Public Health. 2006; 6: 158. doi: 10.1186/1471-2458-6-158. PMID: 16784543.
4) WHO. Global Database on Body Mass Index. 2015. Available from: http://apps.who.int/bmi/index.jsp?introPage=intro_3.html&.
5) Modica MJ, Kanal KM, Gunn ML. The obese emergency patient: imaging challenges and solutions. Radiographics. Radiographics. 2011; 31(3): 811-23. doi: 10.1148/rg.313105138. PMID: 21571658.
6) Choudhry S, Gorman B, Charboneau JW, Tradup DJ, Beck RJ, Kofler JM, et al. Comparison of tissue harmonic imaging with conventional US in abdominal disease. Radiographics. 2000; 20(4): 1127-35. doi: 10.1148/radiographics.20.4.g00jl371127. PMID: 10903701.
7) Paladini D, Vassallo M, Tartaglione A, Lapadula C, Martinelli P. The role of tissue harmonic imaging in fetal echocardiography. Ultrasound Obstet Gynecol. 2004; 23(2): 159-64. doi: 10.1002/uog.962. PMID: 14770397.
8) Shapiro RS, Wagreich J, Parsons RB, Stancato-Pasik A, Yeh HC, Lao R. Tissue harmonic imaging sonography: evaluation of image quality compared with conventional sonography. AJR Am J Roentgenol. 1998; 171(5): 1203-6. doi: 10.2214/ajr.171.5.9798848. PMID: 9798848.
9) Tranquart F, Grenier N, Eder V, Pourcelot L. Clinical use of ultrasound tissue harmonic imaging. Ultrasound Med Biol. 1999; 25(6): 889-94. PMID: 10461715.
10) Uppal T. Tissue harmonic imaging. Australas J Ultrasound Med. 2010; 13(2): 29-31. doi: 10.1002/j.2205-0140.2010.tb00155.x. PMID: 28191082, PMCID: PMC5024862.

11) Kollmann C. New sonographic techniques for harmonic imaging--underlying physical principles. Eur J Radiol. 2007; 64(2): 164-72. doi: 10.1016/j.ejrad.2007.07.024. PMID: 17875378.
12) Paladini D. Sonography in obese and overweight pregnant women: clinical, medicolegal and technical issues. Ultrasound Obstet Gynecol. 2009; 33(6): 720-9. doi: 10.1002/uog.6393. PMID: 19479683.
13) Szopinski KT, Pajk AM, Wysocki M, Amy D, Szopinska M, Jakubowski W. Tissue harmonic imaging: utility in breast sonography. J Ultrasound Med. 2003; 22(5): 479-87. PMID: 12751859.
14) Ranga U, Kalra N, Saxena AK, Bhatia A, Sandhu MS, Duseja AK, et al. Focal hepatic lesions characterisation by different sonographic techniques: a prospective analysis. J Ultrasound. 2015; 19(1): 15-23. doi: 10.1007/s40477-015-0172-3. PMID: 26941878, PMCID: PMC4762844.
15) Bartram U, Darge K. Harmonic versus conventional ultrasound imaging of the urinary tract in children. Pediatr Radiol. 2005; 35(7): 655-60. doi: 10.1007/s00247-005-1415-9. PMID: 15750811.
16) Blaivas M, DeBehnke D, Sierzenski PR, Phelan MB. Tissue harmonic imaging improves organ visualization in trauma ultrasound when compared with standard ultrasound mode. Acad Emerg Med. 2002; 9(1): 48-53. PMID: 11772669.