C H A P T E R

38

Anesthesia for Orthopedic Surgery

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KEY CONCEPTS

1. Clinical manifestations of bone cement implantation syndrome include hypoxia (increased pulmonary shunt), hypotension, arrhythmias (including heart block and sinus arrest), pulmonary hypertension (increased pulmonary vascular resistance), and decreased cardiac output.
2. Use of a pneumatic tourniquet on an extremity creates a bloodless field that greatly facilitates the surgery. However, tourniquets can produce potential problems of their own, including hemodynamic changes, pain, metabolic alterations, arterial thromboembolism, and pulmonary embolism.
3. Fat embolism syndrome classically presents within 72 h following long-bone or pelvic fracture, with the triad of dyspnea, confusion, and petechiae.
4. Deep vein thrombosis and pulmonary embolism can cause morbidity and mortality following orthopedic operations on the pelvis and lower extremities.
5. Neuraxial anesthesia alone or combined with general anesthesia may reduce thromboembolic complications by several mechanisms, including sympathectomy-induced increases in lower extremity venous blood flow, systemic antiinflammatory effects of local anesthetics, decreased platelet reactivity, attenuated postoperative increase in factor VIII and von Willebrand factor, attenuated postoperative decrease in antithrombin III, and alterations in stress hormone release.
6. For patients receiving prophylactic low-molecular-weight heparin once daily, neuraxial techniques may be performed (or neuraxial catheters removed) 10–12 h after the previous dose, with a 4-h delay before administering the next dose.
7. Flexion and extension lateral radiographs of the cervical spine should be obtained preoperatively in patients with rheumatoid arthritis severe enough to require steroids, immune therapy, or methotrexate. If atlantoaxial instability is present, intubation should be performed with inline stabilization utilizing video or fiberoptic laryngoscopy.
8. Effective communication between the anesthesiologist and surgeon is essential during bilateral hip arthroplasty. If major hemodynamic instability occurs during the first hip replacement procedure, the second arthroplasty should be postponed.
9. Adjuvants such as opioids, clonidine, ketorolac, and neostigmine when added to local anesthetic solutions for intraarticular

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injection have been used in various combinations to extend the duration of analgesia following knee arthroscopy.

10 Effective postoperative analgesia facilitates early physical rehabilitation to maximize postoperative range of motion and prevent joint adhesions following knee replacement.

11 The interscalene brachial plexus block using ultrasound or electrical stimulation is ideally suited for shoulder procedures. Even when general anesthesia is employed, an interscalene block can supplement anesthesia and provide effective postoperative analgesia.

Orthopedic surgery challenges the anesthesia provider. The comorbidities of these patients vary widely based on age group. Patients may present as neonates with congenital limb deformities, as teenagers with sports-related injuries, as adults for procedures ranging from excision of minor soft-tissue mass to joint replacement, or at any age with bone cancer. This chapter focuses on perioperative care issues specific to patients undergoing common orthopedic surgical procedures. For example, patients with long bone fractures are predisposed to fat embolism syndrome. Patients are at increased risk for venous thromboembolism following pelvic, hip, and knee operations. Use of bone cement during arthroplasties can cause hemodynamic instability. Limb tourniquets limit blood loss but introduce additional risks.

Neuraxial and other regional anesthetic techniques play an important role in decreasing the incidence of perioperative thromboembolic complications, providing postoperative analgesia, and facilitating early rehabilitation and hospital discharge. Advances in surgical techniques, such as minimally invasive approaches to knee and hip replacement, are necessitating modifications in anesthetic and perioperative management to facilitate overnight or even same-day discharge of patients who formerly required days of hospitalization. It is impossible to cover the anesthetic implications of diverse orthopedic operations in one chapter; hence, the focus here on perioperative management considerations and strategies for the anesthetic management of patients undergoing select orthopedic surgical procedures. Anesthesia for surgery on the spine is discussed in Chapter 27.

PERIOPERATIVE MANAGEMENT CONSIDERATIONS IN ORTHOPEDIC SURGERY

Bone Cement

Bone cement, **polymethylmethacrylate**, is frequently required for joint arthroplasties. The cement interdigitates within the interstices of cancellous bone and strongly binds the prosthetic device to the patient's bone. Mixing polymerized methylmethacrylate powder with liquid methylmethacrylate monomer causes polymerization and cross-linking of the polymer chains. This exothermic reaction leads to hardening of the cement and expansion against the prosthetic components. The resultant intramedullary hypertension (>500 mm Hg) can cause embolization of fat, bone marrow, cement, and air into venous channels. Systemic absorption of residual methylmethacrylate monomer can produce vasodilation and a decrease in systemic vascular resistance. The release of tissue thromboplastin may trigger platelet aggregation, microthrombus formation in the lungs, and cardiovascular instability as a result of the circulation of vasoactive substances.

1 The clinical manifestations of bone cement implantation syndrome include hypoxia (increased pulmonary shunt), hypotension, arrhythmias (including heart block and sinus arrest), pulmonary hypertension (increased pulmonary vascular resistance), and decreased cardiac output. Emboli most frequently occur during insertion of a femoral prosthesis for hip arthroplasty. Treatment strategies

for this complication include increasing inspired oxygen concentration prior to cementing, monitoring to maintain euvolemia, creating a vent hole in the distal femur to relieve intramedullary pressure, performing high-pressure lavage of the femoral shaft to remove debris (potential microemboli), or using a femoral component that does not require cement.

Another source of concern related to the use of cement is the potential for gradual loosening of the prosthesis over time. Newer cementless implants are made of a porous material that allows natural bone to grow into them. Cementless prostheses generally last longer and may be advantageous for younger, active patients; however, healthy active bone formation is required and recovery may be longer compared to cemented joint replacements. Therefore, cemented prostheses are preferred for older (>80 years) and less active patients who often have osteoporosis or thin cortical bone. Practices continue to evolve regarding selection of cemented versus cementless implants, depending on the joint affected, patient, and surgical technique.

Pneumatic Tourniquets

2 Use of a pneumatic tourniquet on an extremity creates a bloodless field that greatly facilitates surgery. However, tourniquets can produce potential problems of their own, including hemodynamic changes, pain, metabolic alterations, arterial thromboembolism, and pulmonary embolism. Inflation pressure is usually set approximately 100 mm Hg higher than the patient's baseline systolic blood pressure. Prolonged inflation (>2 h) routinely leads to transient muscle dysfunction from ischemia and may produce rhabdomyolysis or permanent peripheral nerve damage. Tourniquet inflation has also been associated with increases in body temperature in pediatric patients undergoing lower extremity surgery.

Exsanguination of a lower extremity and tourniquet inflation cause a rapid shift of blood volume into the central circulation. Although not usually clinically important, bilateral lower extremity exsanguination can cause an increase in central venous pressure and arterial blood pressure that may not be well tolerated in patients with noncompliant ventricles and diastolic dysfunction.

Awake patients predictably experience tourniquet pain with inflation pressures of 100 mm Hg above systolic blood pressure for more than a few minutes. The mechanism and neural pathways for this severe aching and burning sensation defy precise explanation. **Tourniquet pain gradually becomes so severe over time that patients may require substantial supplemental analgesia, if not general anesthesia, despite a regional block that is adequate for surgical anesthesia.** Even during general anesthesia, stimulus from tourniquet compression often manifests as a gradually increasing mean arterial blood pressure beginning approximately 1 h after cuff inflation. Signs of progressive sympathetic activation include marked hypertension, tachycardia, and diaphoresis. The likelihood of tourniquet pain and its accompanying hypertension may be influenced by many factors, including anesthetic technique (regional anesthesia versus general anesthesia), extent of dermatomal spread of regional anesthetic block, choice of local anesthetic and dose ("intensity" of block), and supplementation with adjuvants either intravenously or in combination with local anesthetic solutions when applicable.

Cuff deflation invariably and immediately relieves tourniquet pain and associated hypertension. In fact, cuff deflation may be accompanied by a precipitous decrease in central venous and arterial blood pressure. Heart rate usually increases and core temperature decreases. Washout of accumulated metabolic wastes in the ischemic extremity increases partial pressure of carbon dioxide in arterial blood ($Paco_2$), end-tidal carbon dioxide ($Etco_2$), and serum lactate and potassium levels. **These metabolic alterations can cause an increase in minute ventilation in the spontaneously breathing patient and, rarely, arrhythmias**. Tourniquet-induced ischemia of a lower extremity may lead to the development of deep venous thrombosis. Transesophageal echocardiography can detect subclinical pulmonary embolism (miliary emboli in the right atrium and ventricle) following tourniquet deflation even in minor cases such as diagnostic knee arthroscopy. Rare episodes of massive pulmonary embolism during total knee arthroplasty have been reported during leg exsanguination, after tourniquet inflation, and following tourniquet deflation. Tourniquets have been safely used in patients with sickle cell disease, although particular attention should be paid to maintaining oxygenation, normocarbia or hypocarbia, hydration, and normothermia.

Fat Embolism Syndrome

Some degree of fat embolism probably occurs with all long-bone fractures. **Fat embolism syndrome** is less frequent but potentially fatal (10–20% mortality). 3 It classically presents within 72 h following long-bone or pelvic fracture, with the triad of dyspnea, confusion, and petechiae. This syndrome can also be seen following cardiopulmonary resuscitation, parental feeding with lipid infusion, and liposuction. The most popular theory for its pathogenesis holds that fat globules are released by the disruption of fat cells in the fractured bone and enter the circulation through tears in medullary vessels. An alternative theory proposes that the fat globules are chylomicrons resulting from the aggregation of circulating free fatty acids caused by changes in fatty acid metabolism. Regardless of their source, the increased free fatty acid levels can have a toxic effect on the capillary–alveolar membrane leading to the release of vasoactive amines and prostaglandins and the development of acute respiratory distress syndrome (ARDS; see Chapter 57). Neurological manifestations (eg, agitation, confusion, stupor, or coma) are the probable result of capillary damage in the cerebral circulation and cerebral edema. These signs may be exacerbated by hypoxia.

The diagnosis of fat embolism syndrome is suggested by petechiae on the chest, upper extremities, axillae, and conjunctiva. Fat globules occasionally may be observed in the retina, urine, or sputum. Coagulation abnormalities such as thrombocytopenia or prolonged clotting times are occasionally present. Serum lipase activity may be elevated but does not predict disease severity. Pulmonary involvement typically progresses from mild hypoxia and a normal chest radiograph to severe hypoxia or respiratory failure with radiographic findings of diffuse pulmonary opacities. Most of the classic signs and symptoms of fat embolism syndrome occur 1–3 days after the precipitating event. During general anesthesia, signs may include a decline in E_{TCO_2} and arterial oxygen saturation and a rise in pulmonary artery pressures. Electrocardiography may show ischemic-appearing ST-segment changes and a pattern of right-sided heart strain.

Management is two-fold: preventative and supportive. Early stabilization of the fracture decreases the incidence of fat embolism syndrome and, in particular, reduces the risk of pulmonary complications. Supportive treatment consists of oxygen therapy with continuous positive airway pressure ventilation to prevent hypoxia and with specific ventilator strategies in the event of ARDS. Systemic hypotension will require appropriate pressor support, and vasodilators may aid the management of pulmonary hypertension. High-dose corticosteroid therapy is not supported by randomized clinical trials.

Deep Venous Thrombosis & Thromboembolism

4 Deep vein thrombosis (DVT) and pulmonary embolism (PE) can cause morbidity and mortality following orthopedic operations on the pelvis and lower extremities. Risk factors include obesity, age greater than 60 years, procedures lasting more than 30 min, use of a tourniquet, lower extremity fracture, and immobilization for more than 4 days. Patients at greatest risk include those undergoing hip surgery and knee replacement or major operations for lower extremity trauma. Such patients will experience DVT rates of 40–80% without prophylaxis. The incidence of clinically important PE following hip surgery in some studies is reported to be as high as 20%, whereas that of fatal PE may be 1–3%. Underlying pathophysiological mechanisms include venous stasis with hypercoagulable state due to localized and systemic inflammatory responses to surgery.

Pharmacological prophylaxis and the routine use of mechanical devices such as intermittent pneumatic compression (IPC) have been shown to decrease the incidence of DVT and PE. While mechanical thromboprophylaxis should be considered for every patient, the use of pharmacological anticoagulants must be balanced against the risk of major bleeding. For patients at increased risk for DVT but having "normal" bleeding risk, low-dose subcutaneous unfractionated heparin (LUFH), warfarin, or low-molecular-weight heparin (LMWH) may be employed in addition to mechanical prophylaxis. Patients at significantly increased risk of bleeding may be managed with mechanical prophylaxis alone until bleeding risk decreases. In general, anticoagulants are started the day of surgery in patients without indwelling epidural catheters. Warfarin may be started the night before surgery depending on the particular orthopedic surgeon's routine.

5 Neuraxial anesthesia alone or combined with general anesthesia may reduce thromboembolic complications by several mechanisms. These include sympathectomy-induced increases in lower extremity venous blood flow, systemic antiinflammatory effects of local anesthetics, decreased platelet reactivity, attenuated postoperative increases in factor VIII and von Willebrand factor, attenuated postoperative decreases in antithrombin III, and alterations in stress hormone release.

According to the Third Edition of the American Society of Regional Anesthesia and Pain Medicine Evidence-Based Guidelines on regional anesthesia and anticoagulation, patients currently receiving antiplatelet agents (eg, ticlopidine, clopidogrel, and intravenous glycoprotein IIb/IIIa inhibitors), thrombolytics, fondaparinux, direct thrombin inhibitors, or therapeutic regimens of LMWH present an unacceptable risk for spinal or epidural hematoma following neuraxial anesthesia. Performance of neuraxial block (or removal of a neuraxial catheter) is not contraindicated with subcutaneous LUFH when the total daily dose is 10,000 units or less; there are no data on the safety of neuraxial anesthesia
6 when larger doses are given. For patients receiving prophylactic LMWH, the guidelines vary based on regimen. With once-daily dosing, neuraxial techniques may be performed (or neuraxial catheters removed) 10–12 h after the previous dose, with a 4-h delay before administering the next dose. With twice-daily dosing, neuraxial catheters should not be left in situ and should be removed 2 h before the first dose of LMWH. Patients on warfarin therapy should not receive a neuraxial block unless the international normalized ratio (INR) is normal, and catheters should be removed when the INR is 1.5 or lower. The Third Edition of the guidelines also suggests that these recommendations be applied to deep peripheral nerve and plexus blocks and catheters (see Suggested Reading). Revisions to these guidelines occur regularly.

Hip Surgery

Common hip procedures performed in adults include repair of hip fracture, total hip arthroplasty, and closed reduction of hip dislocation.

FRACTURE OF THE HIP

Preoperative Considerations

Most patients presenting for hip fractures are frail and elderly. An occasional young patient will have sustained major trauma to the femur or pelvis. Studies have reported mortality rates following hip fracture of up to 10% during the initial hospitalization and over 25% within 1 year. Many of these patients have concomitant diseases such as coronary artery disease, cerebrovascular disease, chronic obstructive pulmonary disease, or diabetes.

Patients presenting with hip fractures are frequently dehydrated from inadequate oral intake. Depending on the site of the hip fracture, occult blood loss may be significant, further compromising intravascular volume. In general, intracapsular (subcapital, transcervical) fractures are associated with less blood loss than extracapsular (base of the femoral neck, intertrochanteric, subtrochanteric) fractures (Figure 38–1). A normal or borderline-low preoperative hematocrit may be deceiving when hemoconcentration masks occult blood loss.

Another characteristic of hip fracture patients is the frequent presence of preoperative hypoxia that may, at least in part, be due to fat embolism; other factors can include bibasilar atelectasis from immobility, pulmonary congestion (and effusion) from congestive heart failure, or consolidation due to infection.

Intraoperative Management

The choice between regional (spinal or epidural) and general anesthesia has been extensively evaluated for hip fracture surgery. A meta-analysis of

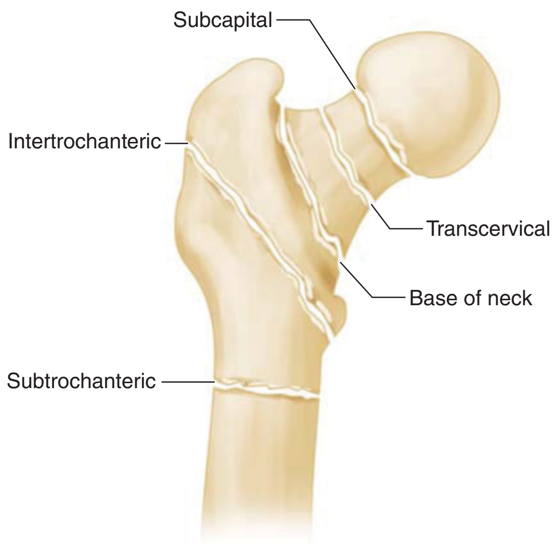

FIGURE 38–1 Blood loss from hip fracture depends on the location of the fracture (subtrochanteric, intertrochanteric > base of femoral neck > transcervical, subcapital) because the capsule restricts blood loss by acting like a tourniquet.

FIGURE 38–2 Uncemented total hip arthroplasty.

15 randomized clinical trials showed a decrease in postoperative DVT and 1-month mortality with regional anesthesia, but these advantages do not persist beyond 3 months. The incidence of postoperative delirium and cognitive dysfunction may be lower following regional anesthesia if intravenous sedation can be minimized.

A neuraxial anesthetic technique, with or without concomitant general anesthesia, provides the additional advantage of postoperative pain control. If a spinal anesthetic is planned, hypobaric or isobaric local anesthesia facilitates positioning since the patient can remain in the same position for both block placement and surgery. Intrathecal opioids such as morphine can extend postoperative analgesia but require close postoperative monitoring for delayed respiratory depression.

Consideration should also be given to the type of reduction and fixation to be used. This is dependent on the fracture site, degree of displacement, preoperative functional status of the patient, and surgeon preference. Undisplaced fractures of the proximal femur may be treated with percutaneous pinning or cannulated screw fixation with the patient in the supine position. A hip compression screw and side plate are most often employed for intertrochanteric fractures. Displaced intracapsular fractures may require internal fixation, hemiarthroplasty, or total hip replacement (Figure 38–2). Surgical treatment of extracapsular hip fractures is accomplished with either an extramedullary implant (eg, sliding screw and plate) or intramedullary implant (eg, Gamma nail).

Hemiarthroplasty and total hip replacement are longer, more invasive operations than other procedures. They are usually performed with patients in the lateral decubitus position, are associated with greater blood loss, and, potentially, result in greater hemodynamic changes, particularly if cement is used. Therefore, one should secure sufficient venous access to permit rapid transfusion.

TOTAL HIP ARTHROPLASTY

Preoperative Considerations

Most patients undergoing total hip replacement suffer from osteoarthritis (degenerative joint disease), autoimmune conditions such as rheumatoid arthritis (RA), or avascular necrosis. Osteoarthritis is a degenerative disease affecting the articular surface of one or more joints (most commonly the hips and knees). The etiology of osteoarthritis appears to involve repetitive joint trauma. Because osteoarthritis may also involve the spine, neck manipulation during tracheal intubation should be minimized to avoid nerve root compression or disc protrusion.

RA is characterized by immune-mediated joint destruction with chronic and progressive inflammation of synovial membranes, as opposed to the articular wear and tear of osteoarthritis. RA is a systemic disease affecting multiple organ systems (Table 38–1). RA often affects the small joints of the hands, wrists, and feet causing severe deformity; when this occurs, intravenous and radial artery cannulation can be challenging.

Extreme cases of RA involve almost all synovial membranes, including those in the cervical spine and temporomandibular joint. Atlantoaxial subluxation, which can be diagnosed radiologically, may lead to protrusion of the odontoid process into the foramen magnum during intubation, compromising vertebral blood flow and compressing the spinal cord or brainstem (Figure 38–3). 7 Flexion and extension lateral radiographs of the cervical spine should be obtained preoperatively in patients with RA severe enough to require steroids, immune therapy, or methotrexate. If atlantoaxial instability is present, tracheal intubation should be performed with inline stabilization utilizing video or fiberoptic laryngoscopy. Involvement of the temporomandibular joint can limit jaw mobility and range of motion to such a degree that conventional orotracheal intubation may be impossible. Hoarseness or inspiratory stridor may signal a narrowing of the glottic opening caused by cricoarytenoid arthritis. This condition may lead to postextubation airway obstruction even when a smaller diameter tracheal tube has been used.

Patients with RA or osteoarthritis commonly receive nonsteroidal antiinflammatory drugs (NSAIDs) for pain management. These drugs can have serious side effects such as gastrointestinal bleeding, renal toxicity, and platelet dysfunction.

TABLE 38–1 Systemic manifestations of rheumatoid arthritis.

Organ System	Abnormalities
Cardiovascular	Pericardial thickening and effusion, myocarditis, coronary arteritis, conduction defects, vasculitis, cardiac valve fibrosis (aortic regurgitation)
Pulmonary	Pleural effusion, pulmonary nodules, interstitial pulmonary fibrosis
Hematopoietic	Anemia, eosinophilia, platelet dysfunction (from aspirin therapy), thrombocytopenia
Endocrine	Adrenal insufficiency (from glucocorticoid therapy), impaired immune system
Dermatological	Thin and atrophic skin from the disease and immunosuppressive drugs

Intraoperative Management

Total hip replacement (THR) involves several surgical steps, including positioning of the patient (usually in the lateral decubitus position), dislocation and removal of the femoral head, reaming of the acetabulum and insertion of a prosthetic acetabular cup (with or without cement), and reaming of the femur and insertion of a femoral component (femoral head and stem) into the femoral shaft (with or without cement). THR is also associated with three potentially life-threatening complications: bone cement implantation syndrome, intra- and postoperative hemorrhage, and venous thromboembolism. Thus, invasive arterial monitoring may be justified for select patients undergoing these procedures. Neuraxial administration of opioids such as morphine in the perioperative period extends the duration of postoperative analgesia.

A. Hip Resurfacing Arthroplasty

The increasing number of younger patients presenting for hip arthroplasty and of other patients who require revision of standard (metal-on-polyethylene) total

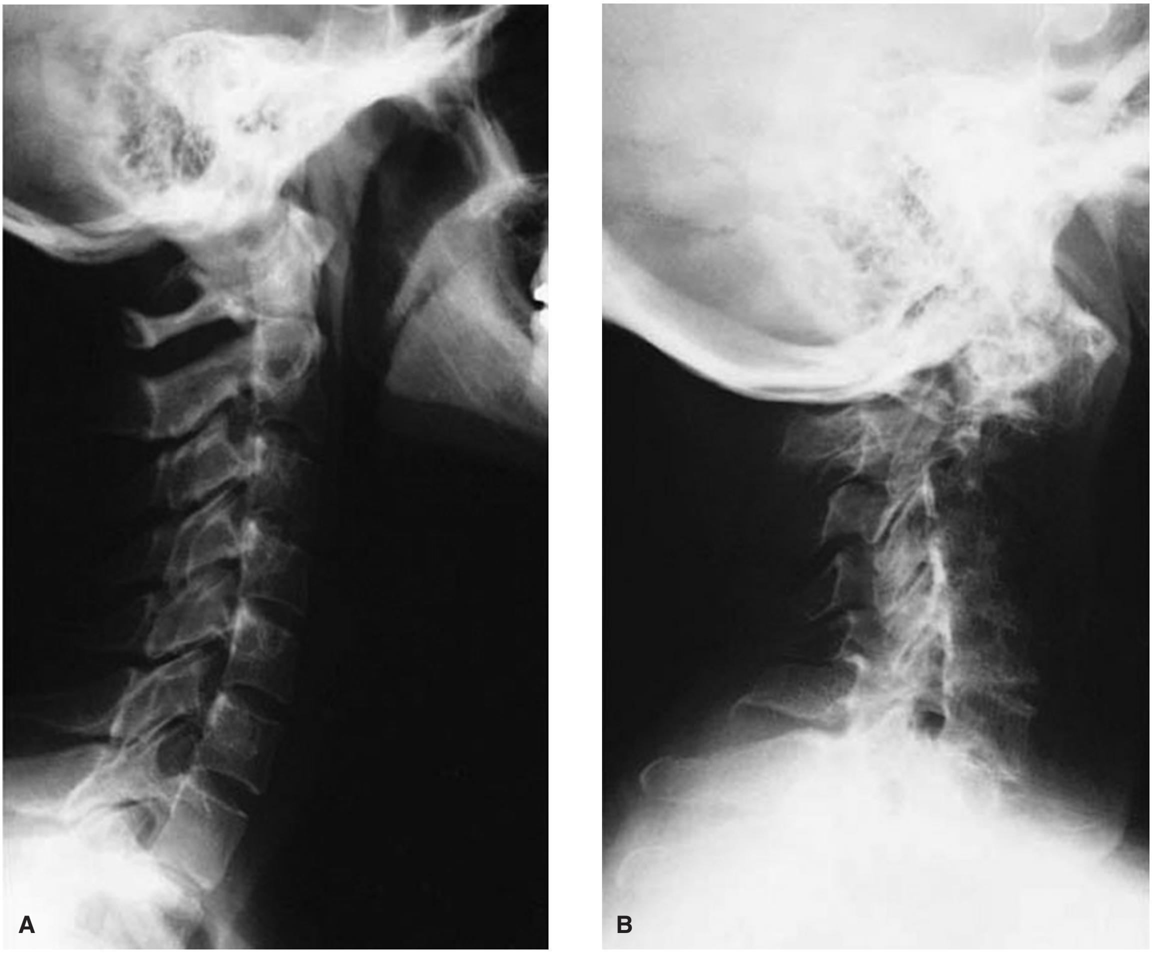

FIGURE 38–3 Because instability of the cervical spine may be asymptomatic, lateral radiographs are mandatory in patients with severe rheumatoid arthritis. **A**: Radiograph of a normal lateral cervical spine. **B**: Lateral cervical spine of a patient with rheumatoid arthritis; note the severe C1–C2 instability.

hip arthroplasty implants has led to redevelopment of hip resurfacing arthroplasty techniques. Compared with traditional hip arthroplasty implants, hip resurfacing maintains patients' native bone to a greater degree. Metal-on-metal hybrid implants are usually employed. Surgical approaches can be anterolateral or posterior, with the posterior approach theoretically providing greater preservation of the blood supply to the femoral head. With the posterior approach, patients are placed in the lateral decubitus position similar to traditional hip arthroplasty.

Outcomes data related to hip resurfacing versus traditional total hip arthroplasty are controversial. Prospective studies have not shown a difference in gait or postural balance at 3 months postoperatively. A recent meta-analysis favored resurfacing in terms of functional outcome and blood loss despite comparable results for postoperative pain scores and patient satisfaction. Of particular concern is the finding that patients who undergo resurfacing are nearly twice as likely to require revision surgery as those receiving traditional hip arthroplasty. There is a higher incidence of aseptic component loosening (possibly from metal hypersensitivity) and femoral neck fracture, particularly in women. Finally, the presence of metal debris in the joint space (from metal-on-metal contact) has led to a marked narrowing of indications for the prostheses and the procedure.

B. Bilateral Arthroplasty

Bilateral hip arthroplasty can be safely performed in fit patients as a combined procedure, assuming the absence of significant pulmonary embolization after insertion of the first femoral component. Monitoring may include echocardiography. Effective communication between the anesthesia provider and surgeon is essential. If major hemodynamic instability occurs during the first hip replacement procedure, the second arthroplasty should be postponed.

8

C. Revision Arthroplasty

Revision of a prior hip arthroplasty may be associated with much greater blood loss than in the initial procedure. Blood loss depends on many factors, including the experience and skill of the surgeon. Some studies suggest that blood loss may be decreased during hip surgery if a regional anesthesia technique is used (eg, spinal or epidural anesthesia) compared with general anesthesia even at similar mean arterial blood pressures. The mechanism is unclear. Because the likelihood of perioperative blood transfusion is high, preoperative autologous blood donation and intraoperative blood salvage should be considered. Preoperative administration of vitamins (B_{12} and K) and iron can treat mild forms of chronic anemia. Alternatively (and more expensively), recombinant human erythropoietin (600 IU/kg subcutaneously weekly beginning 21 days before surgery and ending on the day of surgery) may also decrease the need for perioperative allogeneic blood transfusion. Erythropoietin increases red blood cell production by stimulating the division and differentiation of erythroid progenitors in the bone marrow. Maintaining normal body temperature during hip replacement surgery reduces blood loss.

D. Minimally Invasive Arthroplasty

Computer-assisted surgery (CAS) may improve surgical outcomes and promote early rehabilitation through minimally invasive techniques employing cementless implants. Computer software can accurately reconstruct three-dimensional images of bone and soft tissue based on radiographs, fluoroscopy, computed tomography, or magnetic resonance imaging. The computer matches preoperative images or planning information to the position of the patient on the operating room table. Tracking devices are attached to target bones (Figure 38–4) and instruments used during surgery, and the navigation system utilizes optical cameras and infrared light-emitting diodes to sense their positions. CAS thus allows accurate placement of implants through

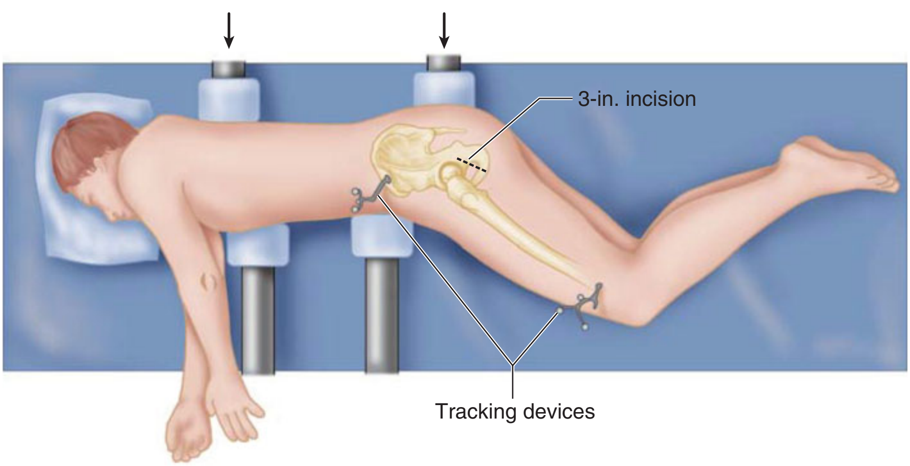

FIGURE 38–4 Minimally invasive total hip arthroplasty: lateral approach. Note the small 3-in. incision and tracking devices for the CAS navigation system.

small incisions, and the resulting reduction in tissue and muscle damage could lead to less pain and early rehabilitation. The lateral approach utilizes a single 3-in. incision with the patient in the lateral decubitus position (Figure 38–4); an anterior approach utilizes two separate 2-in. incisions (one for the acetabular component and another for the femoral component) with the patient supine. Minimally invasive techniques can reduce hospitalization to 24 h or less. Anesthetic techniques should promote rapid recovery and can include neuraxial regional anesthesia or total intravenous general anesthesia.

E. Hip Arthroscopy

In recent years, hip arthroscopy has increased in popularity as a minimally invasive alternative to open arthrotomy for a variety of surgical indications such as femoroacetabular impingement (FAI), acetabular labral tears, loose bodies, and osteoarthritis. At present, there is fair evidence in the published literature (small, randomized controlled trials) to support hip arthroscopy for FAI, but evidence is lacking for other indications.

CLOSED REDUCTION OF HIP DISLOCATION

There is a 3% incidence of hip dislocation following primary hip arthroplasty and a 20% incidence following total hip revision arthroplasty. Because less force is required to dislocate a prosthetic hip, patients with hip implants require special precautions during positioning for subsequent surgical procedures. Extremes of hip flexion, internal rotation, and adduction increase the risk of dislocation. Hip dislocations may be corrected with closed reduction facilitated by use of a brief general anesthetic. Temporary paralysis can be provided by succinylcholine, if necessary, to facilitate the reduction when the hip musculature is severely contracted. Successful reduction should be confirmed radiologically prior to the patient's emergence.

Knee Surgery

The two most frequently performed knee surgeries are arthroscopy and total or partial joint replacement.

KNEE ARTHROSCOPY

Preoperative Considerations

Arthroscopy has revolutionized surgery of many joints, including the hip, knee, shoulder, ankle, elbow, and wrist. Joint arthroscopies are usually performed as outpatient procedures. Although the typical patient undergoing knee arthroscopy is often thought of as being a healthy young athlete, knee arthroscopies are frequently performed in elderly patients with multiple medical problems.

Intraoperative Management

A bloodless field greatly facilitates arthroscopic surgery. Fortunately, knee surgery lends itself to the use of a pneumatic tourniquet. The surgery is performed as an outpatient procedure with the patient in a supine position under general anesthesia or neuraxial anesthesia. Alternative anesthetic techniques include peripheral nerve blocks, periarticular injections, or intraarticular injections employing local anesthetic solutions with or without adjuvants combined with intravenous sedation.

Comparing neuraxial anesthesia techniques, success and patient satisfaction appear to be equal between epidural and spinal anesthesia. However, for ambulatory surgery, time to discharge following neuraxial anesthesia may be prolonged compared with general anesthesia.

Postoperative Pain Management

Successful outpatient recovery depends on early ambulation, adequate pain relief, and minimal nausea and vomiting. Techniques that avoid large doses of systemic opioids have obvious appeal. Intraarticular local anesthetics (bupivacaine or ropivacaine) usually provide satisfactory analgesia for
9 several hours postoperatively. Adjuvants such as opioids, clonidine, ketorolac, epinephrine, and neostigmine when added to local anesthetic solutions for intraarticular injection have been used in various combinations to extend the duration of analgesia. Other multimodal pain management strategies include systemic NSAIDs, gabapentin, and single or continuous peripheral nerve blocks for arthroscopic ligament reconstruction.

TOTAL KNEE REPLACEMENT

Preoperative Considerations

Patients presenting for total knee replacement (Figure 38–5) have similar comorbidities to those undergoing total hip replacement (eg, RA, osteoarthritis).

Intraoperative Management

During total knee arthroplasty, patients remain in a supine position, and intraoperative blood loss is limited by the use of a tourniquet. Cooperative patients usually tolerate a neuraxial anesthetic technique with intravenous sedation. Bone cement implantation syndrome following insertion of a femoral prosthesis is possible but is less likely than during hip arthroplasty. Subsequent release of emboli into the systemic circulation may exaggerate any tendency for hypotension following tourniquet release.

Preoperative placement of a lumbar epidural or perineural catheter can be very helpful in

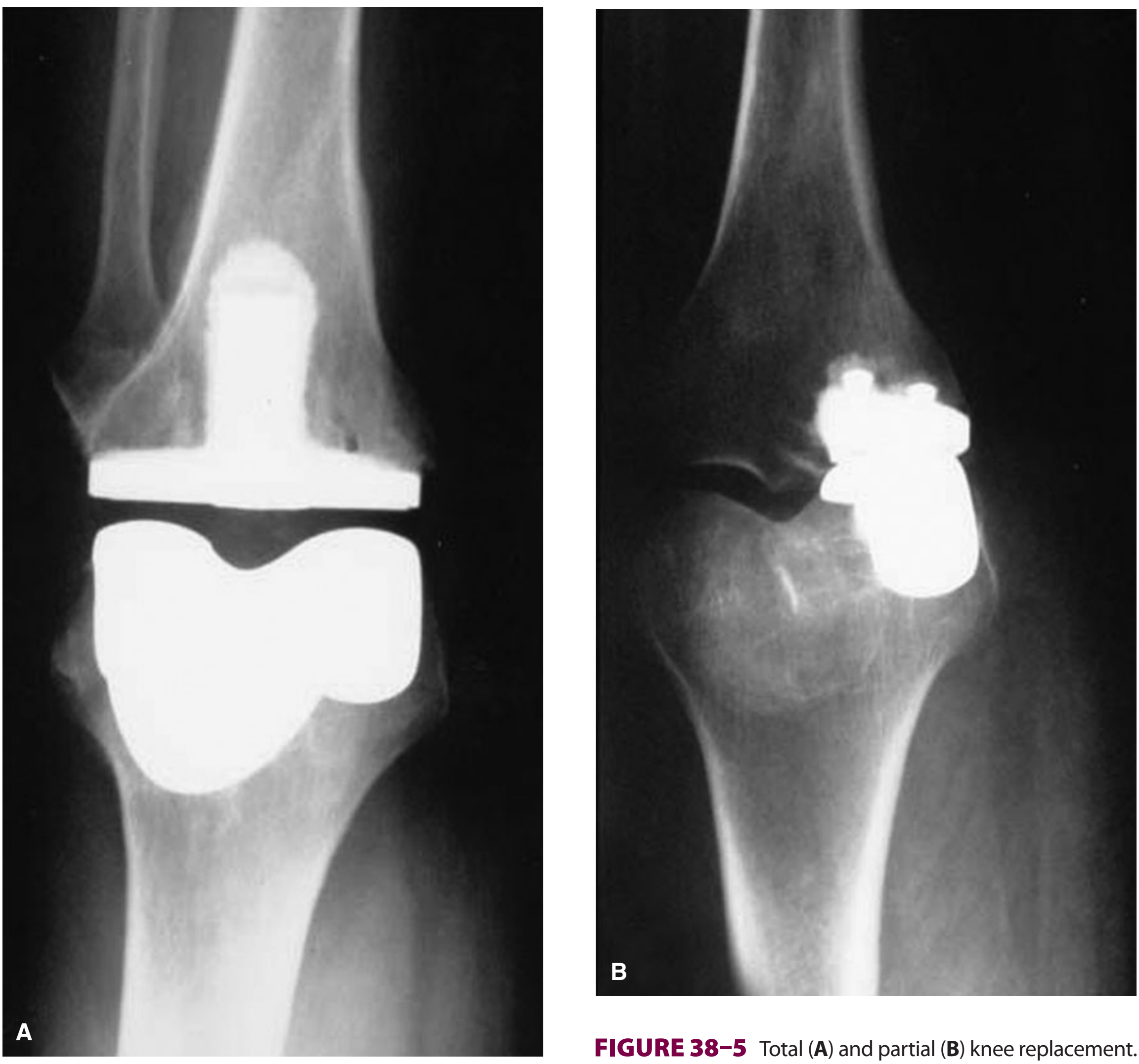

FIGURE 38–5 Total (**A**) and partial (**B**) knee replacement.

managing postoperative pain, which is typically more severe than pain following hip replacement 10 surgery. Effective postoperative analgesia facilitates early physical rehabilitation to maximize postoperative range of motion and prevent joint adhesions following knee replacement. It is important to balance pain control with the need for an alert and cooperative patient during physical therapy. Epidural analgesia is useful in bilateral knee replacements. **For unilateral knee replacement, lumbar epidural and femoral perineural catheters provide equivalent analgesia while femoral perineural catheters produce fewer side effects (eg, pruritus, nausea and vomiting, urinary retention, or orthostatic lightheadedness).** Preoperative placement in a "block room" can prevent operating room delays and ensure that patients receive this beneficial analgesic technique (Figure 38–6).

Partial knee replacement (unicompartmental or patellofemoral) and minimally invasive knee arthroplasty with muscle-sparing approaches have been described. With strict patient selection, these techniques may reduce quadriceps muscle damage, facilitating earlier achievement of range-of-motion and ambulation goals, and may allow for discharge within 24 h following surgery if outpatient physical therapy is arranged. Anesthetic management and postoperative analgesia should accommodate and facilitate the accelerated recovery schedule. Single or continuous peripheral nerve blocks, alone or in combination, can provide target-specific pain control and facilitate early rehabilitation. **In randomized clinical trials, continuous peripheral nerve block catheters with subsequent perineural local anesthetic infusions have been shown to decrease time to meet discharge criteria for total knee arthroplasty.** The management of perineural catheters takes a hands-on team approach and can be incorporated into integrated clinical pathways involving surgery, nursing, and physical therapy. Among the complications of lower extremity perineural local anesthetic infusions, those involving patient falls are of greatest concern, and comprehensive fall prevention programs need to be in place wherever these techniques are employed.

FIGURE 38–6 A "block room" can be located in a preoperative holding area, induction room, or postanesthesia care unit and should offer standard monitoring (as outlined by the American Society of Anesthesiologists) and ample storage for regional anesthesia supplies and equipment.

Surgery on the Upper Extremity

Procedures on the upper extremities include those for disorders of the shoulder (eg, subacromial impingement or rotator cuff tears), traumatic fractures, nerve entrapment syndromes (eg, carpal tunnel syndrome), and joint arthroplasties (eg, rheumatoid arthritis).

SHOULDER SURGERY

Shoulder operations may be open or arthroscopic. These procedures are performed either in a sitting ("beach chair") or, less commonly, the lateral decubitus position. **The beach chair position may be associated with decreases in cerebral perfusion as measured by tissue oximetry; cases of blindness, stroke, and even brain death have been described, emphasizing the need to accurately measure blood pressure at the level of the brain.** When using noninvasive blood pressure monitoring, the cuff should be applied on the upper arm because systolic blood pressure readings from the calf can be 40 mm Hg higher than brachial readings on the same patient. If a surgeon requests controlled hypotension, an arterial catheter for invasive blood pressure monitoring is recommended, and the transducer should be positioned at least at the level of the heart or, preferably, the brainstem (external meatus of the ear).

11 The interscalene brachial plexus block using ultrasound or electrical stimulation is ideally suited for shoulder procedures. The supraclavicular approach also can be used. Even when general anesthesia is employed, an interscalene block can supplement anesthesia and provide effective postoperative analgesia. Intense muscle relaxation is usually required for major shoulder surgery during general anesthesia, particularly when not combined with a brachial plexus block.

Preoperative insertion of an indwelling perineural catheter with subsequent infusion of a dilute local anesthetic infusion solution allows postoperative analgesia for 48–72 h with most fixed-reservoir disposable pumps following arthroscopic or open shoulder operations (see Chapter 46). Alternatively, surgeons may insert a subacromial catheter to provide continuous infusion of local anesthetic for postoperative analgesia. Direct placement of intraarticular catheters into the glenohumeral joint with infusion of bupivacaine has been associated with postarthroscopic glenohumeral chondrolysis in retrospective human and prospective animal studies and is not currently recommended. Multimodal analgesia, including systemic NSAIDs (if no contraindications) and local anesthetic infusions in the perioperative period, can help reduce postoperative opioid requirements.

DISTAL UPPER EXTREMITY SURGERY

Distal upper extremity surgical procedures generally take place on an outpatient basis. Minor soft tissue operations of the hand (eg, carpal tunnel release) of short duration may be performed with local infiltration or with intravenous regional anesthesia (IVRA, or Bier block). The limiting factor with IVRA is tourniquet tolerance.

For operations lasting more than 1 h or more invasive procedures involving bones or joints, a brachial plexus block is the preferred regional anesthetic technique. Multiple approaches can be used to anesthetize the brachial plexus for distal upper extremity surgery (see Chapter 46). Selection of brachial plexus block technique should take into account the planned surgical site and location of the pneumatic tourniquet, if applicable. Continuous peripheral nerve blocks may be appropriate for inpatient and select outpatient procedures to extend the duration of analgesia further into the postoperative period or facilitate physical therapy. Brachial plexus blocks do not anesthetize the intercostobrachial nerve distribution (arising from the dorsal rami of T1 and sometimes T2); hence, subcutaneous infiltration of local anesthetic may be required for procedures involving the medial upper arm.

Anesthetic considerations for distal upper extremity surgery should include patient positioning and use of a pneumatic tourniquet. Most procedures can be performed with the patient supine; the operative arm abducted 90° and resting on a hand table; and the operating room table rotated 90° to position the operative arm in the center of the room. Exceptions to this rule often involve surgery around the elbow, and certain operations may require the patient be in lateral decubitus or even prone position. Because patients are often scheduled for same-day discharge, perioperative management should focus on ensuring rapid emergence and preventing severe postoperative pain and nausea (see Chapter 44).

CASE DISCUSSION

Managing Blood Loss in Jehovah's Witnesses

A 58-year-old Jehovah's Witness presents for hemipelvectomy to resect a malignant bone tumor (osteogenic sarcoma). The patient has received chemotherapy over the last 2 months with multiple drugs, including doxorubicin. The patient has no other medical problems, and the preoperative hematocrit is 47%.

How does the care of Jehovah's Witnesses particularly challenge the anesthesiologist?

Jehovah's Witnesses, a fellowship of more than 1 million Americans, object to the administration of blood for any indication. This objection stems from their interpretation of the Bible ("to keep abstaining from . . . blood," Acts 15:28,29) and not for medical reasons (eg, the fear of hepatitis). Physicians are obliged to honor the principle of autonomy, which upholds that patients have final authority over what is done to them. Witnesses typically sign a waiver releasing physicians of liability for any consequences of blood refusal.

Which intravenous fluids will Witnesses accept?

Witnesses abstain from blood and blood products (eg, packed red blood cells, fresh frozen plasma, platelets) but not non–blood-containing solutions. They accept crystalloids, hetastarch, and dextran replacement solutions. Witnesses often view albumin, erythropoietin (because of the use of albumin), immune globulins, and hemophiliac preparations as a gray area that requires a personal decision by the believer.

Do they allow the use of autologous blood?

According to their religion, any blood that is removed from the body should be discarded ("You should pour it out upon the ground as water," Deuteronomy 12:24) and not stored. Thus, the usual practice of autologous preoperative collection and storage would not be allowed. Techniques of acute normovolemic hemodilution and intraoperative blood salvage have been accepted by some Witnesses, however, as long as their blood maintains continuity with their circulatory systems at all times. For example, up to 4 units of blood could be drawn from the patient immediately before surgery and kept in anticoagulant-containing bags that maintain a constant link to the patient's body. The blood could be replaced by an acceptable colloid or crystalloid solution then reinfused as needed during surgery.

How would the inability to transfuse blood affect intraoperative monitoring decisions?

Hemipelvectomy involves radical resection that can lead to massive blood loss. This is particularly true for large tumors removed using the more invasive internal approach. Invasive arterial blood pressure and central venous pressure monitors would be indicated in most patients undergoing this procedure. Techniques that minimize intraoperative blood loss (eg, controlled hypotension, aprotinin) should be considered. In a Jehovah's Witness, the management of life-threatening anemia (Hb <5 g/dL) may be improved by monitoring cardiac output, oxygen delivery, and oxygen consumption. Continuous electrocardiographic ST-segment analysis may signal myocardial ischemia.

What physiological effects result from severe anemia?

Assuming the maintenance of normovolemia and the absence of preexisting major end-organ dysfunction, most patients tolerate severe anemia surprisingly well. Decreased blood viscosity and vasodilation lower systemic vascular resistance and increase blood flow. Augmentation of stroke volume increases cardiac output, allowing arterial blood pressure and heart rate to remain relatively unchanged. Coronary and cerebral blood flows increase in the absence of coronary artery disease and carotid artery stenosis. A decrease in venous oxygen saturation reflects an increase in tissue oxygen extraction. Oozing from surgical wounds as a result of dilutional coagulopathy may accompany extreme degrees of anemia.

What are some of the anesthetic implications of preoperative doxorubicin therapy?

This anthracycline chemotherapeutic agent has well-recognized cardiac side effects, ranging from transient arrhythmias and electrocardiographic changes (eg, ST-segment and T-wave abnormalities) to irreversible cardiomyopathy and congestive heart failure. The risk of cardiomyopathy appears to increase with a cumulative dose greater than 550 mg/m^2, prior radiotherapy, and concurrent cyclophosphamide treatment. Mild degrees of cardiomyopathy can be detected preoperatively with endomyocardial biopsy, echocardiography, or exercise radionuclide angiography. The other important toxicity of doxorubicin is myelosuppression manifesting as thrombocytopenia, leukopenia, and anemia.

Are there any special considerations regarding postoperative pain management in the Jehovah's Witness?

Witnesses generally refrain from any mind-altering drugs or medications, although opioids prescribed by a physician for severe pain are accepted by some believers. Insertion of an epidural catheter can provide pain relief with local anesthetics, with or without opioids.

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