Imaging Obese Patients

- Obese patients present unique challenges for an imaging department:
  - Table weight and aperture opening limits for CT, MR, and fluoroscopy
  - Image quality issues due to attenuation (x-ray and ultrasound), photon scattering, and limited field of view
  - Increased radiation doses in obese patients

- Some of these challenges have been addressed by the introduction of bariatric imaging equipment with larger table weight limits and aperture diameters

- In addition, new CT image reconstruction algorithms at Massachusetts General Hospital aim to decrease radiation dose and improve image quality in obese patients

The rates of obesity have risen dramatically over the past two decades. Even in Massachusetts, the state with the second lowest rate of obesity in the nation, 21.4% of the adult population was reported to be obese in 2009. Nationally, 5.7% of adults are morbidly obese, with a BMI ≥ 40.

Obesity is associated with an increased incidence of several conditions, including cardiovascular disease, gallbladder disease, and some cancers. Obese patients present many unique challenges to health care facilities: the ability to fit patients on hospital beds, surgical beds, and the ability to transport them within the facility on wheelchairs and stretchers. Imaging is integral to the care of these patients. Many obese patients now present to MGH for gastric bypass surgery. However, obesity limits the ability to acquire and perform imaging examinations and interventions. Table weight limits and gantry diameter limits present physical limitations in the ability to accommodate them on CT, MRI, or fluoroscopy. Large body habitus also degrades image quality, making it difficult or impossible to obtain adequate images for clinical interpretation. Of all the modalities, ultrasound examinations are the most limited by body habitus (Table 1).

### Table 1. Percentage of All Imaging Studies at Mass General that are Limited by Body Habitus

<table>
<thead>
<tr>
<th>Imaging Modality</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Ultrasound</td>
<td>2%</td>
</tr>
<tr>
<td>Chest x-ray</td>
<td>0.5%</td>
</tr>
<tr>
<td>Abdominal CT</td>
<td>0.4%</td>
</tr>
<tr>
<td>Chest CT</td>
<td>0.25%</td>
</tr>
<tr>
<td>Abdominal x-ray</td>
<td>0.25%</td>
</tr>
<tr>
<td>MRI</td>
<td>0.1%</td>
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**Ultrasound**

Ultrasound energy is attenuated by fat tissue (Figure 1). At the frequency of 7 MHz, 50% of the beam intensity (watts/cm²) is attenuated per centimeter of fat and the signal strength drops by 3 decibels (dB). In an obese patient with 8 cm of extra-peritoneal fat, only 6% of the original beam intensity enters the peritoneal cavity (Figure 1). To some extent, this problem can be addressed by using lower frequencies. For example, if a 2 MHz transducer is used (the lowest frequency available at MGH), 50% of the beam intensity is attenuated per 2.5 cm of fat tissue. It may be possible to reposition the patient and/or increase transducer pressure to minimize the distance the beam must travel before reaching the target organ. In addition, image quality can be somewhat improved by using tissue harmonic imaging. Although ultrasound is limited by obesity, it is very hard to predict which obese patients will have limited quality images as the distribution of fat is a factor. Obese patients with predominately subcutaneous fat will have lower quality images compared to obese patients with minimal subcutaneous fat but more intraperitoneal fat.
Figure 1. Right upper quadrant ultrasound images in (A) a patient weighing 250 lbs and (B) a patient weighing 150 lbs. Subcutaneous fat attenuates the ultrasound beam and renders the image uninterpretable.

X-ray Imaging

Image quality on plain radiographs and fluoroscopy is limited by attenuation and increased photon scatter as the beam penetrates through larger patients. Raising the x-ray tube voltage and current increases the penetration through excess tissue but reduces image contrast (Figure 2). Increasing exposure time can also improve image quality, although it can cause motion artifact. However, increasing tube current or exposure time increases the radiation dose to the patient. In extremely obese patients, much of the radiation is absorbed by excess subcutaneous fat and a recent phantom study from MIT showed that radiation dose can be minimized by positioning the patient so that the thinnest layer of fat is closest to the image receptor. In addition scatter can be reduced with tight collimation and by using a grid of alternating radiopaque and radiolucent strips to avoid detection of scattered photons, which are typically not directed perpendicular to the grid (Figure 2).

Fluoroscopy is routinely used to perform a gastrograffin swallow study in post gastric bypass patients. The industry standard for fluoroscopy table weight limit is 350 lb and the aperture opening is 45 cm (19 inches). The Massachusetts General Hospital has recently purchased bariatric fluoroscopy equipment (Figure 2) that can accommodate patients up to 550 lbs and has an aperture opening of 112 cm (48 inches).

| Table 2. Weight and Size Limits for Imaging and Radiologic Intervention at MGH |
|---------------------------------------------|---------------------------------------------|---------------------------------------------|---------------------------------------------|
| **Industry Standard** | **Upgraded MGH Bariatric Equipment** | **Field of View** | **Maximum Weight** | **Maximum Aperture Diameter** | **Field of View** |
| **MRI** | Maximum Weight | Maximum Aperture Diameter | Field of View | Maximum Weight | Maximum Aperture Diameter | Field of View |
| | 350 lb | 60 cm | 45-50 cm | 550 lb* | 70 cm |
| **Fluoroscopy** | 350 lb | 45 cm | 499 lb | 112 cm |
| **CT** | 425-450 lb | 70 cm | 50 cm | 500 lb | 80 cm |
| **Nuclear Medicine** | 400 lb | | | | |
| **Radiography** | None | | | | |
| **Ultrasound** | None | | | | |
| **Prone Standing** | 480 lb | N/A | 14 x 17 in. | 14 x 17 in. | |
| **Standing** | None | N/A | | | |

Note: 60 cm diameter = 74 inches circumference; 70 diameter = 87 inches circumference
*Will be operational from September 2011 for inpatients only
Figure 2. Two chest radiographs in the same patient. (A) Fat tissue attenuates the x-ray beam, resulting in a limited quality image using standard methods of image acquisition. (B) Increasing the kVp and mAs and using an antiscatter grid can improve the image quality.

Mammography
In mammography, there are numerous challenges to the proper positioning necessary to obtain high quality images. Breast tissue is very mobile and large breasts can easily be distorted by twisting or rolling, making it difficult to accurately localize lesions for diagnostic views. Breast folds can be a major problem, and additional views may be necessary to eliminate them. Mosaic or tile imaging may be needed to obtain adequate compression and/or to image all breast tissue. Small breasts may wrap around laterally if the woman is obese and require additional views.

CT
The industry standard weight limit for the CT tables is 450 lbs. The gantry diameter limit is 70 cm. In the past two years, MGH has purchased a bariatric CT that can accommodate patients up to 500 lbs and has a 80 cm diameter aperture.

In addition to physical constrains of table weight and gantry diameter, CT image quality can be compromised in obese patients by X-ray attenuation resulting in photon starvation (Figure 4A). Increasing the tube voltage and current can improve image quality. However it also increases the radiation dose in obese patients. Newly adopted image reconstruction algorithms such as adaptive statistical iterative reconstruction (ASIR) are now being used to improve the image quality at a lower radiation dose (Figure 4B).

The field of view (FOV) for image reconstruction is smaller than the aperture. Therefore, if the patient is too big, truncation artifacts can appear as bright edges on the image. These can be minimized by using specialized software that allows FOV extrapolation.

Figure 3. (A) Compare standard fluoroscopy equipment on the left to new (B) bariatric scanner on right with larger aperture opening (lines) to accommodate morbidly obese patients.
Nuclear Imaging

Although there are table weight limits for nuclear imaging, many gamma cameras are portable and the patient can be imaged while on a stretcher. However, image quality is limited in obese patients due to absorption and photon scattering, especially for lower energy isotopes. Therefore, $^{99m}$Tc, which emits higher energy photons than $^{201}$T-thallium, is likely to provide higher quality images in obese patients. Even these images may be of low quality because half of the photons emitted by $^{99m}$Tc are attenuated by 4-5 cm of soft tissue, so that an additional 10 cm of soft tissue will cause loss of 75% of the emitted photons. This limitation in quality is especially problematic for myocardial perfusion SPECT, since it is difficult to know whether a drop in photons detected is due to a soft tissue attenuation artifact or myocardial ischemia. This can be a source of real confusion in obese patients, who are more likely to have coronary disease than non-obese patients but are also more likely to have soft tissue attenuation artifacts.

The quality of PET images is also lower in obese patients because of photon scattering and increased photon attenuation in a larger body mass. Moreover, it may not be possible to give an optimal dose of isotope. For FDG-PET, optimal image quality is obtained with an injected dose of 0.22 mCi/kg, which is equivalent to 15 mCi in a patient weighing 68.2 kg (150 lb). The maximum dose recommended by the Society of Nuclear Medicine is 20 mCi. Therefore, for a patient weighing 300 lbs, the maximum dose is equivalent to 0.147 mCi/kg and for 400 lb it is 0.11 mCi/kg; doses that are well below optimal.

MRI

MRI image quality is least affected by obesity although increased body habitus introduces noise and the large field of view needed decreases the in-plane resolution of the images. The main limitations of MRI are the size of the bore and the table weight limits, which prevent imaging of large patients. MRI bore diameters are smaller than those of CT scanners and contact with the bore creates eddy currents that degrade MR images. In some cases, it may be possible to accommodate larger patients by not using surface radiofrequency coils. In addition, bariatric MR scanners are available that have a somewhat larger bore (70 cm) although these are still not large enough for many patients. Open bore MRI systems, which are not available at MGH, can be used to image larger patients, but they generally offer lower field strength, resulting in lower signal to noise ratio and poorer contrast.
Impact on Patient Care
If patients cannot be imaged by the modality of choice, this can adversely affect their care. Difficulties in imaging obese patients can lead to delayed diagnoses. Larger bariatric fluoroscopy and CT imaging and equipment recently purchased at MGH are being used to address some of these issues in obese patients. In addition, adjusting the imaging protocols can help obtain diagnostic quality images at the lowest radiation doses.

Scheduling
Appointments can be scheduled by calling 617-724-9729 or through the Radiology Order Entry system, http://mghroe.

Before ordering an examination or procedure, check that the patient’s weight does not exceed the relevant weight limit. If an obese patient is unable to walk and requires transportation by wheelchair or gurney, it is important to alert Mass General Imaging to enable the staff to arrange for appropriate transport equipment. Failure to do so leads to delays in examinations and longer waits for other patients.

Further Information
For more information about imaging obese patients, please contact Raul N. Uppot, MD, Abdominal Imaging and Intervention, Mass General Imaging, at 617-726-8396.

References


