Role of tissue harmonic imaging in abdominal masses

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Learning objectives

A prospective study was performed on 200 patients to compare the image quality of tissue harmonic sonography with conventional sonography. Each examination was performed using THI sonography (transmitted frequency, 2.0 MHz; received frequency, 4.0 MHz) and conventional sonography at 3.5 and 4.0 MHz. Lesions visibility were compared on four parameters—margins, acoustic enhancement, acoustic shadowing and reverberation artifacts.
Background

In early 1990s P. Ted Christopher, at University of Rochester's Centre for Biomedical Ultrasound in New York developed tissue harmonic imaging technique.

Tissue harmonic imaging (THI) is a new grayscale ultrasound mode that can provide images of higher quality than conventional sonography by using information from harmonics. Harmonics are produced by tissue vibration and are usually integral multiples of the transmitted frequency. In conventional grayscale sonography, the same frequency spectrum that is transmitted into the patient is subsequently received to produce the sonographic image. But in tissue harmonic imaging, the higher harmonics frequencies (multiples) generated by the propagation of the ultrasound beam through the tissues are used to produce the image.

Tissues harmonic imaging has a huge potential for improving image quality because it:

Improves
1) Lateral resolution,
2) Signal to noise
3) Acoustic enhancement

Reduces
1) Reverberation artifacts
2) Side lobe artifacts
3) Near field artifacts

As the ultrasound waves propagate through the tissue, there is non linearities in sound propagation, that gradually change the shape of wave, a change in the shape results in the development of harmonic frequencies with harmonic imaging. The waves. There are no harmonic frequencies present at the transducer face. They develop gradually as the wave propagates through tissue and so in the near field there is very little harmonic energy available for reflection from tissue. Since the near field is a source of much of the artifact in ultrasonography image, selective display of harmonic energy will show dramatically less near field artifact.

Frequency spectrum of the transmitted and received waves. The fundamental wave (f) is generated at the transducer surface and attenuates linearly as it is transmitted through the body. The harmonic wave (2f) is generated as the fundamental wave travels through the
body. The harmonic wave increases exponentially in intensity before attenuating within the deeper tissues. Harmonic imaging uses only the harmonic frequency in the echo signal received by filtering out the transmitted frequency spectrum in the signal.¹

Sonography is generally considered the initial technique of choice for the evaluation of abdominal lesions. However, conventional sonography often displays image artifacts that limits diagnostic accuracy. Tissue harmonic sonography is a new mode with potential advantages over conventional sonography, including the elimination of unwanted artifacts. Tissue harmonic sonography technique is based on the nonlinear interaction of an acoustic signal as it propagates through the body. In conventional sonography, echoes are transmitted and received at the same frequency, whereas harmonic sonography uses only the second harmonic frequency for imaging. The current technology uses the second harmonic, which is twice the transmitted frequency, because the higher harmonic necessitates extremely wide bandwidth transducers⁵.

In this prospective study, conventional sonography was compared with tissue harmonic sonography of various abdominal lesions and it was explored that whether theoretical advantages of tissue harmonic sonography improved diagnostic image quality.²⁰⁰ abdominal lesions were evaluated. Tissue harmonic sonography of each lesion was compared with conventional sonography. Of the 200 lesions, 22 (11%) were in the liver, 62 (31%) in the kidneys, 68(34%) in the gallbladder and 48 (24%) in the uterus and ovary. Lesions were classified into two groups based on their sonographic characteristics regardless of the organ of involvement: cystic and solid. Lesions visibility was compared on following parameters-margins, acoustic enhancement or acoustic shadowing and reverberatory artifacts. The margins in both solids and cystic lesions were compared for their distinctness or indistinctness. Acoustic enhancement in cystic lesions and acoustic shadowing in solids like calculus were compared whether good or poor. Reverberatory artifacts in both solids and cystic lesions were compared whether distinguished or undistinguished.

As in previous study done by Shapiro etal in 1998² to compare Tissue Harmonic sonography with conventional sonography in abdominal lesions, have shown that harmonic imaging was superior to conventional imaging with regard to lesion visibility and depicting their margins. This was also proved in our study where tissue harmonic sonography improves lesion margins (p<0.001) over conventional sonography in most of the abdominal lesions both solid and cystic. This is because tissue harmonic creates images that are derived solely from the higher frequency, which is produced when the ultrasound pulse passes through tissues within the body. Tissue harmonics uses various techniques to eliminate the echoes arising from the main transmitted ultrasound beam ("the fundamental frequencies"), from which conventional images are made. Once the fundamental frequencies are eliminated, only the harmonic frequencies are left for image formation. Indeed, the quality of the harmonic image is primarily dependent on
the complete elimination of all echoes derived from the transmitted frequencies. The region of maximal production of harmonics is at the focal zone, because beam intensity is highest at that location. Little or no harmonics are produced by weak waves, such as side lobes, grating lobes, scattered echoes, and at the edges of the main ultrasound beam. As a result, beams formed from tissue harmonic signals have less side lobes, less noise, and improved contrast resolution. But the role of tissue harmonic sonography over conventional sonography in improvement of margins of uterus and ovary lesions is not much in both solid (p=0.115) and cystic lesions (p=0.155). This is because with tissue harmonic sonography penetration decreases. This was also proved in a study done by Oktar et al in 2003.

Tissue Harmonic sonography is necessary for the evaluation of posterior echo pattern. Central acoustic enhancement is a useful sonographic artifact in lesion recognition and conspicuity. It was shown that acoustic enhancement from cystic lesions were better detected in harmonic mode than in conventional mode in a study done by Oktar et al in 2003. In our study, for overall cystic lesions (renal, liver and ovary cysts), tissue harmonic sonography (p < 0.001) is better than conventional sonography. Also in individual organs, in case of ovaries (p=0.00118), liver cyst (p=0.0259) and renal cyst (p<0.001) tissue harmonic sonography improves visualization of acoustic enhancement in all cystic lesions but is more useful in renal and hepatic cysts.

In our study, for solid lesions like renal stones and biliary stones tissue harmonic sonography (p < 0.001) is better than conventional sonography. This was also proved in a study separately done by Yucel et al in 2003 and Dresser et al in 1998, on abdominal and pelvic lesions comparing conventional gray scale imaging with tissue harmonic imaging mode. This may be related to the higher receiving frequency and narrower dynamic range used in tissue harmonic sonography compared to conventional sonography. Because tissue harmonic sonography is efficient for evaluation of posterior echo pattern, it can be used as a complementary imaging method for calculus or cystic lesions to conventional sonography.

Tissue harmonic sonography also makes it easier to observe cystic lesions of the abdominal region, decreasing artifactual echoes in cysts which improves the solid-cystic differentiation of the lesion and changes the final assessment. Reducing reverberatory artifacts in Tissue Harmonic sonography substantially eliminates artifacts in liquid cavities, which appear much darker and cleaner on images. This is also proved in our study where Tissue Harmonic sonography overall reduces reverberatory artifacts in abdominal lesions (p<0.001). Elimination of reverberatory artifacts in case of overall solid lesion in abdomen with tissue harmonic sonography (p<0.001) is marked where as in gall bladder growth (p=0.142) and renal calculus (P=0.105) (solid lesions) on tissue harmonic sonography reduction in reverberatory artifacts is less pronounced compared to other abdominal solid lesions. True echoes from debris in complex cysts are more conspicuous on Tissue Harmonic sonography because of reduced artifacts, and therefore, confidence in diagnosis increases. The harmonic band is generated by tissue itself, harmonics do
not develop in the first few centimeters, but many artifacts do. In particular, multiple reverberations between the transducer and the body wall layers cast a 'haze' that overlays the image. Because in reality these artifacts are mis-registered echoes from the near field, they do not contain harmonics and disappear in the tissue harmonic image. As a result, tissue harmonic sonography contains minimal noise and successfully eliminates some image-degrading artifacts such as reverberation. The resultant image is clearer and relatively free of artifacts compared with the fundamental image.

The limitation of our study is that tissue harmonic images have somewhat less penetration than those produced by conventional sonography. So gain was not same in both modes. Most of the times, it was increased in cases of tissue harmonic mode. Second study of this type is necessarily limited by the subjective nature of evaluations. Thirdly this type of study is also affected by different body habitus of the patients.

In conclusion, Combining tissue harmonic sonography with conventional sonography improves overall image quality, lesion conspicuity, posterior echo pattern and eliminates unwanted artifacts especially in abdominal lesions over pelvic lesions and therefore produces the best results in abdominal lesion scanning.
Imaging findings OR Procedure details

The sonographic evaluation was carried out using real time scanner Philips Evisor C. with multifrequency transducer and tissue harmonic imaging mode. Examinations were carried out with the patient in supine position and after a minimal of 8 hours overnight fasting to avoid any effect of meal and posture on abdominal organs. Tissue harmonic imaging study was conducted in same sitting on same real time scanner with same frequency transducer. The sonographer obtained similar views of abdominal lesions with both harmonic imaging and conventional US.

Harmonic images were acquired at a transmitting frequency of 2.0 MHz and a receiving harmonic bandwidth of 4.0 MHz. Conventional US images were obtained at a frequency of 3.5 MHz, which is a frequency used commonly at abdominal imaging in adults.
Fig. 0: Sonographic image showing comparison of margins and acoustic shadowing in case of gallbladder calculus on tissue harmonic sonographic image left side (THI) with conventional sonographic (2D) right side, showing improvement in both margins and acoustic shadowing in harmonic image.

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**Fig. 0:** Sonographic image showing comparison of margins and reverberatory artifacts in case of liver mass on tissue harmonic image on right side with conventional sonographic image on left side showing improvement in margins of mass with reduction of reverberatory artifacts on harmonic image.

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Fig. 0: Sonographic image showing comparison of margins, reverberatory artifacts and acoustic enhancement in case of right lobe of liver cysts on tissue harmonic sonographic image (THI) right side with conventional sonographic image left side (2D) showing improvement in margins but not in acoustic enhancement and reverberatory artifacts of cyst in harmonic image on right side.

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**Fig. 0:** Sonographic image showing comparison of margins, reverberatory artifacts and acoustic enhancement (AE) in Hepatic cyst on tissue harmonic image (THI) right side with conventional sonographic image left side (B-MODE) showing improvement in margins but no improvement in acoustic enhancement of cyst with reduction of reverberatory artifacts on harmonic image.

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Conclusion

Of the 200 lesions, 22 (11%) were in the liver, 62 (31%) in the kidneys, 68 (34%) in the gallbladder and 48 (24%) in the uterus and ovary. Lesions were classified into two groups based on their sonographic characteristics regardless of the organ of involvement: cystic and solid.

Tissue harmonic sonography improves lesion margins (p<0.001), posterior echo pattern (p < 0.001) over conventional sonography in most of the abdominal lesions. Tissue Harmonic sonography overall reduces reverberation artifacts in abdominal lesions (p<0.001). Improvement of margins of uterus and ovary lesions is not much in both solid (p=0.115) and cystic lesions (p=0.155).

Combining tissue harmonic sonography with conventional sonography improves overall image quality, lesion conspicuity, posterior echo pattern and eliminates unwanted artifacts especially in abdominal lesions over pelvic lesions and therefore produces excellent results in diagnosis of abdominal lesions.
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