Obesity and Medical Imaging Challenges
Obesity is a medical and social condition that can affect radiology in a number of ways. Imaging equipment can be too small or limited in capacity. Determining the appropriate dose of contrast material may be difficult because guidelines do not always specify dose ranges for patients with above-average weight. Because longer exposure to radiation may be necessary to image obese patients, patients and radiologic technologists may be at risk for overexposure. Finally, medical image quality can be compromised by obesity, especially with ultrasonography.

In 2002, a man from New York City sued McDonald’s, Burger King, Wendy’s and Kentucky Fried Chicken for providing what he claimed was deceptive nutritional information for what was actually high-calorie and high-fat foods, which he ate up to 5 times a week. The National Restaurant Association declared the lawsuit frivolous, but the plaintiff’s lawyer sought damages and claimed that deceptive advertising affected his client’s health. This class action suit was filed on behalf of an unspecified number of other obese and ill New Yorkers and was the first broad-based action against the fast food industry for allegedly contributing to obesity.\textsuperscript{1,2}

Declared a national epidemic in the United States, obesity is fast replacing smoking as the biggest threat to public health.\textsuperscript{3} Approximately 69% of Americans are overweight, and nearly half of those people are obese.\textsuperscript{3} Obese patients represent a range of challenges for medical imaging professionals, including the lack of appropriately sized equipment, problems in determining the correct dose of contrast material and difficulty in obtaining quality images for diagnosis.

**Defining Obesity**

Obesity is often defined as a disproportionate ratio of an individual’s weight to his or her height. This ratio is called the body mass index (BMI), which is calculated by dividing weight in kilograms by the square of height in meters. A normal BMI range is 18.5 to 24.9, overweight is 25.0 to 29.9, obese is 30.0 to 39.9 and morbidly obese is 40 or above.\textsuperscript{3}

Obesity involves an imbalance of the caloric intake to energy expenditure, meaning that more calories are consumed than are burned, which causes weight gain. But obesity is more than a simple equation of weight and height; it’s also a complex health issue involving genetics, hormones, culture and environment.\textsuperscript{3} Weight gain also can result from other illnesses or certain medications, such as steroids and...
antidepressants. If obesity is ongoing, it can lead to the following health issues:

- Coronary heart disease.
- Glucose intolerance or type 2 diabetes.
- Certain cancers (endometrial, breast, colon).
- Dyslipidemia.
- High cholesterol.
- Hypertension.
- Stroke.
- Liver and gallbladder disease.
- Osteoarthritis.
- Gout.
- Venous insufficiency.
- Gynecologic complications.
- Sleep apnea and other respiratory problems.

In extreme cases, obesity can lead to substantial increases in morbidity and mortality. In general, a greater degree of obesity leads to a higher likelihood of associated illness.

In addition to its physical effects, obesity also can hamper a person’s quality of life and social standing, because overweight individuals are often ostracized in some cultures in which being thin is considered ideal. The shift from the robust and fleshy women of Renaissance paintings and sculptures being regarded as symbols of femininity and the big-bellied Buddha as representing wealth and beauty is thought to have occurred after World War II, when the ideal physique changed to the slim, sometimes even gaunt, images of women and men. Because thin continues to be the ideal body type in many countries, including the United States, people who are obese may face issues such as difficulty finding a job or being considered as having a character flaw rather than a medical condition.

Statistics

Obesity and Overweight is thought to be the second-leading cause of preventable death in the United States, second only to smoking and tobacco use, which claims some 480,000 lives a year.

Obesity became endemic in the U.S. in the 1990s, with a reported increase of 60% to 75% between 1991 and 2000. Obesity ranks among smoking and chronic alcoholism as a major behavioral risk factor for chronic health conditions and is thought to age the body roughly 20 years. In the United States alone, more than one-third of the adult population can be classified as obese.

Obesity rates in the United States have increased steadily since the 1970s and do not show signs of slowing. According to a 2007-2008 study by the Centers for Disease Control and Prevention (CDC) of 5555 men and women considered to be a representative sample of the American population, the rate of obesity in adults was 33.8% overall. For men, the rate was 32.2%, and among women it was 35.5%.

Soaring obesity rates in the United States are thought to be the result of several social factors, including an increasingly sedentary culture preoccupied with television, computers and other electronics; a larger proportion of the population working at “desk jobs”; increased reliance on cars; and the adoption of a high-calorie, high-fat diet characterized by inexpensive and readily available fast food. An estimated 25% of adults in the United States are completely sedentary.

The percentage of children aged 6 to 11 years in the United States who were obese increased from 7% in 1980 to nearly 18% in 2012. Similarly, the percentage of adolescents aged 12 to 19 years who were obese increased from 5% to nearly 21% over the same period. The problem of increasing childhood obesity can have a lasting effect on individuals if not addressed. According to a 2002 article, only 5% of obese adolescents will lose weight successfully in adulthood if weight loss is not achieved during adolescence. Only 20% of obese adolescents simultaneously restrict caloric intake and increase physical activity.

Obesity is not only a personal issue but also a social problem that costs approximately $147 billion in health care costs and lost wages in the United States every year. It is speculated that the cost of addressing obesity is greater than that of smoking or drinking. Direct medical costs associated with obesity include preventive, diagnostic, and treatment services; indirect costs include loss of income due to decreased productivity, restricted activity, absenteeism and sick days, as well as loss of future income due to death.

A large amount of health care funding is used to treat the chronic conditions that occur as a result of obesity, such as coronary heart disease, hypertension, stroke,
diabetes, and certain cancers. Although much has been done—specially in the United States—to raise awareness about the dangers of smoking and alcohol abuse, little has been done to publically combat the problem of obesity.1

**Radiologic Challenges and Recommendations With Obesity**

Radiologic reports often cite limitations due to body habitus, which refers to the size and shape of a patient's body. A retrospective study by Uppot et al tabulated the number of such reports over a 15-year period from 1989 to 2003. The number of habitus-limited reports was then compared between modalities within a given year and within each modality across the 15-year time frame. Results showed a small but progressive increase in the number of habitus-limited radiology reports over the 15 years studied, and the increase in such reports was significantly correlated with the increase in obesity rates in Massachusetts ($P < .03$).12

On the radiology reports evaluated by the study, the following limitations were noted12:

- Underpenetration of x-rays resulting in insufficient contrast.
- Artifacts caused by patient motion.
- Attenuation of ultrasound signal that made it difficult to distinguish normal anatomy and anatomic landmarks.
- Area of interest located outside the field of view.
- Contact between the patient's body and the imaging bore or gantry that caused beam hardening or near-field artifacts.

The radiologic modalities found to be most affected by habitus-limited reports were ultrasonography and chest radiography. The number of body habitus limitations has significantly increased by an average of 0.15% each year of the study ($P < .001$). Overall, 7,777 of the 5,253,014 reports examined cited inadequate findings due to habitus-related limitations.12

Although radiologists and radiologic technologists often document measurable observations, obesity may be regarded as subjective and can carry a negative social connotation. It also is speculated that reporting obesity may seem threatening to the radiologist or radiologic technologist from a repercussions standpoint; however, the same can be said about not reporting it. Furthermore, it is speculated that the radiologist or radiologic technologist might avoid reporting obesity to avoid adversely affecting a patient's health care insurance status. Finally, it may be the case that radiologists avoid documenting obesity on an imaging report because it is obvious upon physical observation, and therefore might not seem necessary. However, medical literature suggests that it is the radiologist's responsibility to document obesity on the imaging report as a way to remind the treating clinician of the potential health risks associated with the condition to potentially prevent further disease.13

When radiologic images are not of diagnostic quality, they have an economic impact on health care. This is because such images may lead to additional tests, increased hospitalization and missed or incorrect diagnoses. Additionally, equipment also can suffer, such as radiography equipment, which has a higher burnout rate when used to image obese patients because higher technique settings are required.12

**Ultrasonography**

Ultrasonography is the imaging modality most affected by obesity.14 It is also the modality for which imaging reports cite limitations due to patients' body habitus.12 Excess subcutaneous fat typically impairs image quality by attenuating the ultrasound signal,14 and there is a relationship between the thickness of fat and the amount that the ultrasound beam is degraded (see Figure 1).16

In obese individuals, experts recommend that the lowest possible frequency probe be used because ultrasound energy is most attenuated by fat at high frequencies. Another technique is to decrease the target depth by pushing the probe deeper into the skin. Developments such as differential tissue harmonic imaging (DTHI) also have helped improve imaging resolution and allowed for greater penetration in individuals who are obese.17 In patients with dense tissue, DTHI uses enhanced frequency bandwidth to allow for increased visualization of tissue definition and penetration particularly for liver imaging compared with fundamental sonography.

Sonograms used for prenatal care may be affected by maternal obesity. In a study of 1622 sonograms of single
pregnancies analyzed at 28.5 weeks of fetal gestation, no significant impairment of image quality was noted when the mother’s BMI was as high as the 90th percentile. After that point, visualization decreased by an average of 14.5%. Reduction in visualization was most apparent for fetal heart, umbilical cord and spine. The most important determinants of visualization in pregnant women who were not obese included advancing gestation and lower BMI (ie, less than that of an obese person). Among pregnant women who were obese, visualization was not improved with advancing gestation; instead, BMI was the best predictor of visualization.

A study by Liu et al recommended that ultrasonography be used to measure mesenteric fat thickness, which may indicate risk for obesity-related health conditions. In the study, researchers measured thickness of mesenteric fat using sonograms, as well as total abdominal and visceral fat using magnetic resonance (MR) imaging and anthropometric indices to evaluate the relationship between cardiovascular risk factors and abdominal fat. Cardiovascular risk factors were assessed through blood testing and physical examination. Results indicated that mesenteric fat thickness had the highest correlation with total cholesterol, low-density lipoprotein cholesterol (LDL-C), triglycerides, fasting plasma glucose, hemoglobin A1c (HbA1c) and systolic blood pressure in men and with triglycerides and HbA1c in women. These findings led researchers to conclude that sonographic measurement of mesenteric fat thickness is effective in evaluating obesity associated with cardiovascular risk.

Radiography

In obese patients, radiographs may result in x-ray beam attenuation, lower image contrast, longer exposure times and motion artifacts (see Figure 2). The obese patient also may require that abdominal imaging is performed in quadrants, as single images are often too small to completely capture a particular area. Because of the higher burnout rate of radiography equipment used to examine obese patients, radiologic technologists should be knowledgeable regarding methods to optimize settings. Most important, to obtain diagnostic quality images, placement of the obese patient in relation to the x-ray tube and the determination of radiation dose are vital.

In a study by Yanch et al, the relative effective radiation dose for obtaining chest and abdominal radiographs in overweight and obese adults was calculated using phantoms with and without subcutaneous adipose tissue. Chest radiographs were obtained using a 120-kVp photon beam, and the focal point was 182 cm above the image receptor with a 35- x 43-cm field at the image receptor plane. Abdominal images were acquired at 80 kVp and a source-to-image distance of 102 cm. The researchers found that the exponential dose increases associated with increased subcutaneous fat thickness can be reduced substantially by positioning the thinnest layer of fat closest to the image.