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Impact of Obesity on Medical Imaging

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Key Points

1. Obesity is impacting the ability to acquire diagnostic quality images.
2. Obese patients may not be able to fit on imaging equipment.
3. Standard imaging protocols may not be suitable for obese patients.
4. Newer bariatric scanners and adjustments to imaging protocols can improve image quality in obese patients.

Obesity impacts medical imaging. The increases of weight and girth of the patient population are testing the current limits of imaging equipment. With the increasing prevalence of overweight and obese population, more patients are encountering difficulties in obtaining diagnostic quality images.

The purpose of this article is to define the challenges in imaging obese patients and describe current solutions to address these challenges.

Challenges in Imaging Obese Patients

Medical imaging, now used to diagnose and treat a majority of medical conditions, including cardiovascular disease, cancer and trauma, was designed to accommodate patients with defined maximum dimensions. Patients who exceed these defined dimensions of medical imaging equipment pose challenges to acquiring diagnostic medical images (Uppot et al. 2006; Uppot et al. 2007; Uppot 2007; Ginde et al. 2008; Campbell et al. 2009; Buckley et al. 2009; Reynolds 2011; Carucci 2013). The impact of obesity on medical imaging can simply be defined as a twofold problem:

	Industry Standard			Available Bariatric Equipment		
	Maximum Weight	Maximum Aperture Diameter	Field of View	Maximum Weight	Maximum Aperture Diameter	Field of View
MRI	350 lb [158kg]	60 cm	45-50 cm	550 lb [249kg] 499 lb	70 cm	
Fluoroscopy	350 lb [158kg]	45 cm		[226kg] 680 lb	112 cm	
CT	425-450 lb [192-204kg]	70 cm	50 cm	[308kg]	90 cm	70 cm
Nuclear Medicine	400 lb [181kg]					
Radiography		N/A				
Prone	480 lb [217kg]		14 x 17 in. [35.5-43.1cm]			
Standing	None		14 x 17 in.			
Ultrasound	None	N/A	N/A			

Table 1.
Industry Standard Weight Limits And Aperture Diameters For Imaging Equipment Compared

1. Can the patient fit on medical imaging equipment? 2. Can we get diagnostic quality images?

Inability to fit patients on imaging equipment has both a psychological impact on patient and doctor and an economic impact. Patients and their families are devastated when they are told that they cannot fit on imaging equipment to make a diagnosis. Doctors and healthcare workers feel helpless and anxious as to next diagnostic and therapeutic steps. Inability to obtain a scan also results in an economic impact with the potential need for hospitalisation, further observation, additional laboratory work, and possible exploratory surgery for diagnosis.

Can the Patient Fit?

For all medical imaging equipment (except ultrasound) there are industry standard design limitations to accommodate patients (see Table 1).

The first limitation is the table weight. Although CT and MRI tables can physically accommodate patients up to 1500lbs [680lg], the actual table weight limits are lower, owing to limits in the ability of the table motor to move the table into the gantry at an accurate rate. Industry standard table weight limits are 450lbs [204kg] for CT, 350lbs [158kg] for MRI, and 350lbs [158kg] for fluoroscopy.

The second limitation is the aperture diameter. Although a patient may meet table weight limits, the patient’s girth may exceed the aperture diameter. Industry standard limits in aperture opening include 70cm diameter for CT, 60cm diameter for MRI, and 45cm for fluoroscopy.

In the past several years. owing to the increasing need to accommodate larger patients, manufacturers have built larger "bariatric" scanners. There are now tables that can accommodate patients up to 680lbs [308kg] for CT and 550lbs [249kg] for MRI. Manufacturers have also addressed the aperture diameter. There are now bariatric CT scanners that have a gantry opening of 90cm, MRI scanners that have a bore diameter of 70cm, and fluoroscopic equipment with 112cm aperture openings (see Figure 1).

Can We Get Diagnostic Quality Images?

Although patients may fit onto imaging equipment, the next challenge is: can they get diagnostic quality images? Image quality is directly related to the depth of soft tissue penetration. For x-ray beams, which includes CT, plain radiographs and fluoroscopy, the greater thickness of tissue to penetrate through means more image noise and increased motion artifact, all of which reduces image quality and increases radiation dose to the patient. For ultrasound beams there is a direct relationship between depth of tissue and decline in ultrasound energy resulting in a poor quality image. A study reviewing ten years of dictated radiology reports between 1991 -2001 found the modality most affected by obesity was ultrasound with approximately 1.5% of ultrasound reports dictated containing a disclaimer as to the accuracy of the interpretation of the study due to the poor image quality as a result of obesity (Uppot et al. 2006). The second modality most affected by obesity was plain radiographs.

Over the past 10 years, radiologists and technologists have tweaked imaging protocols to optimise image quality in obese patients. These challenges and solutions are specific for each imaging modality.

Figure 1.
Images Comparing Fluoroscopy Equipment
Figure 1a - Industry standard fluoroscopic machine has a table weight limit of 350 lbs [158kg] and 18" [45.7cm] aperture (white arrow).
Figure 1b - Bariatric fluoroscopic equipment has a table weight limit of 500 lbs [226kg] and aperture opening of 44” [111.7 cm] (white arrow).

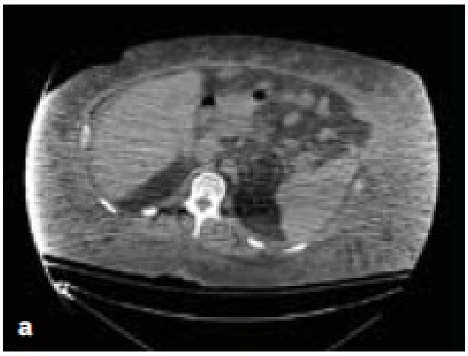

Figure 2.
Axial CT Image of an Obese Patient
Figure 2a showing a poor quality noisy image and beam hardening artifact (arrows) compared to Figure 2b - a similar non-contrast axial CT in a non-obese patient

CT

CT is the workhorse of medical imaging, and is widely prevalent in the United States. Its widespread availability, fast imaging times and excellent resolution make it a near ideal imaging tool for most patients. In addition, of all the imaging equipment available, it is the best imaging modality to accommodate obese populations. CT scanners tend to have the largest weight limits and aperture diameters as described above. Therefore, the main challenge in CT imaging of obese patients is optimising the CT settings to improve image quality in the obese population. If an obese patient can fit onto a CT scanner and CT scanner settings can be optimised, a diagnostic quality image can typically be obtained. Factors to address in CT for obese patients include kilovolatege peak (kvP), miliiamperes per second (mAS) and field of view (FOV).

kvP and mAS represent the energy and number of x-ray beam as it penetrates through a patient. In larger patients with increased soft tissue, these x-ray beams are hindered from reaching the detector, resulting in a poor quality, noisy image (see Figure 2). Standard CT protocols for normal size patients typically are set at 80-120kVP and "fixed" mAS. In order to accommodate larger patients, increasing the kVP to 140 increases the energy of the x-ray beam to help penetrate through the greater thickness of tissue. Making this adjustment decreases image noise. Changing the mAS setting to "automatic" also allos the CT machine to deliver as many numbers of x-ray photons as needed to improve image quality and decrease noise. The change in these settings, however, has a tradeoff of decreased image contrast with increase in kVP and increased radiation dose delivered to the patient. However, with newer iterative reconstructions offered by all CT manufacturers these increases in radiation dose can be minimised while maintaining image quality (Desai et al. 2012). In addition, newer dual source CT can potentially deliver greater energy and improve image quality in obese patients.

All CT scanners have a defined field of view usually smaller than the gantry diameter. Typically for most CT scanners this field of view is 50cm. Obese patients who can fit onto CT scanners, but exceed the 50cm field of view will have a bright truncation artifact (beam hardening artifact) along the edges of their CT image (see Figure 2), which may limit image interpretation of organs adjacent to the artifact. One solution to address this issue includes positioning the patient so that the area of interest lies within the field of view while sacrificing other parts of the body. The second solution is to invest in a larger bariatric scanner that typically also comes with larger field of views up to 65cm.

Fluoroscopy

Fluoroscopy is used to obtain real time 2D views of the body. It is a vitally important imaging modality for obese patients as it is commonly used to image post gastric bypass patients. Patients who undergo laparascopic gastric bypass surgery or lap band surgery always require post surgical gastrograffin swallow. Although most of these studies can be obtained in a standing position obviating table weight limits, the large girth of the patient can be an issue. Two solutions to address this issue include:

1. Doing a limited study by getting serial plain abdominal radiographs. This eliminates the need for using fluoroscopy and the images obtained allow for a 6 feet space between x-ray generator and patient. The limitation of this method is that the images are not real time and may potentially miss a small anastomotic leak.

2. Buying a bariatric fluoroscopy machine.

These "bariatric" machines invert the image intensifier and x-ray generator, and allow for a larger opening for the patient. The tradeoff in these machines is that there is more scattered radiation in the room and therefore radiologists typically manage the fluoroscopic machine controls from behind a leaded glass, as opposed to standing next to the patient

Ultrasound

Of all the imaging modalities, ultrasound is most limited by obesity. There is a direct decrease of ultrasound energy as it penetrates through thickness of tissue and results in poor image quality. However, this does not mean that all obese patients will have poor image quality with ultrasound (see Figure 3). The distribution of fat is critically important for image quality. Obese patients with predominately subcutaneous fat as compared to preponderance of intra-peritoneal fat tend to have poorer image quality, as the ultrasound beam has to penetrate through the thickness of the subcutaneous tissue before it reaches the internal organs. Patients with preponderance of intra-peritoneal and very little subcutaneous fat can have high quality image as the depth from probe to internal organs is small and ultrasound beam energy is not attenuated by the fat.

Solutions to improve standard ultrasound imaging in obese patients include:

1. Using the lowest frequency transducer typically decreasing from 4 to 2 mHz transducer. The lower the frequency of the transducer, the greater the energy of the ultrasound bean and the greater the penetration.

2. Position probe closest to the organ of interest and apply pressure to displace the subcutaneous tissues and decrease depth of penetration.

3. Use acoustical windows.

MRI

As with CT, if patients can fit on MRI machines, imaging protocols can be adjusted to optimise the image quality. The limitations unique to MRI include long bore length, which can make obese patients, who are squeezed into MRI machines, claustrophobic. In addition, obese patients can get minor skin burns if their skin is pushed up against the inner lining of the MR bore and RF energy deposited at the skin results in heating. From an image quality standpoint the biggest issue is adjusting the field of view settings. Patients who exceed the field of view will have a "wrap around artifact" that will limit the quality of the image (see Figure 4).

Interventional Radiology

Interventional radiology has its own unique sets of challenges in obese patients. In addition to the limitations of image quality for ultrasound, fluoroscopy and CT guided procedures, obese patients pose special challenges such as: 1. Are instrument lengths long enough? Can the patient and instruments fit into the CT gantry for CT-guided procedures? 2. Will medications given for sedation be adequate to sedate, and does the patient have obstructive sleep apnoea making conscious sedation challenging? 3. Are obese patients at risk for poor wound healing/infections?

Are Instruments Long Enough?

All interventional equipment, including needles, probes, catheters has set maximum lengths. Typically needles and probes are 25cm in maximum length. Until manufacturers develop longer instruments, solutions to address this issue include meticulous pre-procedural planning to identify the shortest distance to the target via alternative entrance sites, and minimising depth to target by pushing the needle hub into soft tissues to displace the subcutaneous fat. The other issue is whether the patient with needles or probes fits into the limited diameter CT gantry. Solutions to address this include using larger gantry diameter bariatric CT scanners for interventional procedures. In addition, some equipment manufacturers have developed flexible instruments that can bend when the patient is moved into the gantry.

Will Medications Given For Sedation Be Adequate?

Although many medications used for conscious sedation are weight-based, sometimes even very large doses do not adequately control pain in obese patients. In addition, obese patients are at risk for having sleep apnoea and airway compromise. Solutions to address these issues include using more than 2 or 3 medications to help with sedation (ie adding demerol to midazolam hydrochloride and sublimaze fentanyl regimens), or, if this is inadequate and the patient is at risk for respiratory compromise, consulting the anaesthesia department for possible general anaesthesia for the procedure.

Infection/Wound Healing

As with risks for surgical procedures, obese patients who are at risk for diabetes are at risk for poor wound healing after interventional procedures. Meticulous attention to interventional techniques, administering pre-procedure antibiotics and close post procedure monitoring can minimise infections.

Figure 3.
Compare limited quality right upper quadrant ultrasound in an obese patient Figure 3a with right upper quadrant ultrasound in non-obese patient Figure 3b.

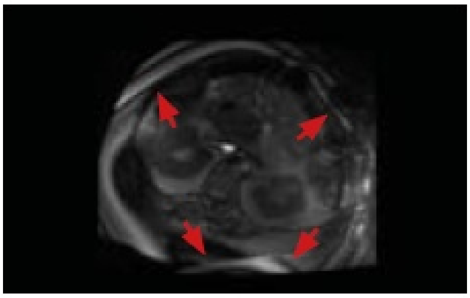

Figure 4.
Image of MRI showing wrap around artifact (arrows) due to patient size exceeding MRI field of view.

Conclusion

Obesity not only poses health risks, but also poses challenges in the delivery of healthcare. Imaging protocols can be adjusted to accommodate larger patients. Of all imaging modalities available CT is the best modality for obese patients as it has the largest table weight limits and aperture openings. There are now bariatric scanners with larger weight limits and gantry diameters to address the growing obesity epidemic.

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