Significance and Advancement of Ultrasonography in obese people
Kush Tripathi and Krishnan Balasubramanium

1Centre for Non-destructive Evaluation and Department of Mechanical Engineering
Indian Institute of Technology, Madras, Chennai-600036, India

Kushtripathi20006@gmail.com

Abstract
In India, obesity is increasing at an alarming rate especially in urban areas. Obesity primarily increases the risks for coronary heart diseases, calculi in liver and gall bladder and reproductive health diseases. These diseases are diagnostically confirmed with the help of ultrasound imaging. This mode of imaging has been predominantly used in quantifying and qualifying the diseases associated with human soft tissues. However, the effectiveness of imaging by ultrasound depends largely on the body fat content. Large deposits of fat below the subcutaneous layer in obese people attenuate the ultrasound waves. This results in reduced penetration of ultrasound into the body, thereby affects the quality of the image. Thus the image taken up by the ultrasound device in obese patient is not of good resolution and doesn't provide enough details to give a substantial diagnosis. This is a potential hazard which may even lead to wrong diagnosis or failure of early detection. So, the obese patients are advised to go for expensive and riskier imaging modalities even when it is not really required. Moreover, obese patients need specially sized MRI, CT gantry which will suit them. But, it is not practically possible for all hospitals to buy those expensive imaging devices and they are not available in India as of now. This paper proposes potential improvements in the imaging technique which would help to solve the challenges faced in carrying out ultrasound imaging on obese patients.

Keywords: Obesity, Ultrasound Imaging, Recent Developments

Introduction
The major focus of the developing countries is to curb malnutrition but at the same time they are now facing another burden called overnutrition. A survey by National Family Health Survey (NFHS) in India shows that more than 50% population is suffering from malnutrition. Unfortunately, it was also found that more than 10% of population was suffering from over-nutrition and was overweight/obese. Out of this 10%, almost 7% population was women and 3% were men [3].

Medical imaging for obese people has been a day-to-day challenge to imaging professionals. The entire process of imaging becomes difficult when the patient is obese. Protocols are modified and exposure dosage levels are altered to improve the quality of the image. But there always exists a stringent trade-off between the quality of the diagnostic images and overexposure or injury to healthy tissues. Reynolds (2011) states that ultrasonography and chest radiography are the most affected imaging modalities due to obesity [1]. This is because the basis of ultrasound imaging lies in observing the attenuation of sound by different tissues. The value of sound attenuation (in decibels) is directly proportional to the thickness of fat (in centimetres) through which it penetrates. Higher the fat thickness, higher is the attenuation and hence lower is the image quality. Carrying out an ultrasound exam on an obese pregnant woman is a Herculean task due to the impaired acoustic window.
WHO guidelines states that a woman is considered obese if her body mass index (BMI) is in the range of 30.0 to 34.9 kg/m$^2$ and morbidly obese if her BMI is more than 35.0 kg/m$^2$. High weight gain during pregnancy leads to complications like infertility, miscarriage, thromboembolism and maternal mortality too. Cases have been reported that obesity in women also augments the risk of congenital anomalies in the fetuses such as malformation of organs, limb reduction defects, spina bifida, congenital heart disease etc. The sonologists are not able to help the patients because of sub-optimal visualization of the fetal anatomy. Wolfe et al. (1990) pointed out that spine and heart are the most difficult structures to visualize in obese women [2].

In India, according to the National Family Health Survey (NFHS), the percentage of married women aged 15-49 years who are overweight or obese increased from 11% in NFHS-2 to 15% in NFHS-3[3]. These women are most likely to get complications in ultrasound imaging during pregnancy. NFHS survey was done in 2006 and since then obesity has increased in India manifold.

**Figure 1: Nutrition distribution in India in 2006**

<table>
<thead>
<tr>
<th>Percentage of nutrition in Indian population</th>
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<tbody>
<tr>
<td>Malnourished 50%</td>
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<tr>
<td>Overweight/obese men 7%</td>
</tr>
<tr>
<td>Overweight/obese women 3%</td>
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<tr>
<td>Adequate nourishment 40%</td>
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**Current Solutions**

Two main limiting factors in ultrasound imaging of obese women are depth of penetration and amount of energy absorbed by the abdominal adipose tissue. Higher the depth of penetration, lower the signal to noise ratio. Reducing the mean array emission frequency to improve penetration is one of the solutions proposed by the ultrasound manufacturers – the output energy levels complying with the guidelines from FDA and other governing bodies.

Another solution presently in use is to use all possible pre and post processing filters to improve the signal to noise ratio – filters include harmonic imaging, speckle reduction filters and compound imaging. Trans-vaginal scan is also performed to resolve the mid trimester anomaly in visualizing anatomical structures.
Simulations – Experimental Setup

In order to address the problem of imaging soft tissues in obese people through ultrasound, we have tried to simulate the actual pathway of ultrasound signals. A phantom is virtually created using software which resembles the real body structures. It has three layers namely – the transducer, fat layer and the tissue layer. In our simulations, we have taken liver tissue as sample. The top most layer is the transducer layer which represents the position of the probe or the transducer which sends and receives ultrasound signal. The layer below the skin is the fat layer whose thickness varies from person to person. The next layer is the tissue layer where we have introduced some lesions.

Thickness of the fat layer is altered and series of simulations have been carried out. In this study, a novel technique called Technique to Image using Virtual Sources (TIVAS) has been employed. This helps in probing deeper and also with high SNR. This technique uses the electronic scan option of the phased array system. It makes use of Synthetic Focusing Algorithms which provide focused imaging capabilities at greater depths. As the virtual sources have greater energies, they can penetrate deeper and also are small enough to be treated as ‘point sources’ [4].

The simulations have been carried out with 1MHz pulsed ultrasound beam created with the help of a 1 MHz phased array transducer containing 256 elements with the pitch of 0.20 mm and width of 0.20mm. The simulations were done for 4 different focal laws, minimum and maximum angle for the scan are 0 and 45 degree for the transducer, the angle step was decided to be 15 degrees. The boundary conditions were defined as the lateral boundaries were made absorbing and the bottom surface was modelled to be a free surface.

Results and Discussions

Series of simulation with varying thickness of fat verified the loss of ultrasound energy at greater depths.

![Figure 2: ‘A scan’ with fat layer thickness - 0 cm](image-url)
Figures 1 & 2 above shows the A scan and B scan of the phantom without any fat layer. The first pulse represents the transmitted signal and the second pulse represents the received signal. The amplitude of the signal clearly shows that the attenuation of the ultrasound waves is very less by the tissue.

Having this as the reference, images were also obtained with fat layer thickness of 1cm and 1.5cm. The images corresponding to these fat layers show remarkable change in amplitude of the received pulse.
Figures 3 & 4 above clearly show reduced amplitude in received signal. It also shows a spike in between which signifies the transition between the fat and tissue layers. This spike is at the interface of fat and tissue layer.
Figures 5 & 6 above very clearly demonstrate the complete attenuation of the transmitted signal. As the fat layer thickness increases, acoustic attenuation increases proportionally. Then it reaches a point where no signal is received by the transducer. This results in very poor quality of image which could not give out any useful information about the internal structures.
Thus, the problem of imaging obese patients, especially obese pregnant women through ultrasound is very clearly stated by the phantom using virtual source simulations.

**Future Work**

Having identified and verified the problem observed in ultrasound imaging, future research would be to conceive an idea to resolve the fat layer absorption issue. This could be done in easier way through the software by applying some kind of adaptive filtering or modifying any post processing methods. The simulated phantom and the virtual sources which act as the probe help in conducting experiments easily rather than physically trying them out. Future research involves in bringing up a new method based on TIVAS to address this issue of imaging obese patients. We also plan out to create various tissue phantoms with differential layer of fats and

**References**


