10

Anesthesia for Orthopedic Trauma

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1. Introduction

Orthopedic trauma surgeons realize the tremendous importance of coordinated care at trauma centers and by trauma systems. The anesthesiologist is an important link in the coordinated approach to orthopedic trauma care. "Musculoskeletal injuries are the most frequent indication for operative management in most trauma centers." Trauma management of a multiply-injured patient includes early stabilization of long-bone, pelvic, and acetabular fractures, provided that the patient has been adequately resuscitated. (Miller, 2009) Early stabilization leads to reduced pain and improved outcomes. (Smith, 2008) Studies have shown that failure to stabilize these fractures leads to increased morbidity, pulmonary complications, and increased length of hospital stay. (Miller, 2009) "Life threatening and limb-threatening musculoskeletal injuries should be addressed emergently." (Smith, 2008)

The chapter will discuss the following orthopedic trauma anesthesia issues:

- Pre-operative evaluation
- Airway management including difficult airways and cervical spine precautions
- Intra-operative monitoring
- Anesthetic agents and techniques (regional vs general anesthesia)
- Intra-operative complications (hypotension, blood loss, hypothermia, fat embolism syndrome)
- Post-operative pain management

2. Pre-operative evaluation

Orthopedic trauma patients can be challenging for Anesthesiologists. These patients can range in age from young to the elderly, may have multiple co-morbid medical conditions, and even a previously healthy patient may have trauma-associated injuries that may have a significant impact on the anesthetic plan. The Anesthesiologist's role is to evaluate the entire patient, with particular focus on the cardiovascular, respiratory, and other major organ system function. All patients undergoing anesthesia for an orthopedic surgery require pre-operative evaluation. (Miller, 2009) The goal of pre-operative evaluation is to obtain pertinent information that may alter the response to anesthetic drugs and increase the risk of complications due to impaired tissue oxygen delivery. Medical complexity, as assessed by the American Society of Anesthesiologists (ASA) physical status, correlates with perioperative morbidity and mortality.

Class	Description
Class I	Normally healthy
Class II	Patient with mild systemic disease (e.g. hypertension)
Class III	Patient with severe systemic disease (e.g. heart failure,), non-decompensated
Class IV	Patient with severe systemic disease, decompensated (e.g., decompensated heart failure, respiratory failure, unstable angina, hepatic encephalopathy)
Class V	Moribund patient, survival unlikely with or without surgery

Table 1. American Society of Anesthesiologists Physical Status (Miller, 2009)

2.1 Major organ systems

Age and functional status are useful in evaluating organ system reserves, and in determining sensitivity to anesthetic drugs. Patients with severe cardiac, pulmonary, hepatic, renal or neurologic disease are at increased risk for developing complications related to anesthesia, as are those with substance abuse and pregnant patients. (Miller, 2009)

2.1.1 Cardiovascular disease

Cardiovascular diseases including uncontrolled hypertension, ischemic heart disease, congestive heart failure, heart block, and arrhythmia increase the risk of anesthesia. Associated cardiac trauma may lead to low cardiac output due to tamponade, myocardial contusion, valvular disruption, and aortic dissection. Ischemic hypoxia and insufficient blood flow leads to cardiogenic shock and inadequate delivery of oxygen to the tissues. Any condition characterized by low cardiac output such as poor heart function, intense vasoconstriction, hypovolemia, or severe obstruction to blood flow should be optimized prior to surgery. Congenital heart disease may lead to intra-cardiac shunt and hypoxia.

Condition	Clinical Characteristics
Rhythm Disturbances	Significant, severe, or new onset arrhythmia, heart block, supraventricular tachycardia, ventricular arrhythmia or tachycardia
Coronary Artery Disease	Severe or unstable coronary syndromes, recent myocardial infarction
Valvular Heart Disease	Severe valvular disease, e.g., aortic stenosis and mitral valve disease
Congestive Heart Failure	Decompensated, worsening, or new heart failure

Table 2. Cardiac conditions requiring evaluation and treatment prior to orthopedic surgery (Fleisher, 2007)

2.1.2 Pacemakers and Internal Cardiac Defibrillators (ICDs)

If electrocautery is used in close proximity to an ICD or pacemaker, the electrical current generated can inhibit the pacemaker resulting in cardiogenic shock if the patient is pacemaker dependent. With an ICD device, use of the cautery may activate the ICD resulting in multiple shocks to the patient. The device itself may be damaged by electrocautery. Injury to cardiac tissue from current induced in leads imbedded in cardiac muscle may occur, leading to device failure. These patients deserve a cardiology consultation to properly manage the device. The ASA practice advisory recommends changing the conventional pacing function to an asynchronous pacing mode in pacemaker-dependent patients. The anti-tachyarrhythmia functions of ICDs, including the ability to provide defibrillation, should be suspended for the duration of surgery, assuming that electrocautery is required. After surgery, the device needs to be reprogrammed and function confirmed.

2.1.3 Respiratory disease

Patients with significant respiratory disease are at increased risk for pulmonary complications because of limited pulmonary reserve and because anesthetic drugs decrease the respiratory response to hypoxia and hypercarbia. This patient population develops hypoxia sooner than patients with normal respiratory function due to lower airway obstruction, lung tissue disease, inadequate alveolar-capillary transfer or intrapulmonary shunt. Respiratory failure may ensue, requiring post-operative mechanical ventilation. Chest trauma including pulmonary contusion, hemothorax, and pneumothorax may contribute to respiratory insufficiency. Pneumothorax may lead to shock if under tension, especially in the presence of positive pressure ventilation. Hemothorax may result in hemorrhagic shock (Smith, 2008)

Hypoxemia- Decreased arterial oxygen tension
Ventilation-Perfusion (V/Q) mismatch
Diffusion impairment
Hypoventilation
Hypercarbia – Increased arterial carbon dioxide (CO2) tension
Increased Dead Space
Increased CO_2 production
Disease affecting respiratory control centers
Respiratory muscle weakness
Increased respiratory muscle load

Table 3. Causes of respiratory failure

Causes of V/Q mismatch include interstitial lung disease, acute lung injury (ALI) or acute respiratory distress syndrome (ARDS), pneumonia, pulmonary edema, and pleural effusion. Causes of hypoventilation include depression of the central nervous system by drugs, diseases affecting the brainstem, neuromuscular disease resulting in respiratory muscle weakness, and chest wall abnormalities.

Increased dead space occurs in conditions such as pulmonary embolus or emphysema. Increased work of breathing due to impaired pulmonary compliance and increased pulmonary resistance may also contribute to respiratory failure. Increased resistance is due to bronchoconstriction, airway inflammation, or secretions in the airway. Decreased lung compliance may be due to pulmonary edema, pneumonia, fibrosis, or atelectasis. Decreased compliance can also be due to muscle or skeletal abnormalities of the chest wall or from intra-abdominal processes such as ascites, distended bowel, or abdominal compartment syndrome.

2.1.4 Morbid obesity

Obesity has become epidemic in industrialized countries and is an important contributor to early death. Patients with a body mass index (BMI) > 40 are considered morbidly obese. The pathophysiologic consequences of obesity impact every major organ system, and increases both morbidity and mortality. (Miller, 2009)

Factor	Considerations
Increased Prevalence of Obstructive Sleep Apnea (OSA) and Obesity-Hypoventilation Syndrome	Risk of hypoventilation, hypercarbia, apnea, hypoxia, arrhythmias, and cardiopulmonary arrest
Decreased Functional Residual Capacity	Decreased oxygen reservoir following period of apnea; Increased right-to-left trans-pulmonary shunt and atelectasis
Increased Work of Breathing	Increased oxygen consumption, increased weight of chest wall, decreased chest wall compliance
Difficult Airway Management	Large head and face makes mask placement difficult; Increased fat infiltration into oropharynx and peri-glottic structures interferes with glottic visualization during laryngoscopy; Increased airway obstruction during bag-mask ventilation; decreased head/neck movement.

Table 4. Respiratory system considerations in morbid obesity

OSA predisposes patients to airway obstruction, especially when sedated. Opioids are especially worrisome due to the potential for impaired control of breathing, post-operative apnea, and hypopneic episodes. OSA patients may require prolonged recovery in a monitored setting. The classic symptoms include daytime somnolence, a history of snoring, and apneic episodes while sleeping. Screening for OSA is routine. The apneic-hypopneic index is a useful measure of OSA severity and is obtained from polysomnography. Pulmonary hypertension, right ventricular failure and arrhythmias are not uncommon.

S. Snoring – "Do you snore loudly (louder than talking or loud enough to be heard through closed doors)?"
T. Tiredness during daytime – "Do you often feel tired, fatigued, or sleepy during daytime?"
O. Stop breathing during sleep – "Has anyone observed you stop breathing during your sleep?"
P. High blood pressure – "Do you have or are you being treated for high blood pressure?"
B. BMI – greater than 35 kg/m^2
A. Age – older than 50 years old
N. Neck circumference – greater than 40 cm (15.75 inches)
G. Gender – male

Table 5. STOP-BANG screening for OSA. High risk if positive for 3 or more of these 8 (Chung, 2008)

2.1.5 Liver disease

The liver is responsible for protein synthesis (albumin, coagulation factors, acute phase reactants), metabolism of carbohydrates, lipids, and amino acids, and drugs. The liver also has a role in immunity endocrine functions, red blood cell degradation and bilirubin excretion. The liver influences the plasma concentration and systemic availability of most drugs. The ability to metabolize and excrete IV anesthetic drugs may be significantly impaired in patients with severe hepatic disease. Common lab abnormalities include anemia, thrombocytopenia, elevated AST, ALT, alkaline phosphatase, increased PT and INR, and decreased albumin. (Miller, 2009)

2.1.6 Renal disease

Patients with kidney failure have multisystem abnormalities including neurological, cardiovascular, pulmonary, gastrointestinal, hematological, and musculoskeletal disease. Serum creatinine and blood urea nitrogen (BUN) are simple routine tests that are helpful as screening guides in management of patients with kidney impairment and provide a rough measure of glomerular filtration rate. The ability to excrete drugs may be significantly impaired in patients with end stage kidney disease. Anemia due to chronic disease, may contribute to hypoxia. Timing of dialysis and protection of dialysis access sites are important prior to surgery. (Miller, 2009)

2.1.7 Neurologic disease

Etiologies include traumatic brain injury, intracranial hypertension, infection, seizure disorder and neuromuscular disease. Dementia, delirium, confusion, poisoning, drug overdose, substance abuse, and metabolic disorders alter the clinical picture of neurologic disease. Neurologic disease can result in a disordered control of breathing, abnormal respiratory patterns, decreased minute ventilation and increased risk of hypoxemia. Patients with acute spinal cord injury may have impaired respiratory and cardiovascular function and present with neurogenic shock. Autonomic dysreflexia occurs in patients with chronic spinal cord injury. In these patients, stimuli below the level of spinal cord transection elicit increased reflex sympathetic activity over the splanchnic outflow tract without the normal descending inhibitory modulatory impulses due to blockade at the level of injury. The response is severe vasoconstriction below the level of transection, but vasodilation and bradycardia above the injury. The syndrome occurs most commonly when the lesion is above the T6 level. Stimuli such as bladder or intestinal distention can cause persistent hypertension, headache, visual changes, sweating, bradycardia and arrhythmias. If untreated, autonomic dysreflexia may cause stroke, seizure and death.

2.1.8 Elderly

Elderly patients have limited physiologic reserves. Illnesses tend to accumulate in both frequency and severity with age. Coronary artery disease, hypertension, and heart failure are more prevalent. There is a decreased heart rate response to hypovolemia due to decreased beta-adrenergic activity. The prevalence of atrial fibrillation is increased. Ventilatory responses to hypoxia and hypercarbia are reduced. The lungs lose their elastic recoil with aging and there is an age-related reduction in vital capacity and minute ventilation. Respiratory muscle strength consistently declines with age. Decreased chest wall compliance and increased alveolar dead space increase the work of breathing. There is an increase in V/Q mismatching, alveolar dead space, and right-to-left transpulmonary shunt. Cough is less vigorous and there may be impaired swallowing reflexes, decreased secretion clearance, and increased incidence of pneumonia. Age-related central nervous system changes predispose the elderly to delirium and ICU psychosis. There is increased vulnerability to cerebral ischemia associated with hypotension. Renal and hepatic functions are reduced. The aging kidney has a decreased ability to dilute and concentrate urine and is vulnerable to nephrotoxins. The volume of distribution for anesthetic drugs is altered due to decreased lean body muscle mass. Serum protein production, including albumin, is decreased. Malnutrition and anemia are common.

2.1.9 Pediatrics

The pediatric age group covers a broad range of physiology and sizes, from newborn infants to adolescents. Infants are more dependent on heart rate to maintain an adequate cardiac output. They are unable to increase their stroke volume to the same extent as adults. Pediatric patients also have relatively high vagal tone and may develop bradycardia in response to vagal stimulation or hypoxia. Children have a higher incidence of upper respiratory tract infections and asthma which may contribute to increased risk of laryngospasm and bronchospasm. History of latex allergy or sensitivity should be specifically obtained since there is a large cohort of potentially latex allergic pediatric patients. Congenital heart disease and specific syndromes need to be documented and appropriately managed.

2.2 Previous anesthetics

Previous adverse experience with regional, general and nerve block anesthesia should be documented, especially with regards to cardiac arrest during anesthesia, unplanned ICU admission and difficult airway management. Malignant hyperthermia (MH) is a life-threatening pharmacogenetic disease resulting from exposure of a susceptible patient to a trigger agent. It is characterized by rapidly increasing temperature (as much as 1ºC every 5 minutes), extreme acidosis, exaggerated CO_2 production, and muscle rigidity. The most common triggering drugs are succinylcholine and inhalation agents (halothane, isoflurane, desflurane, and sevoflurane).

2.3 Medications

Chronic medications should be continued with few exceptions (Table 6). Abrupt cessation of beta-blockers can produce undesirable effects such as rebound hypertension and arrhythmias. Patients on beta-blockers will not show the same degree of cardiovascular response to stress. Abrupt withdrawal of the alpha-2 agonist clonidine may result in severe rebound hypertension.

Long-acting oral agents for diabetes may lead to symptomatic hypoglycemia in a fasting patient. Oral diabetic medication should be discontinued prior to surgery and a finger stick glucose measurement should be obtained prior to initiating anesthesia. There are multiple types of insulin with differing half-lives, time and level of peak effect.

Patients with coronary artery drug-eluting stents should continue on dual antiplatelet therapy (i.e. clopidogrel, and aspirin) for at least one year following placement, and then continue indefinitely with at least one of those drugs thereafter. The risk of bleeding is increased. Individualized patient management is required to determine if the risk of coronary artery stent thrombosis and myocardial infarction is greater than the risk of perioperative bleeding.

Medication	**Interactions with Anesthesia**
Beta Blockers	Decreased heart rate response to hypovolemia; exaggerated hypotension with hypovolemia and anemia
Insulin/ Hypoglycemics	Risk of hypoglycemia during fasting
Antipsychotics	May increase sedative effects
Anxiolytics	May increase sedative effects
Seizure Medications	May increase sedative effects
Alpha Adrenergic Blockers	May increase possibility of hypotension
Calcium Channel Blockers	Risk of hypotension and blunted heart rate response
Antidepressants	Anti-cholinergic induced impairment of sweating
Anticoagulants	Increased risk of bleeding

Table 6. Medications and interactions with anesthesia

2.4 Substance abuse

Substance abuse is frequently encountered in trauma patients and can affect the pulmonary, cardiovascular, nervous, renal and hepatic systems.

Substance	**Considerations**
Alcohol	Risk of alcoholic hepatitis, cirrhosis, portal hypertension, cardiomyopathy, arrhythmias, seizures, neuropathies, dementia, Wernicke-Korsakoff syndrome (ataxia, cognitive dysfunction) Anemia from vitamin deficiencies Delirium tremens Pneumonia Gastrointestinal bleeding Coagulopathies due to hepatic dysfunction or vitamin K deficiency. Life-threatening withdrawal with autonomic instability and hyperpyrexia
Cocaine/ Amphetamine	Risk of hemodynamic instability, cerebrovascular accidents, cardiomyopathy, arrhythmias, coronary artery vasoconstriction, angina, myocardial infarction, pulmonary edema, paranoia, anxiety, and seizures Long-term use: ventricular hypertrophy, myocardial necrosis, nasal septal perforation
Ecstasy	Excessive thirst, hyponatremia; pulmonary or cerebral edema
Marijuana	Tachycardia, dysrhythmias, EKG abnormalities, increased cardiac output
Opioids	Tolerance to opioids Acute use: decreased respiratory rate and cause lethargy and pinpoint pupils Methadone: prolonged QT interval. IV use: hepatitis, HIV, endocarditis, limited IV access

Table 7. Anesthesia considerations for patients with substance abuse

2.5 Pre-operative testing

2.5.1 Laboratory tests

For all emergency orthopedic cases, certain laboratory tests should be ordered as soon as possible: (Miller, 2009)

- Complete blood count (CBC): for baseline hemoglobin, hematocrit, and platelet levels
- Type and screen
- Coagulation panel
- Basic metabolic panel (BMP)
- Consider a toxicology screen
- Consider a hepatic panel
- Further lab work should be performed based on the patients past medical history and mechanism of injury

2.5.2 Electrocardiogram (EKG)

The American College of Cardiology / American Heart Association guidelines recommend pre-operative cardiac testing in patients that are at increased cardiac risk, based on their clinical risk profile, functional capacity, and type of surgery. (Miller, 2009) According to the ACC/AHA guidelines, every patient undergoing a high risk surgery (emergency surgery), especially those ≥ 50 years of age should have an EKG unless time does not allow this. For an emergent surgery, the patient should have continued peri-operative cardiac surveillance, post-operative risk stratification, and risk factor management. Patients undergoing an intermediate risk surgery (orthopedic) and have known coronary artery disease, peripheral arterial disease, cerebrovascular disease, or one clinical risk factor require an EKG prior to surgery. (Fleisher, 2007)

2.5.3 Chest X-ray

A chest X-ray is recommended for patients with: significant chest trauma, significant debilitating pulmonary disease history with no recent chest X-ray (within one year), significant change in pulmonary status within the past 6 months, or a recent pneumonia/ COPD exacerbation. (Fleisher, 2007) Computed tomography (CT) may also be indicated in patients with suspected aortic trauma. Smith, 2008)

2.5.4 Urine BHCG

Trauma in a pregnant patient is associated with a high risk of spontaneous abortion, pre-term labor, and/ or premature delivery. The best treatment for the fetus is rapid and complete resuscitation of the mother. Serious trauma occurring in the first trimester of gestation can lead to birth defects or miscarriage secondary to the hemorrhagic shock with uterine ischemia, pelvic irradiation, or medication effects. A urine BHCG pregnancy test should be performed on all female orthopedic trauma patients of child-bearing age. (Miller, 2009) Trauma occurring in the second or third trimester of pregnancy requires an ultrasound evaluation. Fetal heart monitoring is indicated in the operating room if the fetus would be viable if delivered. Consider left lateral uterine displacement if possible for all patients in their third trimester to alleviate the compression on the inferior vena cava and resulting impaired venous return to the heart and hypotension. The obstetrician should be consulted immediately if it is determined that the patient is pregnant. (Miller, 2009)

2.6 NPO guidelines

The pre-operative fasting guidelines are written for healthy patients undergoing elective procedures requiring general anesthesia, regional anesthesia, and sedation. These guidelines do not apply for trauma patients, women in labor, or emergent surgeries, and do not guarantee complete gastric emptying. A trauma patient presenting for emergency surgery is considered to be a "full stomach" and is at risk for pulmonary aspiration of gastric contents with resultant pneumonia. (ASA Practice Guidelines, 2011) Reasons include ingestion of food or liquids less than 8 hours prior to the injury, swallowed blood from nasal or oral injuries, delayed gastric emptying associated with stress of trauma, and administration of oral contrast for CT.

Type of Food/Drink	Fasting Hours Required
Clear Liquids	• 2 hours • Examples: water, fruit juice without pulp, carbonated beverages, clear tea, and black coffee • Excludes alcohol • Volume of liquid is less important than the type ingested
Breast Milk	• 4 hours
Infant Formula	• 6 hours
Light Meal and Nonhuman Milk	• 6 hours • Example: plain toast and a clear liquid • The volume of nonhuman milk is important in determining the fasting time
Fried or Fatty Foods and Meat	• 8 hours

Table. 8. Pre-operative fasting guidelines (ASA Practice Guidelines, 2011)

3. Airway management

"Advanced trauma life support (ATLS) emphasizes the importance of the ABCDE mnemonic: airway, breathing, circulation, disability, and exposure." Verification of an open airway and acceptable respiratory mechanics are of primary importance, because hypoxia is the trauma patient's most immediate threat to life. The inability to oxygenate a person can lead to permanent brain injury and death within 5-10 minutes. Airway obstruction in a trauma patient can be secondary to: direct facial or neck trauma, hemorrhage of the nose, mouth, or upper airway, decreased consciousness, or aspiration of gastric contents/foreign body. Poor ventilation may be due to decreased respiratory drive, direct injury to the trachea or bronchi, pneumothorax, chest wall injury, pulmonary contusion, aspiration, cervical spine injury, or bronchospasm. (Miller, 2009)

3.1 Basic airway management

Airway management for any patient requires the proper equipment and medications. This becomes especially important in an emergency case. (Smith, 2008)

Equipment Required for Intubation
• Oxygen source • Ventilation: bag-valve-mask device, soft nasal airway, rigid oral airway, laryngeal mask airway (LMA) • Intubation: Laryngoscope (multiple sizes), endotracheal tubes (multiple sizes), gum-elastic bougie (Eschmann tracheal tube introducer), flexible fiberoptic scope, video-laryngoscope (e.g., Glidescope), tape to secure the airway • Suction • Monitor: End tidal CO_2, pulse oximeter • Medications: sedative/hypnotic, neuromuscular relaxant (paralytic), local anesthetics (for airway anesthesia), resuscitation medications • Functioning intravenous (IV) access • Miscellaneous: syringes, needles, IV tubing, emergency tracheotomy/ cricothyroidotomy kit

Table 9. Equipment required for intubation. (Smith, 2008)

Airway management begins with the proper positioning of the patient. Mask ventilation is usually the first technique used to ventilate a patient. Proper mask ventilation can be life saving. The face mask should be applied firmly to the face to ensure an adequate seal. A jaw-thrust maneuver (instead of the chin lift) should be used in any patient with a suspected cervical injury to help facilitate ventilation. The most common cause of airway obstruction during mask ventilation is when the tongue and epiglottis fall back in the supine/ unconscious patient. An oral airway or nasal airway (if not contraindicated) can help to open the airway. The rigid oral airway can cause gagging in a conscious patient resulting in vomiting and increased intracranial pressure. The nasal airway is usually better tolerated in an awake or semiconscious patient, but is contraindicated in certain facial fractures and basal skull injuries. (Smith, 2008)

If the patient's airway exam is not predictive of difficult intubation, rapid sequence induction and intubation (RSI) is preferred following 3-5 minutes of preoxygenation with 100% oxygen. Cricoid pressure has been routine for most Anesthesiologists in an attempt to decrease passive regurgitation of gastric contents after sedation and paralysis. Recently, the value of cricoid pressure has been questioned due to its ability to distort the airway, displace the esophagus, and worsen the laryngeal view during intubation. In a traditional RSI, no attempts to manually ventilate the patient's lungs should be made until the endotracheal tube is secured in the trachea. If preoxygenation is insufficient (uncooperative patient, respiratory distress) or laryngoscopy proves difficult and oxygen desaturation occurs, mask ventilation should be done. Ventilation and oxygenation is the main priority. (Smith, 2008)

Time (min)	Action
-3 min to 0	Preoxygenation is a critical step for RSI
-1 min (optional)	Small dose opioid
0 min	Induction agent (propofol, thiopental, etomidate, or ketamine)
At loss of consciousness	Cricoid pressure (controversial) Neuromuscular blocking agent: • succinylcholine, 1 mg/kg or • rocuronium, 1 mg/kg No manual ventilation (unless inadequate preoxygenation or at risk of hypoxia)
+ 0.75 to 1.5 min (When blockade complete)	Laryngoscopy and tracheal intubation
After tracheal intubation	Confirm end-tidal carbon dioxide & bilateral breath sounds

Table 10. Timing for Rapid Sequence Induction and Intubation (RSI). (Smith, 2008)

When performing RSI in a patient with hemorrhagic shock, etomidate and ketamine are preferred over propofol and thiopental due to less hypotension. Succinylcholine is the gold standard for paralysis due to its rapid onset and short duration. Undesirable side effects of succinylcholine include increased intragastric pressure, intraocular pressure, and intracranial pressure (ICP). Succinylcholine is associated with exaggerated potassium release in patients with certain neuromuscular disorders and burns and is contraindicated in patients with malignant hyperthermia. If succinylcholine is contraindicated, longer acting agents like rocuronium or vecuronium can be used to induce paralysis. The laryngeal mask airway (LMA) should be used whenever bag-mask ventilation is difficult. The LMA can alleviate ventilatory obstruction above the vocal cords. The LMA is not an effective device for periglottic or subglottic pathology, such as laryngospasm. The LMA is not a definitive airway and does not prevent aspiration in a trauma patient with a presumed "full stomach". (Smith, 2008)

Rigid direct laryngoscopy is the most common technique used to place an endotracheal tube. If this technique is unsuccessful, then video laryngoscopy (e.g., Glidescope), flexible fiberoptic scope, or a surgical airway may be indicated. Help should be summoned as soon as the airway management plan is recognized as being difficult. (Smith, 2008)

3.2 Difficult airways

Common predictors of a difficult airway include: facial dissymmetry (trauma), tracheal deviation, cervical fractures, small mouth opening, inability to visualize the faucial pillars and uvula (Mallampati), limited neck range of motion, prominent incisors, distance between the thyroid cartilage and mandible < 6 cm, and a narrow maxillary arch. (Miller, 2009) If after performing an airway exam there is doubt about the ability to intubate the trachea following induction of anesthesia, consideration should be given towards securing the airway with topical anesthesia and mild sedation; induction agents and neuromuscular relaxants should be avoided before the airway is secured. If there is concern of airway injury (stridor, hoarseness, subcutaneous emphysema), spontaneous ventilation is maintained provided the patient is cooperative, stable, and is not in respiratory distress. A surgical airway or rapid sequence fiberoptic intubation may be necessary in these situations. If time permits, lateral neck radiographs, CT scanning, and endoscopy can be used to better define airway anatomy. In patients with difficult or compromised airways, choice of intubation technique is ultimately determined by skills, judgment, experience, available equipment, and urgency of the situation. (Smith, 2008)

3.3 Cervical spine precautions

Blunt trauma patients are assumed to have cervical spine injury until proven otherwise. Distracting injuries, intoxication, and altered mental status can make clearing the cervical spine difficult prior to proceeding to the OR for surgical management. The incidence of cervical spine injury is roughly 2% in patients with a closed-head injury and 2-6% for all blunt trauma patients. During direct laryngoscopy, the primary force applied is the extension of the occiput on C1 combined with flexion of the lower vertebrae. It is therefore possible to aggravate or worsen a cervical injury with the standard direct laryngoscopy approach. (Lovich-Sapola, 2010) Manipulation of the airway can exacerbate a spinal cord injury. Imaging studies of the patient's cervical spine should be reviewed prior to induction of anesthesia, if time permits. In patients with a known spinal cord injury and/or neurological symptoms, awake fiberoptic intubation is a prudent choice provided the patient is cooperative and adequate airway anesthesia can be achieved. A key advantage of a well performed awake fiberoptic intubation is the ability to document neurologic integrity after intubation, before inducing general anesthesia. In other patients, RSI with in-line cervical stabilization is preferred. (Smith, 2008)

3.3.1 How to clear a cervical spine

In an alert patient without intoxication, neck pain, decreased level of consciousness, distracting injury, or neurologic abnormalities, the patient's cervical spine can be cleared clinically. The patient's cervical spine can not be cleared even with the appropriate radiographs if they have a "distracting injury". A normal cervical spine X-ray does not rule out a cervical injury, because ligamentous injuries may not be recognized on an X-ray. A CT scan/MRI may be required to rule out the cervical ligament injury, and there is often no time to do this testing in a trauma situation prior to going to the operating room. (Lovich-Sapola, 2010)

3.3.2 Indications for cervical spine precautions

Indications for Cervical Spine Precautions
• All acute trauma patients with a depressed level of consciousness • Patients reporting neck pain • Patients with midline cervical spine tenderness • Upper extremity paresthesia • Focal motor deficits • Pain from other injuries that would be likely to mask neck pain • Specific mechanisms of injury: falls, diving accidents, high-speed motor vehicle accidents

Table 11. Indications for cervical spine precautions (Lovich-Sapola, 2010)

3.3.3 In-line stabilization

The patient's occiput should be held firmly on the backboard or operating table to limit the amount of "sniff". Immobilization of the spine can be accomplished by an assistant providing manual in-line stabilization. A semi-rigid collar or sandbag placed on both sides of the neck and head can also help in maintaining the proper neck position. A well-fitted hard collar can make an intubation almost impossible and should be removed prior to any intubation attempt. Hold the patient's head in-line with the cervical spine to prevent any cervical twisting. Laryngoscopy will always be more difficult with cervical stabilization. While the cervical neck is immobilized, multiple different techniques can be used to improve the success of intubation, including the McCoy blade, Wu/ Bullard scope, Glidescope, and flexible fiberoptic scope. (Lovich-Sapola, 2010) The use of a Glidescope with in-line stabilization has been shown to provide better glottic visualization, but does not significantly decrease the movement of the cervical spine when compared to direct laryngoscopy. (Robitaille, 2008) If the cervical collar was removed during intubation, it should be replaced immediately after the intubation is confirmed. (Lovich-Sapola, 2010)

4. Intra-operative monitoring

Every anesthetic no matter the location requires standard ASA monitors. These include a person qualified to monitor, evaluate, and care for the patient present in the room at all times and a way to monitor the patient's oxygenation, ventilation, circulation, and body temperature. (Lovich-Sapola, 2010)

Standard ASA Monitor Classifications	Specific Monitors
Oxygenation	• Oxygen analyzer: measures the oxygenation of the inspired gas • Pulse oximeter: measures the oxygenation of the patients blood • Observation: patient color
Ventilation	• Monitor the expired carbon dioxide ($EtCO_2$) • Measure the respiratory volumes • Disconnect alarms on the mechanical ventilator • Observation: clinical signs of chest rise, reservoir bag movement, and auscultation of breath sounds
Circulation	• Electrocardiogram • Blood pressure monitor (at least every 5 minutes) • Heart rate monitor • Observation: pulse palpation, auscultation of heart sounds
Body Temperature	• Continuous body temperature monitoring

Table 12. Standard ASA Monitors (Lovich-Sapola, 2010; Smith, 2008)

4.1 Pulse oximetry

The pulse oximeter uses two wavelengths of light: red (660 nm) and infrared (940 nm). The light is transmitted from one side of the sensor to the photodetector on the opposite side, through pulsatile tissue. Oxy- and deoxyhemoglobin vary in light absorption at different wavelengths. The measured wavelength absorption ratio is converted to percent oxygen saturation. (Smith, 2008)

4.2 Electrocardiogram

The electrocardiogram (EKG) is a measurement of the electrical activity of the heart. Whenever a patient is undergoing anesthesia they must have continuous EKG monitoring. Limb lead II is used to monitor for arrhythmias and chest lead V5 is used to watch for ischemia. (Lovich-Sapola, 2010)

There are multiple EKG changes that are common in a trauma patient. The EKG changes can be a result of metabolic derangements from hemorrhage and resuscitation, structural injury to the heart itself, or central nervous system injury. Trauma patients are also at risk for cardiac ischemia due to high circulating catecholamines in the potential presence of existing coronary disease. (Smith, 2008)

Electrical activity to the heart does not guarantee perfusion, as seen in pulseless electrical activity (PEA). In PEA there is electrical activity to the heart, but no myocardial contraction. PEA can occur in multiple trauma scenarios including, cardiac tamponade, tension pneumothorax, hypovolemia, hyperkalemia, and hypothermia. (Smith, 2008)

4.3 Blood pressure monitoring

Blood pressure should be monitored at least every five minutes while a patient is undergoing anesthesia. Blood pressure can be monitored non-invasively or invasively. Non-invasive blood pressure monitoring requires the use of a manual or automatic blood pressure cuff. This technique is the one most commonly used. Complications of a non-invasive blood pressure cuff include compartment syndrome from overuse of the cuff and inappropriate treatment of erroneous blood pressure readings from the improper positioning/ placement of the cuff. (Lovich-Sapola, 2010)

Indications for the Placement of an Arterial Line
• Continuous, real-time blood pressure monitoring
• Planned pharmacologic or mechanical cardiovascular manipulation
• Repeat blood sampling: arterial blood gas, hematocrit, glucose
• Failure of non-invasive blood pressure monitor: patient obesity, patient positioning
• Supplementary diagnostic information from the arterial waveform: arterial pulse contour analysis (systolic pressure variation, pulse pressure variation)
• Patient with end organ disease
• Patient with large fluid shifts

Table 13. Indications for the placement of an arterial line. (Lovich-Sapola, 2010)

Invasive arterial blood pressure monitoring requires the placement of a catheter into an artery, usually the radial, brachial, or femoral artery. The placement of an arterial line is not without risk. The complications of an arterial line include distal ischemia secondary to thrombosis, proximal emboli, or prolonged shock, pseudoaneurysm, arteriovenous fistula, hemorrhage, hematoma, infection, skin necrosis, peripheral neuropathy, misinterpretation of data, and cerebral air embolism secondary to retrograde flushing of the catheter. (Lovich-Sapola, 2010)

4.4 Temperature monitoring

The patient's core temperature should be monitored for any case requiring anesthesia for longer than 20-30 minutes. Every effort should be made to maintain normothermia throughout the case. (Lovch-Sapola, 2010) Maintaining euthermia can be very challenging in a trauma case secondary to the large volumes of fluid resuscitation and multiple areas of patient exposure. (Smith, 2008) The normal body temperature is 36.7 °C to 37.0 °C ±0.2 ° C to 0.4 ° C. Continuous monitoring is recommended, but 15 minute intervals is acceptable. Core temperature sites for measurement include the pulmonary artery, distal esophagus, tympanic membrane, and nasopharynx. Intermediate sites include the mouth, axilla, bladder, and rectum. (Lovich-Sapola, 2010)

Hypothermia must be avoided in all cases, but especially trauma cases secondary to the resulting coagulation disturbances, cardiac arrhythmias, inappropriate diuresis, delayed drug metabolism, and increased risk of infection caused by prolonged hypothermia. The operating room should be heated for all trauma cases to >24 °C to help prevent further hypothermia. (Smith, 2008)

4.5 Central Venous Pressure (CVP) monitor

CVP is usually obtained by venous access in the internal jugular vein, subclavian vein, or femoral vein. The CVP is an indicator of preload, although there is wide variability due to compliance of the venous system and right atrium. Fluid status can be monitored by following CVP trends. (Smith, 2008)

Indication for Central Venous Access and Central Venous Monitoring
• CVP monitoring • Transvenous cardiac pacing • Required for the insertion of a pulmonary artery catheter • Temporary hemodialysis • Drug administration: vasoactive drugs, hyperalimentation, chemotherapy, prolonged antibiotic treatment • Rapid infusion of fluids: trauma, major surgery • Aspiration of a venous air embolism • Inadequate peripheral access • Sampling site for repeated blood testing

Table 14. Indications for central venous access and central venous monitoring (Lovich-Sapola, 2010)

Complications of Central Venous Access and Central Venous Monitoring
• Mechanical injury: arterial, venous, nerve, and cardiac tamponade • Respiratory compromise: airway compression by hematoma, pneumothorax • Arrhythmias • Thromboembolic event • Infection • Misinterpretation of data

Table 15. Complications of central venous access and central venous monitoring (Lovich-Sapola, 2010)

4.6 Pulmonary Artery Catheter (PAC)

Pulmonary Artery Catheter Measurements	Pulmonary Artery Catheter Indications
• Cardiac output (CO)/ cardiac index (CI) • RV pressure • Pulmonary artery pressure (PAP) • Central venous pressure (CVP) • Calculation of oxygen delivery • Assessment of cardiac work • Mixed venous oxygen saturation (MVO_2) • Pulmonary capillary wedge pressure (PCWP) • Systemic vascular resistance (SVR)	• Cardiac: congestive heart failure, low ejection fraction, left sided valvular heart disease, CABG, aortic cross clamp • Pulmonary: COPD and ARDS • Complex fluid management: shock, burns, acute renal failure • Surgical: high risk for venous air embolism

Table 16. Pulmonary artery catheter measurements and indications (Lovich-Sapola, 2010 & Smith, 2008)

Pulmonary Artery Catheter Complications
• Injury: arterial, venous, nerve • Arrhythmias: Right bundle branch block, complete heart block, ventricular fibrillation, tachycardia • Pulmonary: pneumothorax • Air embolism • Misinterpretation of data • Catheter: pulmonary artery rupture, valve injury, endocarditis, infections

Table 17. Pulmonary artery catheter complications (Lovich-Sapola, 2010)

4.7 Transesophageal Echocardiography (TEE)

TEE has become the preferred method for assessing hemodynamics in trauma patients. TEE is an excellent monitor of ventricular performance and volume. TEE in a trauma patient can be used to asses left and right ventricular function, wall motion abnormalities, valvular disease, pericardial effusion, cardiac tamponade, aortic injury, diastolic function, and pulmonary embolism. TEE can be used to estimate the pulmonary artery systolic pressure, left ventricular end-diastolic pressure, and CVP. In the 2010 practice guidelines update for perioperative TEE, the consultants and ASA members:

- Agree that TEE should be used for noncardiac surgical patients when the patient has known or suspected cardiovascular pathology that might result in hemodynamic, pulmonary, or neurologic compromise.
- Strongly agree that TEE should be used during unexplained persistent hypotension.
- Agree that TEE should be used when persistent unexplained hypoxemia occurs.
- Strongly agree that TEE should be used when life-threatening hypotension is anticipated.
- Agree that TEE should be used during major abdominal or thoracic trauma.
- Disagree that TEE should be used during orthopedic surgery.

Category 1 Indications: • Intra-operative evaluation of acute, persistent, and life-threatening hypotension • Pre-operative use in unstable patients with suspected thoracic aortic injury • Peri-operative use in unstable patients with unexplained hypotension, suspected acute valve lesions or any cardiac emergency
Category 2 Indications: • Peri-operative use in trauma with increased risk of myocardial ischemia or infarction • Peri-operative use with increased risk of hemodynamic disturbance • Pre-operative assessment of suspected acute thoracic aortic injury • Intra-operative use during repair of descending thoracic aortic injury
Category 3 Indications: • Intra-operative monitoring for pulmonary emboli • Intra-operative assessment of thoracic aortic repair • Intra-operative evaluation of pleural effusion • Right ventricular function assessment during lung surgery

Table 18: Indications for use of perioperative TEE in trauma patients, excluding cardiac surgical procedures (Fayad, 2011)

TEE should not be done in patients with known or suspected esophageal disease.

Contraindications
• Esophageal or oropharyngeal trauma • Unprotected airway • Active upper gastrointestinal bleeding • Patient refusal • Esophageal stricture or history of dysphagia • Post-esophageal or gastric surgery • Esophageal or gastric tumor

Table 19. Contraindications to the performance of TEE (Fayad, 2011)

4.8 Urine output

Urine output is a traditional tool used to guide fluid resuscitation in a trauma patient. Urine output is a reflection of organ perfusion. Approximately 0.5 mL/kg/hr is desired for urine production. Trauma patients should all be catheterized for accurate urine output evaluation. If there is a concern of significant bladder injury from the trauma, a Urologist should be consulted. (Smith, 2008)

5. Anesthetic agents and techniques in the operating room

Many orthopedic cases are well suited for regional anesthetic techniques, but there is controversy over whether regional anesthesia has an advantage over general anesthesia. For many orthopedic trauma cases a combined regional and general anesthetic approach is optimal to incorporate the hemodynamic, analgesic, and anxiolytic benefits of each. (Miller, 2009)

5.1 General anesthesia in an orthopedic trauma patient

Advantages	Disadvantages
• Rapid speed of onset • Duration: can last as long as required • Allows multiple procedures on different sites of injury • Greater patient acceptance • Allows for positive pressure ventilation	• Unable to do a global neural examination • Requires airway instrumentation • Hemodynamic management may be more complex • Increased risk of barotrauma to the lungs

Table 20. Advantages and disadvantages of general anesthesia in an orthopedic trauma patient (Miller, 2009)

5.1.1 Goals of general anesthesia

Goals of general anesthesia consist of re-establishing and maintaining normal hemodynamics, maximizing surgical exposure, and minimizing complications. Hypotension is initially treated with fluids. Vasopressors may be required afterwards. Frequent evaluation of acid-base status, hematocrit, and urinary output is routine during major orthopedic trauma. Titration of additional anesthetics can be done if satisfactory hemodynamics. (Bassett, 2011)

Goals of General Anesthesia
• Maximize surgical exposure
• Optimize neuromuscular blockade and surgical relaxation
• Limit hypothermia and coagulopathy
• Warm IV fluids and blood, Keep patient covered with convective warming blanket
• If hypothermic: warm the operating room warm (> 24 ^{o}C)
• If coagulopathic, administer plasma, platelets, cryoprecipitate, fibrinogen, factor concentrates as clinically indicated
• Limit complications to other systems: if head injury, monitor intracranial pressure, maintain cerebral perfusion pressure >70 mmHg
• Monitor peak airway pressure and tidal volume. Be vigilant for pneumothorax

Table 21. Goals of general anesthesia for orthopedic trauma (Bassett, 2011)

Nonvolatile IV anesthetic agents include propofol, etomidate, ketamine, thiopental, and midazolam. Volatile anesthetics include isoflurane, sevoflurane, desflurane, and nitrous oxide. Nitrous oxide is generally avoided in trauma due to its ability to diffuse into air containing cavities, especially in patients with pneumothorax, intestinal obstruction, intracranial air, and air embolism (Bassett, 2011). Most anesthetic agents have direct cardiovascular depressant effects and inhibit compensatory hemodynamic reflexes such as central catecholamine output and baroreceptor reflexes. Baroreceptor depression is typically greater for the volatile agents compared to IV agents. In hypotensive patients, etomidate or ketamine are the preferred induction Etomidate offers greater cardiovascular stability compared to propofol or thiopental. Heart rate, cardiac output, and cardiac contractility usually remain unchanged. Ketamine typically increases blood pressure, heart rate, and cardiac output, making it favorable for hypovolemic patients. Isoflurane, sevoflurane, and desflurane all decrease blood pressure through reductions in systemic vascular resistance and depression of myocardial contractility. Isoflurane and desflurane both cause an increased heart rate to compensate for the fall in blood pressure. Sevoflurane is nonpungent which makes it a good choice for inhalational induction. Emergence delirium after sevoflurane occurs in pediatric patients. Desflurane is associated with fast wakeup times due to its low blood gas solubility. (Bassett, 2011)

Effect	Made worse by	Comments
Common side effects Fasciculations & Myalgia		Especially in muscular individuals
Hyperkalemia	Burns, spinal cord trauma, crush injuries	Previously hyperkalemic patients might be at risk. Increased risk with acidosis
Bradycardia, asystole	More common in children or after 2nd dose	Prevented by atropine
Catecholamine release		
Increased intra-ocular pressure	Light anesthesia, inadequate paralysis	
Increased intracranial pressure	Light anesthesia, inadequate paralysis	Not clinically significant after head trauma
Rare side effects Malignant hyperthermia		Life threatening condition
Masseter spasm		May prevent jaw opening & intubation
Prolonged blockade		In patients with atypical plasma cholinesterase activity
Rhabdomyolysis	Muscle dystrophy, corticosteroid therapy	Risk of hyperkalemic cardiac arrest
Anaphylaxis		

Table 22. Side effects of succinylcholine (Smith, 2008)

Hypotension produced by anesthetic agents can contribute to the development of cerebral ischemia. Thiopental, propofol, midazolam, and etomidate produce dose dependent reductions in cerebral spinal fluid formation, cerebrovascular constriction causing decreased cerebral blood flow, and decreased cerebral metabolic requirement for oxygen ($CMRO_2$). Ketamine increases $CMRO_2$ and causes increased intracranial pressure. Agents for neuromuscular blockade include depolarizers (succinylcholine) and non-depolarizers (all others). Despite its numerous side effects, succinylcholine is commonly used for rapid sequence induction and intubation (RSI). Rocuronium and vecuronium are also used for neuromuscular blockade. (Bassett, 2011)

5.2 Regional anesthesia in an orthopedic trauma patient

Advantages	Disadvantages
• Able to assess mental status (although patients usually require sedation which may limit this evaluation) • Improved post-operative mental status and pain management • Decreased: blood loss and incidence of deep venous thrombosis • Increased: vascular flow • Avoidance of airway instrumentation • Early mobilization	• Difficult to assess nerve function • Not helpful if the patient has multiple sites of injury • Patient refusal is common • Block may wear off before the surgery is completed • May take longer to place the block than to induce a general anesthetic • Patient will still likely require additional sedation • Hemodynamic instability may occur with an epidural/spinal anesthetic • Venous thromboembolism prophylaxis may limit the ability to safely perform the technique • Unknown patient anticoagulation status in a trauma patient may limit the ability to safely perform this technique • Placement may be difficult secondary to restrictions in positioning of a poly-trauma patient

Table 23. Advantages and disadvantages of regional anesthesia in an orthopedic trauma patient (Miller, 2009)

6. Specific orthopedic injury management

Life-threatening Injuries	Limb-threatening Injuries
• Pelvic ring injuries with hemorrhage • Long bone fractures with hemorrhage	• Traumatic amputation • Vascular injury • Compartment syndrome

Table 24. Life and limb threatening injuries (Smith, 2008)

Surgery is Recommended Within 6-8 Hours	Surgery is Recommended within 24 Hours
• Open fracture • Traumatic arthrotomy • Dislocated joint • Displaced femoral neck fracture in a young adult	• Unstable pelvis/acetabulum fracture • Unstable femur fracture • Proximal fracture in the elderly

Table 25. Orthopedic injuries requiring urgent surgical treatment (Smith, 2008)

6.1 Femur fracture

Femur fractures carry a mortality rate as high as 25%. “Life threatening hemorrhage can occur with bilateral femur fractures or multiple long-bone fractures.” The average blood loss from a femur fracture can be as high as 1,500 cc. Secure venous access is mandatory (e.g., two large bore peripheral IV catheters). (Smith, 2008)

Early definitive stabilization of the femur fracture (within 24 hours of the injury) has been shown to be safe in most patients. This includes patients with multiple injuries such as severe abdominal, chest, or head injuries as long as adequate attention has been paid to resuscitation and medical optimization prior to surgery. (Nahm, 2011) This optimization should include fluid resuscitation with crystalloid, colloid, and blood products as needed. The patient should be followed with serial arterial blood gas samples to follow the lactate levels and pH levels to show if the resuscitation is effective. Early consultation with other services including Neurosurgery, General Surgery, Cardiology, Pulmonary, Renal, may be life saving for the patient. (Miller, 2009)

Benefits of Early Definitive Stabilization of a Femur Fracture (< 24 hours)
• Fewer pulmonary complications • Fewer ventilator days • Fewer deep venous thromboses (DVT) • Shorter hospital stay • Lower health care costs

Table 26. Benefits of early definitive stabilization of a femur fracture (Nahm, 2011)

6.2 Pelvic fracture

Pelvic fractures are often caused by a significant trauma to the lower trunk and are “often accompanied by chest (21%), head (16%), and liver/spleen (8%) injuries”. The three-month mortality of a pelvic fracture is around 14%. (Miller, 2009)

The bleeding from a pelvic fracture is often into a closed space and therefore not immediately obvious to an examiner. Pelvic fractures can be associated with several liters of blood loss. Urgent resuscitation and early stabilization of the pelvic fracture can minimize the morbidity and mortality. (Smith, 2008) An arterial line and multiple large gauge venous catheters are recommended. (Miller, 2009)

Pelvic ring fractures require immediate recognition and management by the trauma team. Patients with a pelvic ring fracture are at a high risk for hemorrhage. Bleeding often occurs at multiple disrupted venous beds in the pelvis, and if the pelvis is unstable, there is no anatomic barrier to the continued expansion of this retroperitoneal bleed. Pelvic fractures can result in fatal retroperitoneal bleeding. Surgical exploration is usually not the required treatment. Successful treatment often includes volume resuscitation, external fixation of the unstable pelvis, and angiography. Intubation and anesthesia involvement is often required secondary to the associated hypotension and need for active fluid resuscitation. (Miller, 2009)

Treating an unstable pelvic arterial bleed in angiography is not without risks. Angiography is often performed in remote locations in the hospital. The unstable patient would require transport to the angiography suite and then potentially to the operating rooms. An anesthesia team is often requested to accompany the patient in the angiography suite to perform continued monitoring, airway management, and resuscitation. The anesthesia equipment and monitors used in the remote location should meet the same standards as those used in the operating room. The Anesthesiologist must also have a reliable way to communicate for help if needed. (Smith, 2008)

Most reports suggest that the optimal time for stabilization of a pelvic fracture is within one week of the injury. (Miller, 2009) Recent studies have shown that there are benefits associated with an early (within 24 hours of injury) stabilization or reduction and definitive fixation of an unstable pelvic fracture. These benefits include: control of bleeding, assist with resuscitation, pain relief, ability to mobilize the patient, ease of reduction, improved reduction quality, elimination of traction, elimination of recumbency, reduced risk of pulmonary, septic, and thromboembolic complications, less organ failure, reduced morbidity and mortality, decreased length of stay in the intensive care unit, and shorter overall hospital stay. (Vallier, 2010)

6.3 Hip dislocation

A hip dislocation is a medical emergency, often resulting from a high impact trauma. Failure to quickly diagnose and treat this injury can result in avascular necrosis of the femoral head and significant neurologic injury. A hip dislocation usually requires a very deep level of anesthesia to facilitate a successful reduction. While occasionally the hip dislocation can be reduced in a spontaneously breathing patient with a combination of midazolam, fentanyl, ketamine, and/or propofol, often they require a nondepolarizing muscle relaxant. If a trauma patient requires complete relaxation with a nondepolaring muscle relaxant, then the procedure should be performed in the operating room with full ASA monitors and an endotracheal tube secondary to the trauma patients increased risk of aspiration. Patients that present to the hospital and are inebriated, uncooperative, confused, hemodynamically unstable, or have pulmonary dysfunction, should also be intubated prior to a hip reduction. (Miller, 2009)

6.4 Hip fracture (femoral neck fracture)

Hip fractures are most common in the elderly. They are associated with a significantly high morbidity and one-year mortality (30%). These patients often present in considerable pain, high stress states, and possibly exhibiting symptoms of myocardial ischemia. Early surgery (<12 hours) has resulted in: lower pain scores, decreased length of hospital stay, and reduced peri-operative complications. Compared with delayed surgery, there is no association with increased survival. Early surgery should be the goal for stable patients, combined with early mobilization, rehabilitation, and aggressive medical care. (Miller, 2009)

Hip fractures can result in significant blood loss. The patients are often dehydrated and anemic. A normal intravascular blood volume should be restored prior to anesthesia and surgery. Placement of a central venous catheter and arterial line can guide the fluid management and help prevent congestive heart failure from over-resuscitation. (Miller, 2009)

Peri-operative Complications of Hip Fractures
• Cardiac complications: myocardial ischemia
• Pulmonary complications: fat embolism, pulmonary embolism
• Deep venous thrombosis
• Delirium: secondary to dehydration and electrolyte abnormalities

Table 27. Peri-operative complications of hip fractures (Miller, 2009)

Patients undergoing a hip fracture surgery have the highest risk of death from a pulmonary embolism. A spinal anesthetic is recommended for the actual surgery, but an epidural is rarely indicated for post-operative pain management secondary to the aggressive post-operative anticoagulation that will be initiated. (Miller, 2009)

6.5 Open fracture

Open fractures are surgical emergencies. The infection rate increases after a delay of 6-8 hours. Debridement and irrigation in the operating room plus provisional or definitive fixation of the fracture should happen as soon as it is safely possible. Open fractures require cleaning, pulse lavage, and debridement as soon as possible to minimize the risk of infectious complications. If the patient is not stable enough to go to the operating room, this should be done at the bedside. (Smith, 2008)

6.6 Traumatic amputation

A traumatic amputation requires immediate treatment with pressure, control of the bleeding, early intravenous antibiotics, and tetanus prophylaxis. Emergent surgery is often necessary to control the bleeding and perform surgical debridement. (Smith, 2008)

6.7 Vascular injury

"Injury to the major arterial flow of a limb is a surgical emergency." It is most common after a penetrating trauma, but can be seen with blunt injuries. Traumatic knee dislocations are the most common etiology for a vascular injury in a blunt trauma. A major arterial injury should be suspected in a patient that presents with pallor, coolness, and decreased pulses of the extremity. The patient may also present with an expanding hematoma or massive bleeding. Blood and fluid replacement by the anesthesia team is critical for the patient's survival. (Smith, 2008)

7. Intra-operative complications

7.1 Hypotension

Hypotension can occur during any case in the operating room. In a trauma situation, it is especially important to consider a wide differential so that the true cause of the hypotension is not missed. Hypotension may be caused by hypovolemia: undetected or underestimated blood loss, insensible losses, gastrointestinal loss, renal loss, excessive venodilation, and redistribution of fluid to an extravascular space. All forms of shock including obstructive, cardiogenic, and vasodilated shock should be ruled out. (Smith, 2008)

Type of shock	Differential Diagnoses
Obstructive	• Tension pneumothorax • Pericardial tamponade • Massive pleural effusion • Hemothorax • Abdominal compartment syndrome • Arterial or venous occlusion: air emboli, thrombus, tumor • Pregnancy: aortocaval compression
Cardiogenic	• Blunt cardiac injury: myocardial contusion • Preexisting cardiac disease • Myocardial infarction
Vasodilated	• Spinal cord injury • Anaphylaxis • Adrenal insufficiency • Arteriovenous fistula • Sepsis • Systemic inflammatory disease • Hepatic failure

Table 28. Types of shock (Smith, 2008)

Resuscitation from shock refers to the restoration of normal physiology after injury. Resuscitation after a hemorrhagic shock requires the restoration of a normal circulating blood volume, normal vascular tone, and normal tissue perfusion. (Miller, 2009)

Early resuscitation occurs while active bleeding is still ongoing. The goals in early resuscitation are to maintain the systolic blood pressure at 80 to 100 mmHg, maintain the hematocrit at 25-30%, maintain the coagulation panel and ionized calcium level within a normal range, keep the platelet count > 50,000, maintain the core temperature at > 35 °C, and prevent worsening acidosis. Late resuscitation is defined as after the bleeding is controlled and has separate goals that include maintaining the systolic blood pressure > 100 mmHg, maintaining a normal hematocrit, normalizing the coagulation status, electrolytes, temperature, and urine output, and maximizing the cardiac output. (Miller, 2009)

7.2 Significant blood loss

Patients with orthopedic injury and poly-trauma including orthopedic injury may present with a significant blood loss. Massive transfusion protocols (MTP) have been designed and implemented in many large urban trauma centers to provide a rapidly bleeding patient with automatic regular shipments of blood products to facilitate fluid resuscitation during an emergency surgery. The goal of the design ratio of packed red blood cells, plasma, and platelets built into the protocol are based on the need for volume support, oxygen delivery, and coagulation support required at each stage of the resuscitation. (Smith, 2008)

When should the MTP be initiated? This is often a judgment call made by the Surgeon or Anesthesiologist. It can be guided by these criteria: 5-unit blood loss in one hour, or 10-unit blood loss anticipated for the entire case or within 12-24 hours of observation, or hypovolemic hypotension uncorrected by crystalloid and/or packed red blood cell resuscitation during an ongoing hemorrhage. (Smith, 2008)

During the MTP, a cooler containing blood products is brought one at a time to the operating room as each is finished or until the MTP is terminated. The MTP will vary from hospital to hospital. See below for a sample MTP. (Smith, 2008)

Cooler	Packed Red Blood Cells	Thawed Plasma	5 Pack of Platelets	Cryoprecipitate	Recombinant factor VIIa
1a (No type and screen available.)	5 (O negative)	2 (AB)			
1b (Type and Crossed)	5	2			
2	5	2	1		
3	5	2		10	1
4	5	2	1		

Table 29. Sample massive transfusion protocol (MTP) (Smith, 2008)

7.3 Hypothermia

Hypothermia is defined as a core temperature less than 36 °C. Hypothermia is usually caused by prolonged exposures to cold temperatures. Many trauma patients present to the operating room very cold secondary to prolonged exposure to the elements after the initial trauma. Mild hypothermia, about 1-2 °C below normal triples the incidence of morbid cardiac outcomes, triples the incidence of wound infections, directly impairs immune function, prolongs hospitalization by up to 20%, significantly increases surgical blood loss, and can lead to cold-induced platelet dysfunction. (Lovich-Sapola, 2010)

Trauma patients may enter the operating room already cold, but even if they are normothermic, the patients' core temperatures usually decrease by 0.5-1.5 °C in the first 30 minutes after the induction of anesthesia secondary to the internal redistribution of heat. Mechanisms for heat loss include radiation loss, convection loss, conduction loss, and evaporative loss. (Lovich-Sapola, 2010)

Temperature	Physiologic Effect
33 °C	• Hypertension, tachycardia, and increased cardiac output • Increased oxygen consumption • Hyperventilation • Shivering • Piloerection • Muscle mis-coordination • Confusion
30 °C	• Metabolism is reduced by 50% • Significant neural and organ depression • Loss of consciousness • Body loses its ability to generate heat by shivering. • Prolonged bleeding and clotting times; usually reversible with re-warming
28 °C	• Hyperglycemia: plasma fall in insulin and increased catecholamines from the stress of hypothermia • Hypovolemia: cold diuresis; physiologic increase in hematocrit and hypotension • Cardiac arrhythmias: bradycardia, nodal rhythm, premature ventricular contractions, atrio-ventricular block, ventricular fibrillation • EKG changes: prolonged PR interval, widening of the QRS complex, prolonged QT interval, ST segment elevation, J wave • Oxy-hemoglobin dissociation curve shift to the left • Decreased oxygen consumption • Thrombocytopenia • Metabolic acidosis • Prolonged drug metabolism
<25°C	• Metabolism is reduced by 60% • Ventricular fibrillation • Cessation of respiration • Acid-base disturbances, unless ventilation is maintained

Table 30. Physiologic effects of hypothermia. (Lovich-Sapola, 2010)

Treatment of Hypothermia
• Surface re-warming: warmed blankets, forced air heating blankets, gel pad warming system • Heated (humidified) inspired gases • Fluid warmers • Warming the operating room • Warm body cavity lavage: bladder, stomach, chest, and abdominal cavity • Extracorporeal: hemodialysis, hemofiltration, continuous arteriovenous re-warming, cardiopulmonary bypass

Table 31. Treatment of hypothermia (Lovich-Sapola, 2010 and Smith, 2008)

During the active re-warming of a patient, the following monitors are routine: continuous core temperature monitor and bladder catheterization to monitor the urine output and therefore the adequacy of the intravascular volume and organ perfusion. Arterial line for continuous blood pressure monitoring and frequent blood gas draws is also valuable. On occasion, a pulmonary artery catheter may be useful to follow the cardiac output (Lovich-Sapola, 2010)

7.4 Fat embolism syndrome

Fat embolism syndrome (FES) occurs when microembolism of fat and marrow from the patients long-bones result in clinically significant symptoms. Intra-operative transesophageal echocardiography (TEE) has shown that most patients undergoing long-bone fracture manipulation experience this microembolization, but most patients do not have any clinical impact. Clinically significant FES occurs in about 3-10% of patients having a long-bone repair with the higher incidence if the patient has multiple long-bone fractures. "The presentation of FES can be gradual, developing over 12 to 72 hours, or fulminate leading to acute respiratory distress and cardiac arrest." (Miller, 2009)

Clinical Manifestations of Fat Embolism Syndrome (FES)
Hypoxia
Tachycardia
Mental status change: drowsiness, confusion, obtundation, coma
Petechial rash of the upper body: conjunctiva, oral mucosa, skin folds of the neck, shoulders, axilla, upper arms, and chest
Elevated pulmonary artery pressure
Decreased cardiac index
Lab results: fat microglobulinemia, anemia, thrombocytopenia, high ESR, fat globules in the urine
Chest X-ray: bilateral alveolar infiltrates

Table 32. Clinical manifestation for FES (Miller, 2009; Smith, 2008)

Treatment for Fat Embolism Syndrome (FES)
• Early recognition • Ventilation management: oxygen, higher PEEP, and possible long-term mechanical ventilatory support • Judicious fluid management

Table 33. Treatment for FES (Miller, 2009)

7.5 Acute compartment syndrome

Acute compartment syndrome is defined as a "condition in which increased pressure within a limited space compromises the circulation and function of the tissues within that space." The most common fractures associated with compartment syndrome are the tibial shaft and forearm. The most common cause of compartment syndrome with orthopedic trauma patients is edema secondary to muscle injury and associated hematoma formation. (Miller, 2009)

The diagnosis of acute compartment syndrome is primarily clinical. (Olsen, 2005) The earliest symptoms are often "pain out of proportion to the injury", pain with passive motion, and tense swelling of the affected area. (Miller, 2009; Smith, 2008) Decreased distal sensation and loss of proprioception are seen next, followed by complete anesthesia and muscle weakness. (Smith, 2008) The late-onset "classic"symptoms of pulselessness, pallor, paralysis, and paresthesia often do not present until irreversible loss of function has occurred. (Miller, 2009; Olsen, 2005; Smith, 2008))

The Surgeon and the Anesthesiologist must be careful because certain anesthetic techniques such as nerve blocks and epidural anesthesia can mask these symptoms and lead to a delay in diagnosis. This delay can be limb-threatening. (Olsen, 2005) These same symptoms can also be masked by an altered level of consciousness, deep sedation, or large doses of pain medication; therefore a high index for suspicion is required along with serial physical examinations so that the compartment syndrome is not missed. (Miller, 2009; Smith, 2008)

The treatment for compartment syndrome is a fasciotomy of all involved compartments. To be effective, the fasciotomy must be performed as early as possible to prevent irreversible damage. (Miller, 2009)

Conditions That Can Result in Acute Compartment Syndrome
Trauma: • Fractures: tibial shaft, radius, ulna • Gunshot wounds • Crush injury • Burns • Snake bites
Iatrogenic: • Infiltration form venous or arterial puncture sites • Extravasation of fluids with pulsatile lavage • Pressurized infusions • Casts and circular dressings • Intraosseous fluid replacement in a child/infant
Bleeding disorders
Vascular: • Post-ischemic swelling • Reperfusion injury • Hemorrhage with hematoma formation • Contusions
Drug overdoes: prolonged immobile state
Prolonged limb compression

Table 34. Conditions that can result in acute compartment syndrome (Miller, 2009; Olsen, 2005)

7.6 Crush injury

Crush syndrome is defined as rhabdomyolisis secondary to the associated hypovolemia and toxin exposure after a crush injury with resultant skeletal muscle compression. Rhabdomyolysis occurs when the components of the damaged skeletal muscle enter the patient's circulation. Serum creatinine kinase (CK) levels correlate with the degree of muscle injury, and can be used to assess the severity of the rhabdomyolysis. Acute renal failure (ARF) is the most serious consequence of rhabdomyolysis. ARF "occurs in 4-33% of the cases"and has a "mortality rate of 3-50%". (Malinoski, 2004)

Common Mechanisms of a Crush Injury
• Blunt trauma • Electrical injuries: lightning strikes, high-voltage power lines • Sudden automobile deceleration • Alcohol intoxication: fall, immobility, coma • Earthquakes, landslides, building collapses • Trapped in one position for an extended period of time • Improper intra-operative positioning: extended lithotomy, lateral decubitus • Prolonged tourniquet use • Vascular compromise: arterial thrombosis, embolus, traumatic injury • Soft tissue infections • Medications: steroids, neuromuscular blocking drugs

Table 35. Crush injury mechanisms (Malinoski, 2004; Miller, 2009)

Clinical Symptoms of a Crush Injury
• Shock • Swollen extremities • Rhabdomyolysis • Dark urine secondary to myoglobinuria • Acute renal failure • Electrolyte abnormalities

Table 36. Clinical symptoms of a crush injury (Malinoski, 2004; Miller, 2009)

Treatment and Prevention of Renal Failure after a Crush Injury
Early and vigorous volume replacement: crystalloid • Treat the hypovolemic shock • Treat the hyperkalemia • The total body deficit may be up to 15 L
Confirm the urine flow prior to forced mannitol-alkaline diuresis (controversial treatment) • Mannitol • Alkalization of the urine with sodium bicarbonate • Goal: prevent the precipitation of myoglobin in the renal tubules
Closely monitor the urine output
Closely monitor the electrolytes
Daily hemodialysis or continuous hemodialysis/hemofiltration

Table 37. Treatment and prevention of renal failure after a crush injury (Malinoski, 2004)

8. Post-operative pain management

Managing a patient's pain is always challenging, but it can be especially difficult in a poly-trauma/multiple orthopedic injury patient. Pain management in these patients will require a multimodal approach. Inadequate analgesia can lead to complications with healing, immune function, and autonomic dysfunction. Prolonged untreated pain can lead to the development of a chronic pain state that can be very difficult to treat and may lead to lifelong problems. The goal of pain management in a trauma patient is to reduce the stress response, and provide the patient with pain relief while maintaining cardiovascular stability and tissue homeostasis. (Smith, 2008)

The initial pain management after an orthopedic surgery case usually begins in the recovery room. The administration of rapidly acting intravenous agents in small doses at frequent intervals under continuous monitoring should be continued until adequate pain relief is attained. The total dose of medication required to relieve the patient's pain can then be used to determine the patient's basal requirements before starting a long-acting medication or patient-controlled analgesia (PCA). (Miller, 2009)

Post-operative physical therapy after an orthopedic injury can have a significant impact on the pain medication requirements. It is important to consider the physical therapy schedule and plan the pain medication dosing appropriately. The goal of the dosing is to allow for enough pain relief to successfully perform the physical therapy but not so much that they are too sedated to participate. Physical therapy and activity after an orthopedic trauma is very important because it lowers the risk of pulmonary embolism, venous thrombosus, and decubitus ulcers. While physical therapy is more painful in the short term, the sooner the patient is mobilized, the lower the analgesic doses will be in the long term. (Miller, 2009)

Neuropathic pain occurs when there is direct injury to a major sensory nerve. This type of injury is common after spinal cord trauma, traumatic amputations, and major crush injuries. Neuropathic pain presents with a burning sensation, intermittent electrical shocks, and dysthesia in the affected dermatomal distribution. Neuropathic pain often responds poorly to narcotic analgesics used for somatic pain. The first line of treatment should be with gabapentin, 200 mg three times per day, with daily titration up to a maximum of 2-3 g/day. Persistent neuropathic pain may require selective regional anesthesia to "break the cycle" of spinal cord receptor recruitment. (Miller, 2009)

8.1 Pharmacologic measures

Acetaminophen is an analgesic/ antipyretic drug. It is popular because it is relatively safe compared with other anti-inflammatory medications. Acetaminophen is an important adjuvant to opioid analgesia because it decreases the total amount of opioid required and therefore decreases the adverse effects of excess opioids. The ceiling effect of oral acetaminophen is 1g/dose. (Smith, 2008)

Nonsteroidal anti-inflammatory drugs (NSAIDs) are powerful COX inhibitors and the first line treatment for many pain conditions. NSAIDs are effective for moderate to severe pain. The use of NSAIDs is often limited by their side effect profile: gastric ulcers, renal and platelet dysfunction, and decreased bone fusion and healing which is particularly troublesome in orthopedic trauma patients. (Smith, 2008)

Opioids are the cornerstone of acute pain management. The most commonly used types of opioids include: morphine, meperidine, codeine, fentanyl, hydromorphone, oxycodone, methadone, and buprenorphine. Opioids significantly decrease pain score ratings in trauma patients. Carefully titrated opioids are used as the most common treatment method in trauma cases. The opioids are usually given by a fixed dosing schedule or PCA technique. Opioids can be administered by several routes (oral, intravenous, subcutaneous, intramuscular, intrathecal, epidural, transmucosal, transdermal, inhaled, intra-articular, and local injection into the wound) thus making them very versatile in clinical applications. Side effects of opioids include nausea, vomiting, constipation, sedation, altered sensorium, and respiratory depression. (Smith, 2008)

Ketamine, a phencyclidine derivative, is a noncompetitive inhibitor at the NMDA receptor. Ketamine is unique in that it produces a dissociative state that causes amnesia and an intense analgesia, while maintaining the vital brain stem functions and hemodynamic stability. It provides profound amnesia and analgesia. Ketamine has been shown to decrease opioid requirements. Ketamine is a very useful drug for frequent dressing changes, treating burn patients, and minor trauma procedures. The drawbacks of ketamine include resulting excessive secretions, agitation on recovery, hallucinations, and increase in intracranial and intraocular pressure. The hallucinations can be decreased by giving a benzodiazepine. Ketamine should be avoided in any patient with an associated head trauma. (Smith, 2008)

Tricyclic antidepressants (TCAs) are useful in the treatment of neuropathic pain conditions. TCAs are especially helpful in trauma patients because they can reduce pain, facilitate sleep, and alleviate depression. TCAs have a delayed onset of action; the patient must be educated that it may take days to see results. Recommended TCAs include amitriptyline, nortriptyline, imiprimine, and desipramine. Side effects can include: prolonged QT interval, arrhythmia, and paralytic ileus. (Smith, 2008)

Gabapentin and pregabalin are anticonvulsants used to treat neuropathic, postsurgical, and posttraumatic pain. These medications can only be given in the oral form, so they can not be started until the patient is tolerating food. Side effects may include sedation, dizziness, confusion, and headache. (Smith, 2008)

Multimodal analgesia is the key to the treatment of pain in a poly-trauma patient. The goal is an optimal balance of multiple medications. In addition to pharmacologic methods, non-pharmacologic approaches such as psychologic support, counseling, hypnosis, relaxation techniques, biofeedback, and acupuncture should be considered. (Smith, 2008)

8.2 Regional anesthesia

Regional analgesia from an epidural or continuous catheter should be considered in any orthopedic trauma patient if possible secondary to the resultant sparing of narcotics, high level of patient satisfaction, improved pulmonary function (with associated thoraco-abdominal injury), and facilitated early mobilization. (Miller, 2009) Localized and regional pain can be treated with local, regional, or neuraxial analgesia. Regional blocks provide selective pain relief with fewer hemodynamic side effects than neuraxial blocks. Regional anesthesia can decrease the need for opioids and therefore result in decreased nausea, vomiting, and sedation. Regional anesthesia can also be used for surgical anesthesia as well as post-operative pain management. (Smith, 2008)

Prior to any block, the Anesthesiologist must first evaluate the patient. A review of the patient's medical history including an evaluation for preexisting neurologic injuries, medication history, capability to give informed consent, ability to cooperate for the procedure, availability of landmarks, ability to properly position the patient for the procedure, laboratory values (coagulation studies and platelet count), and finally the approval of the Surgeon to perform the block. A block has the potential to delay the diagnosis of a compartment syndrome and potentially worsen existing nerve damage, and therefore may not be safe in certain patients. (Smith, 2008)

Ultrasound guidance is recommended for the placement of any regional block, but especially in trauma patients, secondary to the maximal benefit of patient safety and comfort. The peripheral nerve stimulation technique can be painful and should be avoided. (Smith, 2008)

8.2.1 Upper limb blocks

Upper Limb Blocks	Indication	Concerns
Interscalene Brachial Plexus	Injuries of the shoulder and upper arm	• Associated with 100% incidence of diaphragm paresis which can last up to 6 hours • Difficult to place in patients with a cervical injury because of difficulty in positioning
Brachial Plexus Around the Clavicle	**Supraclavicular block**: injuries below the shoulder **Infraclavicular block**: injury below the shoulder; better for continuous catheter placement and in patients with cervical injury because the head may stay in a neutral position during placement	• Potential risk for pneumothorax
Axillary Brachial Plexus	Hand and forearm trauma Attractive for patients with coagulopathy secondary to the compressibility of the vessels in this location	• Must be able to abduct the arm • Failure to anesthetize the musculocutaneous nerve
Wrist	Radial, median, and ulnar nerves can be blocked at the wrist	

Table 38. Upper limb blocks (Miller, 2009; Smith, 2008)

8.2.2 Lower limb blocks

Lower Limb Blocks	Indication
Lumbar Plexus	• Patients with unilateral lower limb trauma that are not candidates for an epidural • Femur fracture • Hip fracture • Tibial plateau fracture
Femoral Nerve	• Femoral shaft fracture • ACL repair • Tibial plateau fracture
Fascia Iliaca	• Same indications as a femoral nerve block
Saphenous Nerve	• Medial aspect of the foot (ankle and forefoot fractures) • Tourniquet pain • Must be combined with the sciatic nerve block
Sciatic Nerve	• Analgesia to the posterior compartment of the thigh • Analgesia to most of the lower leg
Ankle	• Surgical procedures of the foot

Table 39. Lower limb blocks (Miller, 2009; Smith, 2008)

8.2.3 Intravenous (IV) regional anesthesia (Bier's block)

IV regional anesthesia is a simple, reliable, cost effective block that is good for short operative procedure on an extremity. Lidocaine is the recommended drug for this block, secondary to it being less cardiotoxic than bupivacaine. IV regional anesthesia requires exsanguination of the limb with a tight bandage, which may be very uncomfortable to an injured limb. Early deflation of the cuff used to keep the local anesthesia in the affected extremity can result in local anesthetic toxicity. (Smith, 2008)

8.2.4 Epidural anesthesia

Epidural anesthesia has been shown to provide superior dynamic analgesia for the treatment of post-operative hip fracture pain during rehabilitation. The patients are significantly less restricted by their pain. However, studies have shown that this decrease in pain does not significantly translate into enhanced rehabilitation. (Foss, 2005) Again, patients undergoing a hip fracture surgery have the highest risk of death from a pulmonary embolism. A spinal anesthetic is recommended for the actual surgery, but an epidural is rarely indicated for post-operative pain management secondary to the aggressive post-operative anticoagulation that will be initiated. (Miller, 2009)

8.2.5 Complications of regional anesthesia

Vascular Injury	• A risk/ benefit analysis is necessary in all patients: special concern if they are coagulopathic, have a low platelet count, are on blood thinners • Evolution of neurologic deficits from an expanding hematoma can take 4 hours to 3 days to manifest itself • Lack of treatment of a hematoma can lead to axon loss and sensory/ motor deficit • Consider pre-existing trauma or vascular injury before the placement of any block
Diaphragm Weakness	• The phrenic nerve lies close to the interscalene groove (easily blocked by the interscalene approach to the brachial plexus) • Unilateral diaphragm weakness is not usually significant in healthy patients, but it can be devastating in patients with chest trauma, poor pulmonary status, or a pneumothorax
Pneumothorax	• Serious complication of the supraclavicular brachial plexus block and intercostal nerve block • Rare after the interscalene and infraclavicular approach • Symptoms can be delayed and present as long as 6-12 hours after the procedure.
Intravascular Injection	• Most nerve plexuses are in the vicinity of a vascular structure • Intravascular injections can lead to convulsions • Careful vigilance, multiple aspirations, and slow fractionated injections are important • The addition of epinephrine to the local anesthetic helps to detect accidental intravascular injection
Horner's Syndrome	• The cervical sympathetic chain is in close proximity to the brachial plexus and can lead to Horner's syndrome • Symptoms: ptosis, miosis, anhydrosis, and unilateral conjunctival engorgement • Rate can be as high as 90% with interscalene and supraclavicular approaches
Infections	• No reported cases in single injections • Increased risk with catheters

Table 40. Complications of regional anesthesia (Smith, 2008)

9. Conclusion

Orthopedic trauma requires a coordinated approach between the Surgeon and the Anesthesiologist. Orthopedic cases can often be some of the most complex for the Anesthesiologist secondary to the associated co-morbidities of the patient and the potential for multiple simultaneous injuries.

Every patient requires a preoperative evaluation that is complete as possible in the time allowed. Airway management may be difficult secondary to the potential for associated cervical spine injuries, and the proper preparation and precautions should be taken. Every patient requires the standard ASA monitors for the procedure, whether the orthopedic procedure is performed in the operating room, emergency room, or angiography suite.

The anesthetic technique should be chosen after careful evaluation of the risks and benefits of regional versus general anesthesia. It is important to remember that often a combination of both will yield the best results.

The Anesthesiologist and the Orthopedic surgeon should be prepared for intra-operative complications including hypotension, blood loss, hypothermia, fat embolism, and compartment syndrome. Vigilance for these potential complications will lead to early diagnosis and treatment, and therefore a potentially improved outcome.

Finally, post-operative pain management also requires a multi-modal approach for the best results. Consider consulting the hospital's Acute Pain Management team for assistance. Untreated pain can lead to chronic pain syndromes and delayed rehabilitation in the orthopedic injury patient.

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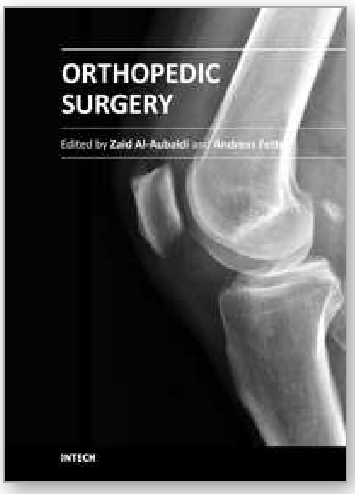

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Orthopaedic surgery is the widest and the strongest growing surgical specialty. It is clear, that the process of improving treatments and patients care, requires knowledge, and this requires access to studies, expert opinion and books. Unfortunately, the access to this knowledge is being materialized. As we believe that access to the medical knowledge should be reachable to everyone free of charge, this book was generated to cover the orthopaedic aspect. It will provide the reader with a mix of basic, but as well highly specialized knowledge. In the process of editing this book, my wife Jurgita has been, as usual, the most supportive person. I would like to thank her for being in my life. I would like to thank Mr. Greblo, the Publishing Process Manager, for all his help and last but not least thanks to our readers, as without them this book would have no meaning.

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