Diagn Interv Radiol DOI 10.5152/dir.2016.16230

INTERVENTIONAL RADIOLOGY

REVIEW

Optimizing care for the obese patient in interventional radiology

Dwight Aberle
Hearns Charles
Steven Hodak
Daniel O'Neill
Rahmi Oklu
Amy R. Deipolyi

With the rising epidemic of obesity, interventional radiologists are treating increasing numbers of obese patients, as comorbidities associated with obesity preclude more invasive treatments. These patients are at heightened risk of vascular and oncologic disease, both of which often require interventional radiology care. Obese patients pose unique challenges in imaging, technical feasibility, and periprocedural monitoring. This review describes the technical and clinical challenges posed by this population, with proposed methods to mitigate these challenges and optimize care.

Over 33% of US adults are obese; this percentage is projected to rise to over 50% by the year 2030 (1). This epidemic impacts all medical specialties because of obesity's association with chronic diseases such as type II diabetes mellitus, cholelithiasis, coronary artery disease, hyperlipidemia, hypertension, and osteoarthritis (2). More recently obesity has been linked with cancers of the colon, breast, and liver, and it is associated with worse cancer outcomes compared with the general population (3). Obesity also attenuates the effects of systemic chemotherapy through impaired drug delivery and pharmacokinetics, tumorigenic adipokines, increased tumor-associated macrophages, insulin resistance, and chronic low-grade inflammation (4). Cancer patients with body mass index (BMI) >40 kg/m^2 are 52% more likely to die from their cancer compared with patients with normal BMI (25 kg/m^2) (5).

As the prevalence of obesity rises, the number of obese patients treated in interventional radiology (IR) increases, both because of the complications of obesity leading to the need for interventions, and because obese patients are often not candidates for other therapies, particularly surgical interventions, due to medical comorbidities (6). For example, obesity is an under-recognized independent risk factor for hepatocellular carcinoma (HCC) in patients with alcoholic cirrhosis (7). Diabetes, which is strongly associated with obesity, has been shown to more than double the risk of HCC (8). Increasing numbers of obese patients will increase the number of obese HCC patients requiring liver-directed therapy. Obesity may be associated with poorer outcomes after treatment in IR (9, 10).

Obesity makes treatment in IR more challenging and potentially less effective. Strategies to mitigate procedural risks and improve outcomes are essential (Table 1).

Procedural challenges posed by the obese patient

Imaging limitations

Obese body habitus adversely impacts image quality. For example, from 1989 to 2003 the proportion of chest radiographs limited by body habitus increased from 0.1% to 0.6%, despite improvements in technology and technique (11). Obese patients require higher peak kilovoltage (kVP) during fluoroscopy to achieve adequate x-ray penetration and sufficient image quality, resulting in higher radiation exposure to both patient and staff (12). One investigation showed that entrance site radiation (ESR) can be up to 10 times higher in the obese patient compared with the nonobese (13). A comparison of fluoroscopy dose during ureteroscopy showed an increase from 0.16 mGy/s in the nonobese to 0.50 mGy/s in patients with BMI ≧35 kg/m^2 (14). Dose reduction strategies, such as performing large-volume paracentesis when indicated, can reduce radiation exposure and improve fluoroscopic visualization. Other strategies include positioning the image receptor as close to the patient as possible and the x-ray tube as far as possible from the patient, reducing pulse rate to

From the Departments of Vascular and Interventional Radiology (D.A., H.C.) and Anesthesiology (D.O.), and the Division of Endocrinology, (S.H.), NYU Langone Medical Center, New York, NY, USA; the Division of Vascular and Interventional Radiology (R.O.), Mayo Clinic, Scottsdale, AZ, USA; Interventional Radiology Service (A.R.D. ✉ *deipolya@mskcc.org*) Memorial Sloan Kettering Cancer Center, New York, NY, USA.

Received 5 May 2016; revision requested 27 May 2016; revision received 29 May 2016; accepted 24 June 2016.

Published online 13 January 2017.
DOI 10.5152/dir.2016.16230

the lowest practical level, or discontinuing the examination when ESR approaches 5 Gy (15). Oblique views tend to result in additional radiation dosing, not only to the patient, but also the IR examiner.

Of all imaging modalities, ultrasonography is most frequently limited by body habitus (11). Subcutaneous fat attenuates the sonographic signal by 0.63 dB/cm and may place the area of interest outside of the focal depth of the probe (16). These factors lead to poor sonographic visualization of the abdominal organs, masses, and fluid collections, leading to higher rates of nondiagnostic percutaneous biopsies and bleeding complications (17). Basic strategies to improve image quality include selecting a lower frequency probe for deeper visualization, alternative patient positioning, and firmer manual compression of patient tissue. For instance, in renal biopsy, supine anterolateral positioning improves patient comfort and breathing without impact on diagnostic yield or complications compared with the prone position (18). When abdominal structures cannot be visualized well with ultrasonography, computed tomography guidance should be used (Fig. 1).

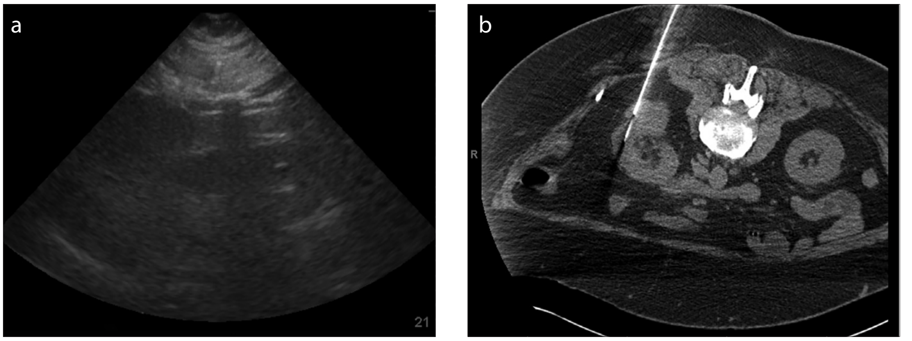

Figure 1. a, b. Nonfocal renal biopsy. A 64-year-old man with morbid obesity (body mass index [BMI], 42 kg/m^2) and renal failure of unknown etiology was scheduled for random kidney sample. Preliminary ultrasonography **(a)** failed to visualize the kidney, due to excessive adipose tissue. The procedure was then performed under computed tomography (CT) guidance **(b)**, and a 16 cm coaxial device was required to reach the renal cortex, as the kidney was more than 12 cm from the skin.

In summary, obesity diminishes imaging quality. Strategies to improve image quality include alternative patient positioning, increasing kVP or pulse rates, selecting different ultrasonography probes, and ultimately consideration of alternative imaging modalities.

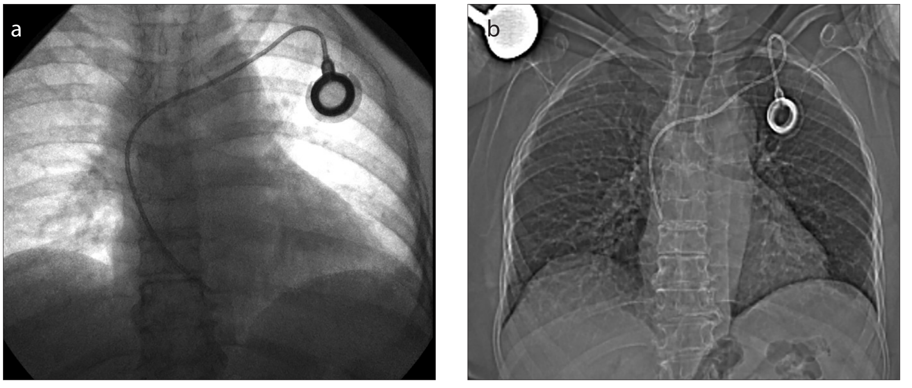

Figure 2. a, b. Variation in tip position. A 70-year-old woman with metastatic urothelial carcinoma and obesity (BMI, 33 kg/m^2) presented for chest venous port placement. Due to prior right shoulder surgery the patient refused a right-sided port. At the time of placement, the catheter tip is located deep in the right atrium **(a)**. Scout image from a chest CT suggests a loop in the catheter **(b)**, with cephalad displacement of the catheter tip. Apparent looping is due to excessive tissue and abducted arm position.

Challenges in equipment availability and selection

Prior to starting a procedure, IR providers must confirm that appropriate equipment is available. Measurement of the distance from skin to target on preprocedure imaging is essential, as the additional tract length from skin to target can result in greater movement of catheter tip position with changes in body position (Fig. 2) (19). As a result, catheter retraction and malposition are more common in the obese patient (Fig. 3). IR physicians must assure availability of appropriately sized devices, such as biopsy needles of sufficient length.

Obese patients may exceed the manufacturer specified equipment weight limit of IR equipment and additional ancillary staff may be needed to assist in moving these patients (20). For example, the industry standard weight limit for a fluoroscopy table is 159 kg with a maximum aperture diameter of 45 cm (16). If the equipment is suitable for the patient's weight, tape or straps may still be needed to safely secure the patient given that tables used in IR are typically narrow. Other strategies include placing the center of gravity of the patient in the middle or on the caudal aspect of the fluoroscopy table and avoiding moving the table during the procedure. Instead, the image intensifier should be moved to minimize mechanical damage to the table and injury to the operator. Hospitals handling a high volume of obese patients have introduced dedicated patient lift teams and have reported a reduction in pressure ulcers and staff injuries (21). For IR suites that treat many obese patients, mechanical lifts can be installed to assist staff in safely moving patients.

Equipment for monitoring and safely sedating obese patients must also be avail-

Main points

- The number of obese patients treated in interventional radiology is increasing, due to the rising epidemic of obesity, and because of the complications of obesity requiring invasive treatments.
- Obese patients pose challenges in imaging quality and in equipment selection and availability, which may be addressed with a variety of strategies, including the selection of alternative imaging modalities and assuring specialized equipment is available before the patient presents for the procedure.
- Periprocedural management of sedation, airway, blood pressure, and glycemic control are particularly difficult in the obese population and can be addressed with a multidisciplinary approach engaging the support of anesthesiologists, endocrinologists, and internists.
- Obese patients are also at greater risk for procedure-related complications and reduced efficacy of certain interventions, which may be addressed with technical strategies and close follow-up, to mitigate these risks.

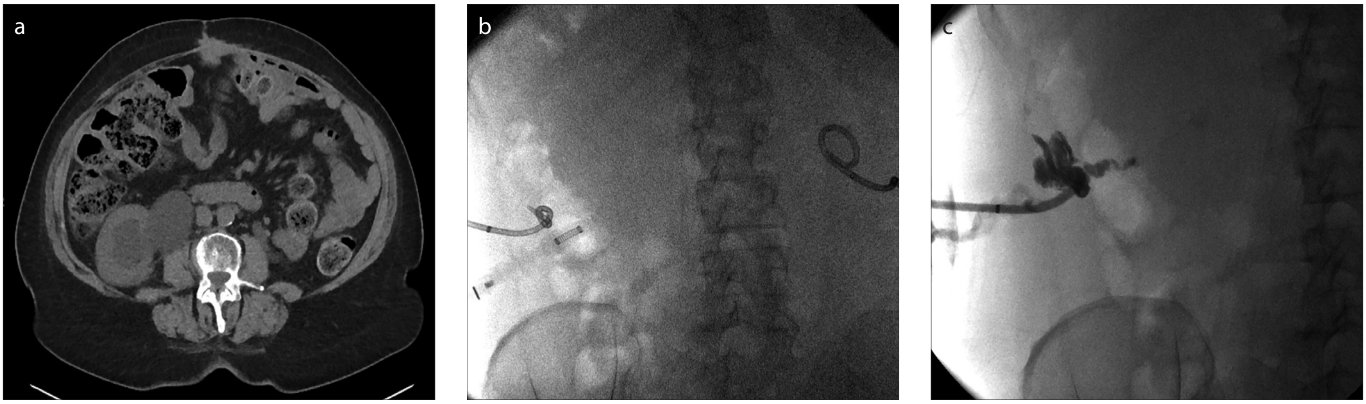

Figure 3. a–c. Retraction of drainage catheter. A 68-year-old obese woman (BMI, 30 kg/m^2) presented with bilateral hydronephrosis secondary to metastatic ovarian cancer. CT image **(a)** demonstrates right renal hydronephrosis with excessive adipose tissue between the skin and kidney. Bilateral nephrostomy tubes were placed. The right tube was later noted to have no output and found to be retracted on scout images **(b)** and after contrast injection **(c)**. The tract could not be rescued and a new primary nephrostomy tube was placed.

Table 1. Challenges managing the obese patient in interventional radiology, with suggested strategies to mitigate risks

Challenges	Strategies
Poor visualization of abdominal structures using ultrasonography	Alternative patient positions
	Alternative imaging modalities
Higher radiation required to penetrate obese body habitus during fluoroscopy	Collimation, reduce frame rate
Longer distances from skin to target structures	Preprocedural review of imaging to assure equipment of appropriate length
Difficult airway	Anesthesiology consultation
Altered pharmacokinetics	Dose adaptations to avoid over-sedation
Periprocedural hypo- and hyperglycemia	Hold oral antiglycemics when patient is NPO
	Early morning appointments for diabetic patients
	Consider medical/endocrinology consultation
Periprocedural hypertension	Instruct patients to take home antihypertensives before procedures
	Consider medical consultation
Increased infection risk	Increased wound care
Increased arterial access site complications	Taping back the pannus for access
	Consider ultrasound-guided access
	Extended manual compression
Worse outcomes after liver therapies, such as thermal ablation	Preprocedural counseling
	Weight reduction strategies

NPO, *nil per os*.

able, such as extra large blood pressure cuffs. Elevating the head of the fluoroscopy table, for instance, may help to ventilate patients more effectively. Patients with BMI >40 kg/m^2 may not be safely cared for in outpatient clinics and are best triaged to settings where such equipment and additional staff support is available.

In summary, IR physicians should be aware of a history of obesity before starting a procedure, to assure that appropriate instruments are available. Specialized equipment such as patient lifts should be incorporated to promote patient and staff safety.

Intraprocedural airway management

Obese patients may be poor candidates for conscious sedation because of problems with airway patency and management. Factors predicting airway complications while undergoing general anesthesia include neck diameter >16.5 inches, micrognathia, history of hypertension, polycythemia, and right ventricular hypertrophy on imaging or electrocardiography (22). Functional residual capacity decreases exponentially with increasing BMI, due to mass loading of the diaphragm (23), which is particularly true for patients undergoing prolonged procedures and those requiring prone positioning. Obese patients must work harder to breathe because of decreased lung and chest wall compliance, often resulting in low tidal volumes and a high respiratory rate (24). Obese patients therefore have increased oxygen requirements, shorter times to desaturation during apnea, and hypoventilation during spontaneous venti-

Table 2. Periprocedural management of patients' outpatient insulin regimen	
Type of insulin	Suggested management
Short- and rapid-acting insulins	Hold on morning of procedure
Long-acting insulins (e.g., glargine, detemir) taken once daily	Take night before procedure or morning of procedure with 20% dose reduction
Long-acting insulins taken twice daily	Take full dose night before procedure and reduce morning dose 50%
NPH insulin	Take 50% evening dose (effect peaks in morning when patient is NPO)
Premixed insulin (e.g., NovoLog® 70/30, 75/25, 50/50, Humulin® 70/30, Novolin® 70/30)	Hold on morning of procedure
Glucagon-like peptide analogs (e.g., liraglutide, exenatide, exenatide extended-release, pramlintide)	Hold on morning of procedure
NPO, *nil per os.*	

lation while supine. Tilting the head of the table up and avoiding sedatives when possible can help mitigate these risks.

Obesity is strongly associated with obstructive sleep apnea (OSA) (25). In patients with OSA, the American Society of Anesthesiologists recommends general anesthesia with a secure airway as opposed to deep sedation without a secure airway for invasive procedures (26). Whereas radiology nurses typically only administer midazolam and fentanyl, anesthesiologists may administer ketamine and/or dexmedetomidine, medications that are associated with less respiratory depression (27). Continuous positive airway pressure (CPAP) and noninvasive positive pressure ventilation can be used intra- and postprocedurally to maintain airway patency in the sedated obese patient. A history of using CPAP at home should instigate a referral to anesthesiology for procedures requiring sedation. To assess for readiness for discharge to an unmonitored setting, the patient with OSA should be examined in an unstimulated setting, preferably while asleep.

In summary, a history of OSA or right ventricular hypertrophy, BMI >40 kg/m^2, or a finding of significant neck diameter or micrognathia contraindicate conscious sedation by radiology nursing and should prompt an anesthesiology consultation if procedural sedation is needed. Avoiding sedation whenever possible and considering patient positions that can promote ventilation can decrease the risk of hypoventilation during procedures.

Intraprocedural sedation management

The physiologic changes of the respiratory and cardiovascular systems in obese patients alter the distribution, elimination, and effect of sedative medications. The net effect of these physiologic changes can increase or decrease the required dose of sedatives (22). A prospective study of over 1000 obese patients found that high BMI and low anesthesiologist expertise were strong predictors of propofol sedation-related complications, highlighting the fact that the increased risk of sedation in obese patients can be managed by experienced providers (28). Dosing sedatives in obese patients by ideal body weight will result in subtherapeutic doses, whereas using total body weight (TBW) will result in overdoses (29). For instance, pharmacokinetic models overestimate fentanyl doses in the morbidly obese, with dosing error increasing with TBW. One study provides a useful chart for dosing fentanyl in obese surgical patients. For example, a patient with TBW of 120 kg should be dosed at a pharmacokinetic weight of 93 kg (30). Dose adaptations are also necessary for midazolam to avoid oversedation, but no numerical guidelines exist (31).

In summary, obese patients may require alteration of doses of fentanyl and midazolam to achieve conscious sedation. However, doses should not be based on TBW, as oversedation may result. Pharmacokinetic models based on population data help to provide rational drug dosing, but real-time drug titration by a dedicated professional focused on both the physiology and pharmacology will increase the likelihood of successfully managing individual patients' needs.

Periprocedural glycemic management

Patients with BMI >40 kg/m^2 are seven times more likely to have type 2 diabetes mellitus (DM) (32). Hyperglycemia leads to impaired chemotaxis and phagocytosis of neutrophils, decreased complement function and subsequent vulnerability to infection and multiorgan dysfunction, whereas hypoglycemia can lead to potentially life-threatening complications (33). To reduce the risk of pulmonary aspiration, all patients are instructed to be *nil per os* (NPO) on the day of an IR procedure, which can complicate periprocedural glycemic control, while stress associated with procedures also increases variance of glucose levels (34).

The Society of Ambulatory Anesthesia (SAMBA) consensus statement provides several recommendations on periprocedural glycemic management (35). First, review of patient history (hemoglobin A1c in the past 3 months, type of antidiabetic therapy, diabetic symptoms, and any related hospitalizations) will reveal how well controlled the patient's diabetes is. Outpatients with diabetes are best scheduled for procedures in the morning to limit the time that they deviate from their normal antidiabetic agent regimen. For patients treated with insulin, specific recommendations can be obtained from the prescribing provider that clearly outline how the antidiabetic regimen should be modified in the periprocedural setting. Type 2 diabetics may use multiple types of insulin in complex treatment regimens. Insulin should be held or given with a modified dose, as patients are NPO (Table 2). Oral antidiabetic agents are held on the day of the procedure and resumed when patients are eating again.

Patients with ketosis-prone type 2 DM and type 1 DM are at risk for diabetic ketoacidosis (DKA) (36, 37). For type 1 DM and ketosis-prone type 2 DM, continuous use of basal insulin is needed to prevent DKA. Patients that use a chronic subcutaneous insulin pump can generally continue the pump without adjustment for procedures less than 4 hours as long as appropriate intraprocedural point-of-care (POC) blood glucose (BG) testing is performed. For pro-

Table 3. Insulin sliding scale

Correction scale selection	Patient type		
Low dose	Type 1 DM		
	Lean, BMI <25 kg/m^2		
	Renal insufficiency		
	Age >70 years old		
	Home insulin dose <20 units/day total		
Medium dose	BMI >25 kg/m^2 and blood glucose 140–200 mg/dL		
	Home insulin dose 20–50 units/day total		
High dose	BMI >25 kg/m^2 and blood glucose >200 mg/dL		
	Home insulin dose >50 units/day total		
	Units of SQ Aspart		
Blood glucose (mg/dL)	Low	Medium	High
70–140	0	0	0
141–180	1	2	3
181–220	2	4	6
221–260	3	6	9
261–300	4	8	12
301–340	5	10	15
341–380	6	12	18
381–420	7	14	21
>420*	8	16	24

Patients are categorized by presenting features as requiring a low, medium, or high dose correction. Most patients require medium dosing. Aspart may be administered every 4 to 6 hours.
DM, diabetes mellitus; BMI, body mass index; SQ, subcutaneous.
*Call endocrinology consult.

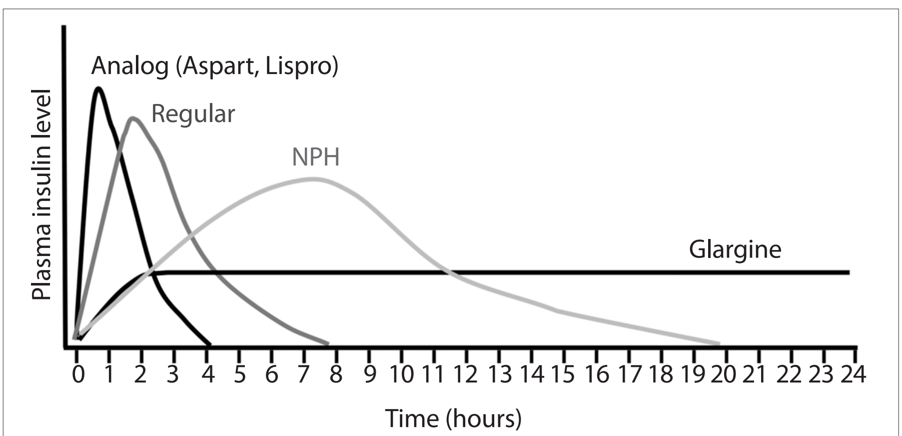

Figure 4. Insulin onset and duration of action. Even the shortest-acting insulins peak 1 hour after subcutaneous administration and have persistent effects for 4 hours or more.

cedures longer than 4 hours, patients likely need a subcutaneous basal insulin or a continuous intravenous insulin infusion (38).

POC BG levels should be obtained for all diabetic patients immediately prior to procedure, every 2–4 hours during the procedure, at the conclusion of the procedure, and just prior to discharge. Ideal BG levels range between 80–180 mg/dL (35). BG >180 mg/dL is not a contradiction to procedures, as short-term hyperglycemia carries few complications and can be tolerated in the absence of significant sequelae. BS >250 mg/dL should be treated with an appropriately selected sliding scale correction dose of rapid-acting insulin (Table 3). Subcutaneous insulin, both short- (e.g., regular) and rapid-acting (e.g., aspart and lispro), requires time for onset of action and acts over several hours (Fig. 4). Insulin will continue to lower glucose for 4–6 hours. Following insulin administration, frequent POC BG assessment every 1–2 hours is reasonable to ensure that BG does not decline too rapidly. BG obtained before an administered insulin dose has achieved its full effect may remain elevated, but should not be interpreted as a dose failure. Additional insulin doses given too soon can lead to "insulin dose stacking" which can cause sudden and serious hypoglycemia (39). Waiting 4 hours after administration to determine the effect is warranted before considering another correction dose. In unusual cases where rapid correction of elevated BG is necessary (e.g., BG >400 mg/dL), an alternative is to administer regular insulin intravenously as a rapid intravenous bolus, which is typically given only following consultation with an endocrinologist.

Signs of severe hypoglycemia are masked by conscious sedation, necessitating frequent monitoring during procedures entailing sedation. Hypoglycemia can be treated with 50 mL of 50% dextrose intravenously over 5 min. POC BG should be measured 15 min after dextrose administration and this process repeated until BG >100 mg/dL and stable without additional dextrose for at least 30 min following moderate hypoglycemia (BG, 40–70 mg/dL) or for at least an hour following an episode of severe hypoglycemia (BG, <40 mg/dL). In emergent situations where intravenous access is lost, 1 mg intramuscular glucagon can be given to temporize, and an appropriately escalated level of medical response should be initiated to restore intravenous access (35).

In summary, review of history including the amount of insulin the patient uses daily is essential in managing periprocedural hyperglycemia. Once a correction has been made, a sufficient time period of 4 hours should elapse before further routine correction doses are administered. Due to rapid fluctuations in NPO patients under stressful conditions and the masking of hypoglycemia by sedatives, frequent blood sugar monitoring every 1–2 hours is required to optimize care.

Hypertension management

Obese patients are more likely to have hypertension, due to a multifaceted pathophysiology involving insulin resistance and renal derangement among other factors

Table 4. Antihypertensive dosing

Agent	Refractory hypertension	Hypertensive emergency	Effect on pulse
Nicardipine	100 μg IV q 5 min prn	IV infusion: 5 mg/h initially, titrate up to 15 mg/h based on response	Increase
Labetalol	5 mg IV q 5 min prn	IV: 20 mg over 2 min	No change or decrease
Hydralazine	3-20 mg IV q 30 min prn	Generally not recommended due to prolonged effect	Reflex tachycardia

IV, intravenous; q, *quaque* (every); prn, *pro re nata* (as necessary)

(40). All patients are at risk for acute elevations in blood pressure during a procedure because of pain-induced sympathetic stimulation and recent discontinuation of oral antihypertensive medications. Peripheral vascular procedures like those commonly performed in IR are considered high risk for acute hypertensive events (41). Diastolic blood pressure ≥100 mmHg is a risk factor for arterial access site bleeding and hematoma (42). This risk is increased in the obese patient where thick subcutaneous tissue limits the effectiveness of manual arterial compression. Hypertensive emergency, defined as blood pressure of >180 mmHg systolic or >110 mmHg diastolic, with symptoms of end-organ impairment manifesting with headache, blurred vision, chest pain, stroke or myocardial ischemia, can be a life-threatening condition and prompt admission.

Prevention of hypertensive emergency is preferred to treatment. This requires consulting the patient's primary physician or cardiologist to craft a medication plan that can include using long-acting oral preparations of the patient's regimen for several days before the procedure. Patients are always instructed to continue outpatient antihypertensive regimens, including on the morning of the procedure. Particular caution is warranted for patients undergoing adrenal interventions, or arterial intervention for renovascular hypertension, particularly during the immediate postprocedure period.

In a hypertensive emergency (blood pressure >180 mmHg systolic or >110 mmHg diastolic with evidence of end organ damage), the goal is to decrease blood pressure over 30–60 min in conjunction with volume expansion with normal saline to prevent hypotension. Preferred agents include nicardipine and labetalol because they have a short onset and short duration of action, are easy to titrate, and have been shown to be safe in the treatment of perioperative hypertension (43). Hydralazine is generally not recommended in the treatment of hypertensive emergency because the half-life of its effect on blood pressure is about 10 hours and dependent on an individual patient's hepatic acetylation and inactivation (44).

More commonly, IR doctors will be managing nonemergent hypertension. Again, nicardipine and labetalol are the preferred agents (Table 4). With hydralazine, it is recommended to stay on the lower end of the proposed range, given its length of action and unpredictable patient response. When assessing the obese patient's readiness for discharge to an unmonitored setting, blood pressure should be less than ±15%–30% the value on entering the IR suite, according to the commonly used postanesthesia modified Aldrete Score (45).

In summary, obese patients are more likely to have baseline hypertension and therefore will be more likely to have periprocedural hypertension and hypertensive emergencies. Nicardipine and labetalol are preferred agents with a goal of restoring a blood pressure within 15%–30% of the patient's preprocedural level. Medical consultation may be required in refractory or emergent cases.

Postprocedure management, complications, and outcomes

Obesity and diabetes are associated with infectious complications, such as postprocedure catheter site infections (46) and surgical site infections after abdominal procedures (47). Deep skin creases, particularly at the groin, are susceptible to increased friction and moisture, which can lead to intertrigo and proliferation of *Staphylococcus aureus* and *Candida albicans* (48). The obese abdominal pannus can interfere with arterial access and access site monitoring and healing, increasing the risk of infection. The choice and dosing of periprocedural antiobiotic prophylaxis may be influenced by comorbidities such as DM or renal failure.

Beyond infectious complications, vascular complications may also result after common femoral arterial access. A study of over 5000 patients undergoing coronary angiography and/or percutaneous coronary intervention demonstrated that high (>35 kg/m^2) BMI patients have increased rates of pseudoaneurysm, large hematoma, arteriovenous fistula, or need for transfusion or surgical vessel repair (49). During the procedure, the pannus can be taped and secured away from a groin access site. Other strategies include using vascular closure devices and extended manual compression times.

Radial artery access is gaining popularity in interventional suites, may especially help in arterial access for obese patients and has been well studied in the setting of coronary intervention. For all patients, radial access is associated with decreased major hemorrhagic complications (50, 51). Radial access may be especially important in reducing access complications (52) and is the strongest independent predictor of low vascular complications in obese patient, with an odds ratio of 0.12 (49).

Postprocedural deep vein thrombosis (DVT) prophylaxis is particularly important in the obese patient, as obesity may be associated with increased risk of venous thromboembolism (53). Obese patients have decreased physical activity and higher levels of inflammation and restriction of venous flow by subcutaneous fat. Obese patients may be less likely to receive appropriate DVT prophylaxis. Weight-based dosing at 0.5 mg/kg (TBW) of enoxaparin for the morbidly obese may be more appropriate than the standard fixed dosing of 40 mg/day (54).

Finally, beyond complications, obese patients may not experience similar efficacy of liver-directed therapies. For example, increased intraperitoneal fat is associated with higher recurrence rates of nonviral, nonalcoholic HCC following percutaneous thermal ablation. Three years after treatment, 75% of patients in the high visceral fat area cohort had recurrent HCC, compared with only 43% of patients in the control group (9). This association is thought to be due to the metabolic and inflammatory effects of obesity, which is supported by other investigations that have demonstrated that insulin resistance is associated with an elevated HCC recurrence rate in patients treated with radiofrequency ablation (55).

Objective patient counseling regarding these poorer outcomes is advised during initial consultation to set patient expectations and to potentially motivate weight reduction strategies that could improve outcomes. More frequent postprocedure imaging in obese patients may be warranted but has not yet been studied. Participants in a large study of patients undergoing lifestyle modification for weight loss reported a "medical event" as the most common trigger for their weight loss attempt (56). The affiliated urgency of many IR procedures does not usually afford the time for significant preprocedure weight loss. Educating referring medical providers about the risks of obesity in regard to IR procedures may be more effective and appropriate than attempts to counsel weight loss directly to the patient.

In summary, obese patients are at greater risk of infectious and vascular access complications, venous thromboembolism, and potentially worsened outcomes after liver-directed therapy. More careful wound monitoring, vascular closure devices or radial access, weight-based modifications of heparin dosing, and realistic and direct postprocedure patient education are strategies that may help mitigate these challenges.

Conclusion

Providing safe and effective care to the obese patient is challenging, but knowledge of the risks will assist the IR physician in minimizing complications and increasing efficacy. The challenges of imaging the obese patient can be met with appropriate selection of imaging modality and equipment. Early recognition of problems with airway and sedation will allow the IR physician to make appropriate choices, including involving anesthesiologists and medical consultants where necessary. Having a collaborative relationship between radiology and consulting services promotes patient safety, efficiency, and procedural success. IR providers should understand symptoms, complications, and treatments for hypertension, sleep apnea, and diabetes, to better communicate with referring providers. Lastly, it is the responsibility of the IR provider to educate patients and referring physicians on the effects of obesity on treatment effectiveness.

Conflict of interest disclosure

The authors declared no conflicts of interest.

References

1. Wang Y, Beydoun MA, Liang L, Caballero B, Kumanyika SK. Will all Americans become overweight or obese? estimating the progression and cost of the US obesity epidemic. Obesity 2008; 16:2323–2330. [CrossRef]
2. Must A, McKeown NM. The disease burden associated with overweight and obesity. In: De Groot LJ, Beck-Peccoz P, Chrousos G, et al., Eds. Endotext. MDText.com, Inc.: South Dartmouth, 2000.
3. Vucenik I, Stains JP. Obesity and cancer risk: evidence, mechanisms, and recommendations. Ann N Y Acad Sci 2012; 1271:37–43. [CrossRef]
4. Lashinger LM, Rossi EL, Hursting SD. Obesity and resistance to cancer chemotherapy: interacting roles of inflammation and metabolic dysregulation. Clin Pharmacol Ther 2014; 96:458–463. [CrossRef]
5. Calle EE, Rodriguez C, Walker-Thurmond K, Thun MJ. Overweight, obesity, and mortality from cancer in a prospectively studied cohort of U.S. adults. NEJM 2003; 348:1625–1638. [CrossRef]
6. Doyle SL, Lysaght J, Reynolds JV. Obesity and post-operative complications in patients undergoing non-bariatric surgery. Obes Rev 2010; 11:875–886. [CrossRef]
7. Nair S, Mason A, Eason J, Loss G, Perrillo RP. Is obesity an independent risk factor for hepatocellular carcinoma in cirrhosis? Hepatology 2002; 36:150–155. [CrossRef]
8. Tateishi R, Okanoue T, Fujiwara N, et al. Clinical characteristics, treatment, and prognosis of non-B, non-C hepatocellular carcinoma: a large retrospective multicenter cohort study. J Gastroenterol 2015; 50:350–360. [CrossRef]
9. Ohki T, Tateishi R, Shiina S, et al. Visceral fat accumulation is an independent risk factor for hepatocellular carcinoma recurrence after curative treatment in patients with suspected NASH. Gut 2009; 58:839–844. [CrossRef]
10. Kew MC. Obesity as a cause of hepatocellular carcinoma. Ann Hepatol 2015; 14.
11. Uppot RN, Sahani DV, Hahn PF, Kalra MK, Saini SS, Mueller PR. Effect of obesity on image quality: fifteen-year longitudinal study for evaluation of dictated radiology reports. Radiology 2006; 240:435–439. [CrossRef]
12. Yanch JC, Behrman RH, Hendricks MJ, McCall JH. Increased radiation dose to overweight and obese patients from radiographic examinations 1. Radiology 2009; 252:128–139. [CrossRef]
13. Wagner LK, Archer BR, Cohen AM. Management of patient skin dose in fluoroscopically guided interventional procedures. J Vasc Interv Radiol 2000; 11:25–33. [CrossRef]
14. Hsi RS, Zamora DA, Kanal KM, Harper JD. Severe obesity is associated with 3-fold higher radiation dose rate during ureteroscopy. Urology 2013; 82:780–785. [CrossRef]
15. Bryk SG, Censullo ML, Wagner LK, Rossman LL, Cohen AM. Endovascular and interventional procedures in obese patients: a review of procedural technique modifications and radiation management. J Vasc Interv Radiol 2006; 17:27–33. [CrossRef]
16. Uppot RN, Sahani DV, Hahn PF, Gervais D, Mueller PR. Impact of obesity on medical imaging and image-guided intervention. AJR Am J Roentgenol 2007; 188:433–440. [CrossRef]
17. Fine DM, Arepally A, Hofmann LV, Mankowitz SG, Atta MG. Diagnostic utility and safety of transjugular kidney biopsy in the obese patient. Nephrol Dial Transplant 2004; 19:1798–1802. [CrossRef]
18. Gesualdo L, Cormio L, Stallone G, et al. Percutaneous ultrasound-guided renal biopsy in supine antero-lateral position: a new approach for obese and non-obese patients. Nephrol Dial Transplant 2008; 23:971–976. [CrossRef]
19. Nazarian GK, Bjarnason H, Dietz CA, Jr., Bernadas CA, Hunter DW. Changes in tunneled catheter tip position when a patient is upright. J Vasc Interv Radiol 1997; 8:437–441. [CrossRef]
20. Cowley SP, Leggett S. Manual handling risks associated with the care, treatment and transportation of bariatric (severely obese) clients in Australia. Work 2011; 39:477–483.
21. Walden CM, Bankard SB, Cayer B, et al. Mobilization of the obese patient and prevention of injury. Ann Surg 2013; 258:646–651. [CrossRef]
22. Adams JP, Murphy PG. Obesity in anaesthesia and intensive care. Br J Anaesth 2000; 85:91–108. [CrossRef]
23. Biring MS, Lewis MI, Liu JT, Mohsenifar Z. Pulmonary physiologic changes of morbid obesity. Am J Med Sci 1999; 318:293–297. [CrossRef]
24. Koenig SM. Pulmonary complications of obesity. Am J Med Sci 2001; 321:249–279. [CrossRef]
25. Vgontzas AN, Papanicolaou DA, Bixler EO, et al. Sleep apnea and daytime sleepiness and fatigue: relation to visceral obesity, insulin resistance, and hypercytokinemia. J Clin Endocrinol Metab 2000; 85:1151–1158. [CrossRef]
26. Gross J, Bachenberg K, Benumof J, et al. Practice guidelines for the perioperative management of patients with obstructive sleep apnea: a report by the American Society of Anesthesiologists Task Force on Perioperative Management of patients with obstructive sleep apnea. Anesthesiology 2006; 104:1081. [CrossRef]
27. Arcangeli A, D'Alo C, Gaspari R. Dexmedetomidine use in general anaesthesia. Curr Drug Targets 2009; 10:687–695. [CrossRef]
28. Wani S, Azar R, Hovis CE, et al. Obesity as a risk factor for sedation-related complications during propofol-mediated sedation for advanced endoscopic procedures. Gastrointest Endosc 2011; 74:1238–1247. [CrossRef]
29. Ingrande J, Lemmens H. Dose adjustment of anaesthetics in the morbidly obese. Br J Anaesth 2010; 105:i16–i23. [CrossRef]
30. Shibutani K, Inchiosa MA, Jr., Sawada K, Bairamian M. Accuracy of pharmacokinetic models for predicting plasma fentanyl concentrations in lean and obese surgical patients: derivation of dosing weight ("pharmacokinetic mass"). Anesthesiology 2004; 101:603–613. [CrossRef]
31. Brill MJ, van Rongen A, Houwink AP, et al. Midazolam pharmacokinetics in morbidly obese patients following semi-simultaneous oral and intravenous administration: a comparison with healthy volunteers. Clin Pharmacokinet 2014; 53:931–941. [CrossRef]
32. Mokdad AH, Ford ES, Bowman BA, et al. Prevalence of obesity, diabetes, and obesity-related health risk factors, 2001. JAMA 2003; 289:76–79. [CrossRef]
33. Lipshutz A, Gropper MA. Perioperative glycemic control. Anesthesiology 2009; 110:408–421. [CrossRef]
34. Dhatariya K, Levy N, Kilvert A, et al. NHS Diabetes guideline for the perioperative management of the adult patient with diabetes. Diabet Med 2012; 29:420–433. [CrossRef]
35. Joshi GP, Chung F, Vann MA, et al. Society for Ambulatory Anesthesia consensus statement on perioperative blood glucose management in diabetic patients undergoing ambulatory surgery. Anesth Analg 2010; 111:1378–1387. [CrossRef]

36. Newton CA, Raskin P. Diabetic ketoacidosis in type 1 and type 2 diabetes mellitus: clinical and biochemical differences. Arch Intern Med 2004; 164:1925–1931. [CrossRef]
37. Misra S, Oliver N, Dornhorst A. Diabetic ketoacidosis: not always due to type 1 diabetes. BMJ 2013; 346:f3501. [CrossRef]
38. Sobel SI, Augustine M, Donihi AC, Reider J, Forte P, Korytkowski M. Safety and efficacy of a peri-operative protocol for patients with diabetes treated with continuous subcutaneous insulin infusion who are admitted for same-day surgery. Endocr Pract 2015; 21:1269–1276. [CrossRef]
39. Heise T, Meneghini LF. Insulin stacking versus therapeutic accumulation: understanding the differences. Endocr Pract 2015; 20:75–83. [CrossRef]
40. Kurukulasuriya LR, Stas S, Lastra G, Manrique C, Sowers JR. Hypertension in obesity. Med Clin North Am 2011; 95:903–917. [CrossRef]
41. Goldman L, Caldera DL. Risks of general anesthesia and elective operation in the hypertensive patient. Anesthesiology 1979; 50:285–292. [CrossRef]
42. Rosen R. Angiography: general techniques, complications and risk management. In: Little JB, Taveras JM, Eds. Radiology diagnosis imaging-intervention. Lippincott: Philadelphia, 1992.
43. Varon J, Marik PE. Perioperative hypertension management. Vasc Health Risk Manag 2008; 4:615. [CrossRef]
44. Marik PE, Varon J. Hypertensive crises: challenges and management. Chest J 2007; 131:1949–1962. [CrossRef]
45. White PF, Song D. New criteria for fast-tracking after outpatient anesthesia: a comparison with the modified Aldrete's scoring system. Anesth Analg 1999; 88:1069–1072. [CrossRef]
46. Toure A, Vanhems P, Lombard-Bohas C, Souquet JC, Lauverjat M, Chambrier C. Is diabetes a risk factor for central venous access port-related bloodstream infection in oncological patients? Eur J Clin Microbiol Infect Dis 2013; 32:133–138. [CrossRef]
47. Winfield RD, Reese S, Bochicchio K, Mazuski JE, Bochicchio GV. Obesity and the risk for surgical site infection in abdominal surgery. Am Surg 2016; 82:331–336.
48. Shipman AR, Millington GW. Obesity and the skin. Br J Dermatol 2011; 165:743–750. [CrossRef]
49. Cox N, Resnic FS, Popma JJ, Simon DI, Eisenhauer AC, Rogers C. Comparison of the risk of vascular complications associated with femoral and radial access coronary catheterization procedures in obese versus nonobese patients. Am J Cardiol 2004; 94:1174–1177. [CrossRef]
50. Ando G, Capodanno D. Radial access reduces mortality in patients with acute coronary syndromes: results from an updated trial sequential analysis of randomized trials. JACC Cardiovasc Interv 2016; 9:660–670. [CrossRef]
51. Jolly SS, Amlani S, Hamon M, Yusuf S, Mehta SR. Radial versus femoral access for coronary angiography or intervention and the impact on major bleeding and ischemic events: a systematic review and meta-analysis of randomized trials. Am Heart J 2009; 157:132–140. [CrossRef]
52. McNulty PH, Ettinger SM, Field JM, et al. Cardiac catheterization in morbidly obese patients. Catheter Cardiovasc Interv 2002; 56:174–177. [CrossRef]
53. Ageno W, Becattini C, Brighton T, Selby R, Kamphuisen PW. Cardiovascular risk factors and venous thromboembolism: a meta-analysis. Circulation 2008; 117:93–102. [CrossRef]
54. Rondina MT, Wheeler M, Rodgers GM, Draper L, Pendleton RC. Weight-based dosing of enoxaparin for VTE prophylaxis in morbidly obese, medically-Ill patients. Thrombosis research 2010; 125:220–223. [CrossRef]
55. Imai K, Takai K, Nishigaki Y, et al. Insulin resistance raises the risk for recurrence of stage I hepatocellular carcinoma after curative radiofrequency ablation in hepatitis C virus-positive patients: A prospective, case series study. Hepatol Res 2010; 40:376–382. [CrossRef]
56. Wing RR, Phelan S. Long-term weight loss maintenance. Am J Clin Nutr 2005; 82:222s–225s.