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Orthopaedic Snafus

When Adverse Events Happen in Orthopaedics

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The potential for adverse events exists when treating and managing orthopaedic patients in the intraoperative or postoperative environments, especially when it comes to falls, surgical site infections, venous thromboembolism, and injuries to nerves and blood vessels. Orthopaedic nurses play a vital role in the promotion and use of evidence-based interventions to decrease the incidence of these adverse events, improve quality of care, and minimize the financial burden related to these adverse events.

There is always the potential for adverse events when treating and managing patients with orthopaedic conditions in the intraoperative or postoperative environment. Adverse events that could develop among orthopaedic patients in these environments include injuries to nerves and blood vessels, falls, surgical site infections (SSIs), venous thromboembolism (VTE). There is no doubt that these adverse events have a negative impact on patient outcomes, which can also have a financial impact on healthcare organizations. The purpose of this article is to discuss these four adverse events, identify risk factors, and review evidence-based interventions that will serve to minimize the development of these adverse events among orthopaedic patients and enhance the quality of care delivered to orthopaedic patients. The relationship of these adverse events to the Medicare Access and CHIP Reauthorization Act of 2015 (MACRA) Quality Payment Program (QPP) and value-based purchasing (VBP) is also discussed.

The Adverse Four

Injuries to nerves and blood vessels, falls, SSIs, and VTE are four adverse events that may be encountered in the intraoperative and postoperative orthopaedic settings. These adverse events contribute to negative patient outcomes such as a permanent injury that leads to long-term disability or even death. In addition to negative patient outcomes, they contribute to longer hospital stays and prolonged treatment, which ultimately increases healthcare cost and contributes to a poor quality of life.

Nerve and Blood Vessel Injuries

Injuries to nerves and blood vessels in the orthopaedic setting can result in temporary or permanent damage. There are various causes for injuries to nerves and blood vessels in the intraoperative and postoperative environments. In the intraoperative and postoperative settings, damage to nerves or blood vessels may be related to factors such as suboptimal surgical technique, excessive traction and tourniquet use, patient positioning for surgery, surgical team error, and equipment malfunction and misuse. It is important for nurses to be mindful of their individual role in the prevention of injury to nerves and blood vessels.

Nerve Injury

Nerves are more sensitive to injury than blood vessels. Injury to the nerves may lead to temporary or permanent damage. Injury to a nerve can be classified into three types based on the extent of the injury to the nerve fiber and the continuity of the nerve itself (Seddon, 1942). The three types of nerve injury include neuropraxia, axonotmesis, and neurotmesis. Neuropraxia is the least severe and correlates with complete recovery. It is commonly caused by myelin damage that may be attributed to compression or ischemia of the nerve and affects more motor function than sensory function, with autonomic function intact (Hall, 2005). Axonotmesis is more severe and is due to disruption of the neuronal axon, with paralysis of motor, sensory, or autonomic functions. Axonotmesis is more associated with a crushing injury or contusion but can result from excessive stretching of the nerve, and there is potential for the

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The authors and planners have disclosed no potential conflicts of interest, financial or otherwise.

DOI: 10.1097/NOR.0000000000000324

axon to regenerate and lead to recovery. Neurotmesis is the most severe type of nerve injury that can result from laceration of the axon, severe contusion, excessive stretching, or toxicity from a local anesthetic agent. There is usually complete loss of motor, sensory, and autonomic functions, but there is still potential for recovery (Hall, 2005).

Preoperative regional anesthetic blocks put the orthopaedic patient at risk for peripheral nerve injury, as do excessive traction and prolonged pressure to the contralateral side or bony prominences during surgery. Lack of effective communication among the surgical team, incorrect patient positioning on the operating room table, surgical team error, and equipment malfunction and misuse are also contributory factors of peripheral nerve injury.

Injury to the peripheral nerves due to regional anesthesia is not a common complication. However, research has shown the incidence of peripheral nerve injury from regional anesthetic blocks to be 10%–15% (Jeng, Torrillo, & Rosenblatt, 2010). Evidence-based research has shown the incidence of nerve injury is decreased when nerve stimulation and ultrasound guidance are used to administer peripheral nerve blocks (Walker, McGrattan, Aas-Eng, & Smith, 2009).

Injury to peripheral nerves during orthopaedic surgery can also occur due to incorrect surgical positioning of the patient. Therefore, it is imperative for the surgical team to be familiar with proper positioning of orthopaedic patients on the operating room table when it comes to preventing peripheral nerve injury. All surgical positions have the potential for causing peripheral nerve injury. However, the lateral and prone positions carry a greater risk than other positions (Gerken, 2013).

Lateral decubitus positioning is more commonly used for shoulder, elbow, and hip surgical procedures and carries with it the increased risk for damage to the brachial plexus, radial nerve, and peroneal nerve. Prone positioning is commonly used for orthopaedic surgical procedures of the spine and is associated with an increased risk of brachial plexus nerve injury. Nerve injury from the lateral position can result from excessive retraction of the operative extremity, prolonged pressure of the dependent contralateral side, and direct compression of bony prominences (Gerken, 2013). Prevention involves the use of correct positioning, avoidance of excessive traction, and the use of assistive positioning devices such as axillary rolls and beanbags.

Blood Vessel Injury

Blood vessels are more forgiving than nerves when it comes to injury. However, blood vessel injuries still occur in the intraoperative and postoperative orthopaedic settings. Blood vessel injuries are commonly a result of accidental penetration, hematoma formation, and excessive swelling or compression. These conditions may result from suboptimal surgical technique, excessive tourniquet use, surgical team error, and equipment malfunction and misuse. Excessive tourniquet use on extremities during surgery can lead to prolonged swelling of the operative extremity during the postoperative period, which can lead to ischemia of the surrounding tissues. According to Fitzgibbons, DiGiovanni, Hares, and Akelman (2012), tourniquet pressures greater than 350 mmHg for longer than 2 hours have shown to result in significant edema and mild nerve injury. It is important for the surgical team to follow evidence-based recommendations to avoid injury to blood vessels.

Preventive Measures

Prevention of nerve and blood vessel injuries involves a multitude of elements that focus on the use of best practices when it comes to clinical practice recommendations and effective team-based communication. Examples of the prevention of nerve injury in the perioperative environment include the use of correct positioning, avoidance of excessive traction, and the recommended use of assistive positioning devices such as axillary rolls and beanbags. Prevention of tourniquet-related blood vessel injuries includes avoiding use of the tourniquet for longer than the recommended time and using the least amount of pressure needed to achieve adequate hemostasis. Consideration should also be given to protect the skin surface by using a protective sleeve underneath the tourniquet cuff, in addition to proper location of cuff application by avoiding placement over joints or bony prominences.

Best practices should be followed when applying postoperative dressings, splints, and braces, in addition to using evidence-based modalities that minimize postoperative swelling and hematoma formation. Dressings and splints should be applied in a manner that avoids excessive compression, with attention being given to sufficient padding around bony prominences when applying splints. Modalities such as cold compression therapy, elevation of extremities, and compressive dressings should be considered when it comes to minimizing postoperative swelling and hematoma formation (Van den Bekerom et al., 2012). Proper education should be acquired regarding the appropriate use of intraoperative and postoperative equipment, and individual institutional policies should be followed when it comes to equipment malfunction to avoid the potential for patient injury.

Compartment Syndrome

The most serious complication of nerve and blood vessel injuries is compartment syndrome. A compartment is defined as a closed space containing muscle, bone, nerve, and blood vessels that are contained by a fascial sheath (Rasul, 2016). There are 46 compartments in the body, with 38 being in the arms and legs and most likely to be affected (Walls, as cited in Parker, 2013; Walsh, 2015). Compartment syndrome is characterized by intracompartmental tissue pressure that exceeds perfusion pressure, leading to ischemia of the contents of the compartment, especially the muscle. Ischemic changes lead to increased intracompartmental pressure (ICP), and a vicious cycle of ischemia–fluid shifts continues to cause increased ICP (Parker, 2013; Rusal, 2016).

There are two major categories of precipitating factors: external factors and internal factors (see Table 1). For the purposes of this article, the external factor of the surgical environment is discussed. In the perioperative setting, tourniquets, special orthopaedic surgical tables,

Table 1. Factors Contributing to Compartment Syndrome

External Factors	Internal Factors
Circumferential dressing	Bleeding/hemorrhage into compartment
Casts	Coagulation disorders
Splints Eschar and/or scars Prolonged lying in one position such as in drug overdoses	Iatrogenic causes a. Infiltrated intravenous catheters b. Improper positioning c. Arterial blood gas punctures
	Venous pooling or obstruction to flow
	Increased capillary permeability a. Trauma/surgery b. Tissue ischemia/reperfusion injury c. Thermal/electrical burns d. Snake/spider bites e. Supranormal trauma resuscitation (Walsh, 2015)

and range of motion outside the normal parameters can all lead to compartment syndrome (Parker, 2013). In trauma patients, massive fluid resuscitation and fluid shifts can also precipitate compartment syndrome (Rasul, 2016). These patients most likely are the ones who are surgical candidates, and the use of specialized equipment and length of time to perform surgery can be a factor in developing compartment syndrome. Prolonged lying in one position is also a known risk factor for the development of acute compartment syndrome ([ACS]; Walsh, 2015). Nurses in the perioperative setting must recognize the individual patient risk factors for developing ACS and plan care accordingly.

Acute compartment syndrome is often a clinical diagnosis based on the patient's mechanism of injury, injury pattern, and patient subjective complaints. When assessing a patient for ACS, it is important for the nurse to recognize the classic "6 Ps" of ACS:

- Pain
  - Pain out of proportion to injury or pain that continues to increase despite multimodal pain management.
  - Pain on passive stretch.
- Paresthesias along dermatomal patterns—use 2-point discrimination as is more sensitive and specific.
- Paralysis of affected extremity.
- Pulses
  - Early—bounding distal pulses as a compensatory mechanism to deliver blood to the extremity;
  - Late—pulselessness;
  - The traditional 5 Ps of acute ischemia in a limb are not clinically reliable; these may manifest only in late stages of ACS by which time extensive and irreversible soft-tissue damage may have already taken place. Peripheral pulses and capillary refill may remain normal in upper extremity ACS.
- Pallor of affected limb late in the course of ACS
  - There may be rubor of extremity early in the course due to vasodilation.
- Polar-limb becomes cold or assumes temperature of ambient environment due to the loss of arterial blood flow. (Walsh, 2015, p. 503)

Elevation of the extremity above the heart level in a patient with ACS is contraindicated, as the incline gradient makes it more difficult for arterial blood to flow to the extremity, and cold therapy is contraindicated because it contributes to vasoconstriction of the vessels (Rasul, 2016; Walsh, 2015). All surgical bandages, splints, and casts should be removed or loosened immediately. Surgical fasciotomy is the treatment of choice and is required to decrease the pressure within the compartment. Various studies have found that ischemia that lasts anywhere from 6 to 12 hours can cause irreversible damage to the muscle (Rasul, 2016). It is generally recognized that the sooner the compartment decompression is achieved, the better the patient outcome (Rasul, 2016). The usual postfasciotomy dressing, especially for wounds that will require delayed closure, is a negative pressure wound vacuum. It often is used in conjunction with oxygen therapy and has been found to decrease infection and accelerate tissue regeneration (Rasul, 2016).

According to the American College of Surgeons Trauma Quality Improvement Program (2016), patients at risk for ACS should have neurovascular assessments every 1–2 hours for at least 24–48 hours. This is an important nursing assessment, and any changes in neurovascular function needs to be reported immediately. Nurses caring for patients with potential ACS should also do bedside assessments at shift change so that there is a standard baseline from which assessments are made.

The nurses caring for patients with the potential for developing ACS are in a unique position to prevent the negative outcomes of ACS. Nurses are with the patients 24/7 and can identify early signs of ACS when surgical decompression may prevent irreversible muscle ischemia and death. Accurate and timely assessments and reporting of symptoms may positively alter the life of a patient.

Falls

A child can take 1 year to acquire movement that is independent movement and 10 years to acquire mobility that is independent, and an elderly person can lose both of these in 1 day when he or she sustains a fall (Isaacs, 1992). Any untoward descent to the floor is included in

many of the various definitions of a fall. Ninety percent of hip fractures in the elderly population occur as the result of falls from a standing height (Baumgaertner & Higgins, 2002). Falls are the main cause of fatal and nonfatal injuries among individuals in the United States who are 65 years and older (Centers for Disease Control and Prevention [CDC], 2015). Oftentimes, falls occur in older adults who have multiple impairments in cognitive, sensory, and gait domains. A National Center for Health Statistics brief reveals that during 2012–2013, 55% of all unintentional deaths among adults aged 65 years and older were due to injuries sustained from falls and the fall death rate among adults aged 85 years and older was nearly four times higher than people aged 75–84 years and 16 times higher than those aged 65–74 years (Kramarow, Chen, Hedegaard, & Warner, 2015).

Organizations such as the CDC, National Safety Council, Fall Prevention Center of Excellence, Center for Healthy Aging, Agency for Healthcare Research and Quality, Home Safety Council, and National Institutes of Health identify patient falls as being the most frequently experienced adverse event that leads to hospitalization (Fall Prevention Center of Excellence, 2015). The negative impact of falls within residential community settings, as well as hospital settings, is tremendous from quality and economic standpoints. Falls are a large burden on society due to the potential for severe physical and mental impairments and even death. In the year 2013, the direct medical costs that third party payers and elderly patients paid related to falls totaled $34 billion and 78% of costs related to falls are paid by Medicare (CDC, 2015; Stevens, Corso, Finkelstein, & Miller, 2006). In many cases, falls are preventable. Minimizing the risks for and incidence of falls is a Healthy People 2020 initiative that also focuses on reducing death and disability due to unintentional falls (Healthy People 2020, 2015). Therefore, orthopaedic clinicians should give close consideration to the identification of risk factors and implementation of preventive measures related to falls.

Risk Factors

All healthcare providers should be knowledgeable of the various risk factors related to the increased incidence of falls. The risk factors for falls include the presence of intrinsic and extrinsic factors. Intrinsic factors refer to person-specific factors such as a chronic disease that leads to decreased cognition or urinary incontinence. Intrinsic factors may be associated with the use of medications such as benzodiazepines, antidepressants, and antiarrhythmics that can cause orthostatic hypotension and lightheadedness. Intrinsic factors may also lead to postural imbalance, lower extremity weakness, and unsteady gait. Extrinsic factors refer to the person's environment and how it can contribute to falls such as the lack of appropriate lighting, insufficient traction of floor, shower, and bathtub surfaces, and the presence of floor clutter. A history of falls should be a hallmark risk factor when it comes to assessing for fall-related risk factors (Levin, Shanley, & Hill, 2011).

There are a variety of fall risk assessment tools that are utilized in facilities to identify those individuals who are at risk for falls. These include the Morse Fall Scale, the John Hopkins Fall Risk Assessment Tool, and the Hendrich Scale. These are rapid and simple methods used to assess patients at risk for falls (Levin et al., 2011).

Preventive Measures

Nurses play a vital role in education and implementation of evidence-based preventive measures related to fall prevention. Fall prevention programs frequently include a two-step process, with the first process being the identification of risk factors and the second process being the implementation of appropriate preventive interventions. An example would be placing a high fall risk patient in a room that is closest to the nursing station, which allows the nursing staff to assess the patient more frequently due to close proximity. Other examples include hourly rounding where the nurse checks in with the patient and asks if there are any needs related to thirst, elimination, and assistance with basic hygiene and any other needs. Hourly rounding may also be beneficial for patients with impaired cognition, because nurses can frequently reorient the patient to his or her surroundings, the date, time, and reason for the hospitalization, or other topics of concern that the patient may have.

Other prevention factors include the use of antiskid socks, placing the bed in the lowest position, using a bed/chair alarm, and asking the family to stay with the patient or getting a sitter to stay with the patient. Restraints should only be used as the last resort and in situations where the patient is at risk for harming himself/herself or others in the environment (Smith, Duell, & Martin, 2011). When treating orthopaedic patients, there can be conflicting goals, as providers want orthopaedic patients to become increasingly independent yet they must also promote the orthopaedic patient's safety. Finding balance among orthopaedic patients when it comes to improving functional independence and maintaining safety involves including the patient in the process. Identifying and implementing fall prevention strategies are vital because fall-related injuries are associated with significant morbidity, decline in functional status, increased length of hospital stay, poor quality of life, increased medical spending, and increased institutional liability.

Patient falls remain the most common adverse event reported in acute care facilities. All nurses are faced with the challenges and dilemma of trying to protect patients from falls. When injury is sustained, there is a higher chance a lawsuit is filed by the patient and/or the patient's representative. A legal team who want to determine whether the standard of care in nursing was met reviews these cases. The nursing standard of care describes a competent level of nursing care as demonstrated by the nursing process, involving assessment, diagnosis, outcomes identification, planning, implementation, and evaluation. The American Nurses Association and the National Association of Orthopaedic Nurses publish standards of care for the orthopaedic nurse. When standards of care have been met, then nurses often are not found liable for the patient's injury or death.

Case Examples

Nurses are responsible for the performance and documentation of a physical assessment of their patients. The following case examples illustrate several deviations from the standard of care including failure to assess and update the plan of care:

> Mrs. B. was a 72-year-old woman who was admitted to the hospital after a fall in her home, and she sustained a right femur fracture. Surgical intervention was warranted and an ORIF (open reduction internal fixation) was done under general anesthesia. Her other health history included atrial fibrillation, and she had been taking Coumadin (warfarin) for several years. Her laboratory results on admission to the hospital was INR (international normalized ratio) = 1.6 (subtherapeutic for her atrial fibrillation). Postoperative, she was restarted on Coumadin. During the immediate postoperative period, Mrs. B. was confused. On the second postoperative day, Mrs. B. attempted to climb out of bed during the day shift and then again during the night. The nursing staff saw her climbing over the railing the second time and made an attempt to reorient her. The nursing staff testified they repeatedly educated Mrs. B. to use the call bell when she wanted to get out of bed because she needed assistance. On the third postoperative day, Mrs. B. was found crying on the floor near the door to her bathroom. Mrs. B. was confused, scared, and bleeding from the back of her head. The nursing staff assisted her back to bed, completed an assessment, and cleaned the laceration on the back of her head. Mrs. B. denied any injuries. The nursing staff communicated the incident to the physician and informed the physician that it did not appear there were any injuries. The nursing staff never informed the physician about the laceration on the back of Mrs. B.'s head. The physician evaluated the patient, ordered a variety of x-rays studies, and documented there were no orthopaedic injuries. On postoperative day 4, Mrs. B. was found lethargic. A variety of tests were ordered by the physician, and Mrs. B. was diagnosed with an extensive bleed and died the next day. Upon review of the medical record, it was determined there were no interventions or plan of care defined within the medical record for the prevention of falls. This case settled on behalf of the plaintiff/decedent for a confidential amount.

> In another scenario, Mr. H. was a 67-year-old man who was hospitalized with a right total knee replacement. Physical therapy was initiated on the day of his surgery, and on the first postoperative day, he ambulated 20 feet. On the second postoperative day, Mr. H. was sitting in a chair eating his breakfast. He dropped his phone onto the floor. As Mr. H. leaned forward to pick it up, he fell and fractured his right clavicle and sustained a wound dehiscence to the right knee. Surgical intervention was necessary. Mr. H. and his family alleged the nursing staff failed to provide for his safety. The hospital and the nurse argued that Mr. H. was alert and oriented to person, place, and time and worked with the physical therapist who determined Mr. H. was independent with sitting. There was a fall risk assessment, and a plan of care, which included hourly rounds and confirming the call light, was within his reach. The case concluded, finding neither the hospital nor the nurse liable or negligent for this patient's fall.

Surgical Site Infections

Surgical site infections are a serious complication that costs the United States approximately $5.7 billion per year (Sydnor & Perl, 2011). The CDC has defined an SSI as an infection that occurs after surgery in the part of the body where the surgery took place. Surgical site infections can sometimes be superficial infections involving only the skin. Other SSIs are more serious and can involve tissues under the skin, organs, or implanted material (CDC, 2012).

In orthopaedic surgery, approximately 355,000 patients acquire an SSI each year (Eislet, 2009). Many of these infections are related either to emergency surgery or to dirty and contaminated surgical procedures (Uçkay et al., 2010). These infections have contributed to increased readmission rates and hospital costs (Bachoura et al., 2011). Although there have been advances made in the prevention of SSIs, they continue to be a major factor in mortality, morbidity, and death. According to Awad (2012), there is an approximately 3% mortality rate, with 75% of these deaths attributed to SSIs.

Risk Factors

It has long been recognized that there are both patient characteristics and procedure characteristics that contribute to orthopaedic SSIs (Bachoura et al., 2011; Uçkay et al., 2010). These factors can be divided into modifiable and nonmodifiable factors. See Table 2 for a list of host-specific and procedure-specific modifiable and nonmodifiable risk factors.

Examples of host-specific risk factors for SSIs include poor nutritional status, especially low-protein and albumin levels, renal failure, and advanced age (Smith & Dahlem, 2013). Examples of procedure-specific risk factors that may lead to SSIs include the following: preoperative skin preparation, duration of surgical scrub, preoperative shaving, antimicrobial prophylaxis, inadequate operating room ventilation, inadequate sterilization of instruments, introduction of foreign material into the surgical site, surgical drains, surgical technique with poor hemostasis, presence of fluid imbalance, failure to obliterate dead space, tissue trauma, and improper postoperative wound care (Mangram, Horan, Pearson, Silver, & Jarvis, 1999, as cited in Smith & Dahlem, 2013). It is critical that nurses caring for these patients are aware of these risk factors, identify patients with these risk factors, and plan their care accordingly to minimize the influence these identified risk factors may have on the development of SSIs (Association for Professionals in Infection Control and Epidemiology [APIC], 2010; Lamagni, Elgohari, & Harrington, 2015).

Preventive Measures

The use of evidence-based clinical practice guidelines (CPGs) can help minimize the incidence of SSIs (APIC, 2010; Cataife, Weinberg, Wong, & Kahn, 2015; Eislet, 2009; Smith & Dahlem, 2013; Uçkay et al., 2010). Clinical quality indicators (CQIs) are measures of specific areas of care that can be tracked and can allow for identification of areas where there could be improvement in performance. An active surveillance program that tracks CQIs may decrease SSI rates by merely reporting data without any other formal interventions (Uçkay, 2010). These two entities, CPGs and CQIs, work

Table 2. Risk Factors for Orthopaedic Surgical Site Infections

	Host Specific	Procedure Specific
Modifiable risk factors	Obesity	Estimated blood loss of >1 L
	Smoking	Longer procedure time
	Hematocrit <36	Suboptimal timing of prophylactic antibiotic
	↑ Serum glucose levels	Two or more surgical residents participating in the procedure
	Colonized with *Staphylococcus aureus*	Prolonged wound drainage
		Spinal procedure via the posterior or anterior/posterior approach
Nonmodifiable risk factors	Diabetes	Estimated blood loss of >1 L
	Male gender	Longer procedure time
	Rheumatoid arthritis	Previous infection at the site
	ASA score of 3 or greater	Prolonged wound drainage
	Recent weight loss	Low volume of procedures performed at the hospital
	Dependent functional status	Low volume of procedures performed by the surgeon
	Disseminated cancer	
	Admission from a healthcare facility	

Note. ASA = American Society of Anesthesiologists. From *Guide to the Elimination of Orthopedic Surgical Site Infections*, by Association for Professionals in Infection Control and Epidemiology, 2010. Retrieved from http://www.apic.org/Resource_/EliminationGuideForm/34e03612-d1e6-4214-a76b-e532c6fc3898/File/APIC-Ortho-Guide.pdf. Copyright 2010 by the Association for Professionals in Infection Control and Epidemiology. Adapted with permission.

in tandem to guide clinicians in best practices and evaluate those practices in clinical settings.

In 2003, the Surgical Care Improvement Project (SCIP) was developed by the Centers for Medicare & Medicaid Services (CMS), the CDC, and a group of national healthcare quality organizations interested in improving surgical care by significantly reducing surgical complications (The Joint Commission, 2015). One focus of the SCIP is to reduce postoperative surgical complications by implementing evidence-based core measures to decrease SSIs (Smith & Dahlem, 2013). The adherence to the SCIP protocols has demonstrated a statistically significant reduction in SSIs (Cataife, Weinberg, Wong, & Kahn, 2014). This article is limited to the SCIP discussion to infection prevention.

The SCIP guidelines for SSI prevention include the following:

- SCIP Inf-1: Prophylactic antibiotic received within 1 hour prior to surgical incision
- SCIP Inf-2: Prophylactic antibiotic selection for surgical patients
- SCIP Inf-3: Prophylactic antibiotics discontinued within 24 hours after surgery end time
- SCIP Inf-6: Surgical patients with appropriate hair removal
- SCIP Inf-10: Surgical patients with perioperative temperature management. (The Joint Commission, 2015)

Evidence-based prevention and minimization of SSIs must occur across the continuum of care to include the preoperative, intraoperative, and postoperative settings. Nurses caring for these patients must recognize that there are multiple entrance sites for bacteria along this continuum and be vigilant in monitoring for actual or potential bacterial invasion (APIC, 2010). Preoperative SSI prevention may include aspects such as skin preparation with chlorhexidine gluconate (CHG) or nasal decontamination with mupirocin or povidone-iodine (Anderson et al., 2015). Intraoperative SSI prevention focuses on aspects such as adherence to recommended timing of antibiotic administration, utilization of hand asepsis, clipping of hair, preparing the surgical site with antimicrobial solutions, maintaining sterile technique during gowning, gloving, and draping throughout the surgical procedure, and promotion of normothermia. Postoperative SSI prevention measures are tied to the delivery of patient education, act of hand washing, maintenance of initial surgical dressing by keeping it clean, dry, and intact during the early postoperative phase, and the use of sterile technique during dressing changes.

Many SSIs result from colonization of the surgical site with the patient's own flora, and colonization with *Staphylococcus aureus* is a known risk factor for SSIs (Kluytmans et al., 1995). Methicillin-resistant *Staphylococcus aureus* (MRSA) remains a risk factor for SSIs, and nasal decolonization with topical mupirocin has been shown to decrease the incidence of SSIs (Perl et al., 2002). A study published by Bebko, Green, and Awad (2015) found there was a statistically significant decrease in the number of SSIs in orthopaedic patients who received both skin decontamination with CHG and nasal topical mupirocin. There have been concerns about bacterial resistance with the use of mupirocin due to the low compliance rate associated with the required 5 days of treatment required prior to the date of surgery. Therefore, many organizations have elected not to routinely screen for nasal contamination (APIC, 2010). An emerging practice includes the use of intranasal povidone-iodine-based antiseptic an hour prior to surgery. A study published by Anderson et al. (2015) showed the use of a

povidone-iodine skin and nasal prep significantly reduced the bioburden of *Staphylococcus aureus* among porcine mucosa, and when combined with a mucin rinse, there was complete prevention of MRSA infection.

In the intraoperative environment, clipping hair immediately before an operation also has been associated with a lower risk of SSIs than shaving or clipping the night before an operation because small abrasions on the skin from shaving increase the risk of infections (CDC, 2011). Timing of antibiotic administration prior to surgery has shown that maximal tissue concentration of antibiotic peaks between 30 and 60 minutes prior to the surgical incision, which is when the antibiotic should be given (Alexander, Solomkin, & Edwards, 2011). The appropriate antibiotic is also critically important and should be considered as well, based on the patient's allergies and existing comorbid conditions. The nurse preparing the patient for surgery should, in collaboration with the anesthetist, ensure that the antibiotic is available and administered at the appropriate time while remaining aware of the patient's allergies.

Hand washing is the single most important factor in the reduction of SSIs (APIC, 2010). All healthcare personnel involved in the care of the patient should wash their hands according the institution's policy before and after contact with the patient. Skin contaminants on the patient may be transferred to the caregiver and then passed on to another patient if strict adherence to hand washing is not maintained (APIC, 2010). Surgical hand asepsis is a critical part of preventing SSIs, with the purpose being reduction of the number of skin flora (APIC, 2010; World Health Organization, 2009). Sterile gowning and gloving by surgical personnel involved in the surgery are paramount. In the postoperative environment, strict adherence to hand washing and sterile technique is an important nursing action when caring for orthopaedic surgical patient. The incision should be protected for the first 24–48 hours, and any dressing changes should be performed using sterile technique (APIC, 2010; Smith & Dahlem, 2013).

Maintaining normothermia is another aspect of perioperative care that the nurse needs to monitor. The SCIP Inf-10 measure was created because intraoperative hypothermia has been associated with an increase in SSIs (Sappenfield, Hong, & Galvagno, 2013). Warming blankets or forced air warming blankets should be readily available.

Patient discharge teaching is critical, and these instructions should reflect the patient's individual informational needs specific to home care, response to unexpected events, and postoperative follow-up (Association of periOperative Registered Nurses, 2012). It is important that the patient understands and is compliant with postoperative instructions that include the signs and symptoms of infection after surgery such as fever, malaise, erythema of the incision site, and drainage from the incision site. Nurses should also remain aware of the comorbidities that are associated with impaired healing such as obesity, immunosuppression, use of steroids, chronic illnesses, diabetes, and advanced age (APIC, 2010, p. 52).

Prevention of SSIs is a multifaceted, interprofessional endeavor that involves the patient, the family, healthcare providers, and the healthcare system as a whole. The nurse caring for orthopaedic patients undergoing surgery is an integral part of the team when it comes to infection prevention measures. The role of the orthopaedic nurse in infection prevention is significant and includes following evidence-based CPGs and organizational protocols, in addition to delivering patient-centered education to encourage patient participation and compliance.

Venous Thromboembolism

Venous thromboembolism is one of the most potentially life-threatening complications that may be experienced following hip or knee arthroplasty and can result into deep venous thrombosis (DVT) that are symptomatic or asymptomatic and/or pulmonary embolism (PE), with PE increasing the incidence of a fatal outcome. Venous thromboembolism is estimated to occur in approximately 35% of this patient population when prophylaxis is not provided (Mostafavi Tabatabaee, Rasouli, Maltenfort, & Parvizi, 2015). With evidence supporting a high incidence of VTE after hip and knee replacement surgery and a strong relationship between DVT and PE, there is broad support for VTE prophylaxis to decrease both patient mortality and the potential for chronic morbidity after total joint replacement (Rachidi et al., 2013).

Precipitating Factors

Although the causes of VTE vary and are not always positively and clearly identified, specific risk factors and other extrinsic factors such as surgical technique have been shown to potentially increase the incidence of VTE following joint replacement surgery. Specific risk factors may include prior episodes of VTE, cardiovascular disease, neurological disease, and a high level of the American Society of Anesthesiologists physical status of classification system score (Zeng et al., 2014). However, rather than relying on certain risk factors or developing a "blanket policy" for all patients, the best management strategy before deciding on the type of chemical prophylaxis may be to conduct individual patient risk assessments, considering and discussing all risk factors with each patient, and balancing those factors against the risk of bleeding and infection. (Zhang, Chen, Zheng, Breusch, & Tian, 2015). The use of a tourniquet during total knee arthroplasty is associated with complications including increased swelling and stiffness of the joints, skin burns, soft tissue and muscle damage, injury of calcified vessels, nerve injury, and paralysis. Acute pulmonary edema and cardiac arrest after release of a tourniquet have been noted on rare occasions (Alcelik et al., 2012). Tourniquet use and other extrinsic factors may place additional burden on the human body, making the environment ripe for a VTE event and the argument for VTE prophylaxis even stronger.

Preventive Measures

The preventive measures for VTE prophylaxis fall into two broad categories: mechanical and pharmacological. Despite overwhelming evidence to support as a standard of care for both hip replacement and knee replacement, no consensus on the ideal thromboprophylactic strategy has been achieved. Clinical practice guidelines

released by the American Association of Orthopedic Surgeons (AAOS) and the American College of Chest Physicians (ACCP) are most frequently consulted (AAOS, 2011; ACCP, 2012). Both organizations agree that patients undergoing hip and knee arthroplasty are at high risk for VTE, bleeding, and bleeding-associated complications and recommend mechanical prophylaxis over pharmacological agents for patients at risk for these complications. There is, however, disagreement on the effectiveness of screening for risk of VTE, as well as limited recommendations pertaining to the type of pharmacological agent and the initiation and duration of treatment to manage VTE prophylaxis. Without a universal standard of care for thromboprophylactic therapy, collaboration between the surgeon and the internist to develop a patient-centered plan of care for patients undergoing hip and knee arthroplasty would be ideal to encourage optimal patient outcomes.

Historically, potent anticoagulants, such as warfarin, were the method of choice and gold standard for VTE prophylaxis. However, the use of potent anticoagulants has the potential to increase the incidence of bleeding and hematoma formation, potentially placing the patient at risk for infection and other adverse events that may lead to additional surgery, prolonged hospitalization, and increased hospital readmissions following hospital discharge (Stacy, 2013). There has therefore been an introduction of more novel anticoagulants within the pharmaceutical industry, along with the increasing use of aspirin as a prophylactic anticoagulant among patients undergoing hip and knee arthroplasty (Stacy, 2013).

Aspirin is gaining support as a VTE prophylactic agent of choice for hip and knee arthroplasty in lieu of more potent anticoagulants for patients who are at a lower risk for developing VTE (Jameson, Baker, Deehan, Port, & Reed, 2014). The most recent ACCP guidelines for the prevention of VTE in orthopaedic patients and the revised SCIP guidelines list aspirin as an acceptable prophylactic agent for total hip and total knee replacement except when relied upon as the sole thromboprophylaxis (ACCP, 2012; The Joint Commission, 2015). Although the AAOS does not endorse one prophylactic agent over another, it does list aspirin as a potential chemoprophylactic agent (AAOS, 2011).

Multimodal regimens for VTE prophylaxis are gaining ground in the literature and in practice, especially as an adjunct to prophylactic use of aspirin. These regimens are designed to safely and effectively reduce the risk of VTE while also decreasing the need for potent anticoagulation medicines. Regimens vary but may include one or more of the following practices: preoperative risk stratification, discontinuation of procoagulant medication, avoidance of autologous blood donation, use of regional anesthesia, intraoperative heparin administration, early postoperative mobilization, and consistent use of mechanical compression devices, which may include both the in-hospital and postdischarge phases of care. Multimodal regimens remain inclusive of chemoprophylactic agents and favor aspirin as the preferred choice when no contraindications are present. In addition to causing fewer complications, aspirin garners acceptance from both the patient and the surgeon, as it is inexpensive, usually well tolerated, and does not require monitoring (Gesell et al., 2013).

Postoperative care and patient education provided by nursing are essential to the success of VTE avoidance. Early and rapid mobilization after joint replacement surgery may assist in decreasing blood clot formation and enhancing rehabilitation efforts, as well as encouraging pulmonary and gastrointestinal health. When the patient is stable, initial mobilization may be implemented by nursing or by physical therapy and should include patient fall precautions to prevent injury. Mechanical compression devices are often implemented in conjunction with pharmacological agents to prevent VTE. These devices are routinely used intraoperatively and postoperatively and are on the rise for home use postdischarge due to rising evidence to support such use and advancements made in portable pneumatic compression units. Although mechanical compression has been shown to influence VTE reduction, it carries a high risk for poor efficacy due to variability in use (Colwell et al., 2014). Nursing must be vigilant to monitor in-hospital use of these devices, as well as to reinforce the need for patient compliance if ordered for home.

Comprehensive patient education for VTE prevention should stress the importance of taking anticoagulation medications as prescribed and the need for monitoring when indicated. It should also include a demonstration of injection technique if applicable, discussion of side effects and precautions related to the medication, reinforcement of consistent use of mechanical compression devices as mentioned earlier, and recognition of the signs and symptoms for both hyperanticoagulation and the presence of VTE.

Quality Payment Program

Implementation of the Patient Protection and Affordable Care Act, also known as the Affordable Care Act (ACA), in 2010 has led reform of the U.S. healthcare system from the standpoints of decreasing cost and improving quality (U.S. Department of Health and Human Services, 2015). The shift from a fee-for-service model to a valued-based model to produce more cost-effective, high-quality birthed MACRA, with additional offspring being the QPP (CMS, 2016a), to begin in 2017. The adverse events discussed in this article correlate closely with the MACRA QPP merit-based incentive payment system performance measures related to quality and improvement activities (CMS, 2016b).

An abbreviated list of MACRA QPP performance measures related to quality that apply to the four adverse events discussed in this article include the following:

- Falls as they relate to
  - the plan of care
  - risk assessment
  - screening for future fall risk
- Functionality as it relates to
  - outcomes assessment
  - functional status assessment for total hip replacement
  - functional status assessment for total knee replacement

- Surgical-related activities
  - patient-centered surgical risk assessment and communication
  - perioperative care: selection of prophylactic antibiotic—first- or second-generation cephalosporin
  - perioperative care: VTE prophylaxis when indicated in all patients
  - surgical site infection
  - total knee replacement: preoperative antibiotic infusion with proximal tourniquet
  - total knee replacement: venous thromboembolic and cardiovascular risk evaluation. (CMS, 2016b)

The MACRA QPP improvement activities related to these four adverse events include implementation of the following:

- Documentation improvements for practice/process improvements
- Episodic care management practice improvements
- Fall screening and assessment programs
- Formal quality improvement methods, practice changes, or other practice improvement processes
- Improvements that contribute to more timely communication of test results
- Practices/processes for developing regular individual care plans. (CMS, 2016b)

Table 3 contains a list of the MACRA QPP performance measures related to quality and improvement activities in orthopaedics as they relate to the four adverse events discussed in this article. Orthopaedic nurses will play a major role in the implementation and monitoring of these quality and improvement activities, in addition to developing programs related to these activities as they best apply to their practice site and patient culture. Orthopaedic nurses possess a wealth of power and influence when it comes to leading excellence in the delivery of orthopaedic nursing care.

Value-Based Purchasing

Although surgical complications have always been important to both the bedside nurse and healthcare organizations, the changing reimbursement culture in healthcare has increased the pressure to achieve the best patient outcomes. Healthcare services have historically been reimbursed on the basis of volume, such as the number of procedures done by a provider or the length of stay in a hospital. With the introduction of the ACA, a stronger emphasis has been placed on value as it pertains to the delivery of healthcare services that has led to the development of VBP as an incentive-based payment program for hospitals (CMS, 2011; Van Lare & Conway, 2012). Table 4 shows examples of value-based care models.

Value-based purchasing rewards hospitals based on measures within four domains: clinical practice (core measures), patient experience, outcomes (including mortality, safety, and healthcare-associated conditions), and efficiency (Stratis Health, 2015). Each of these domains can be directly linked to surgical complications; therefore, VBP is an important focus to consider when addressing surgical complications. For example, if a hospital is not following evidence-based clinical practices and the patient has a longer length of inpatient stay due to a surgical complication, the patient may not be satisfied with his or her experience and the hospital could be penalized in all four domains within VBP for

Table 3. MACRA QPP Quality and Improvement Performance Measures Related to Orthopaedics and the Four Adverse Events

Quality performance measures
- Falls as they relate to
  - the plan of care
  - risk assessment
  - screening for future fall risk
- Functionality as it relates to
  - outcomes assessment
  - functional status assessment for total hip replacement
  - functional status assessment for total knee replacement
- Surgical-related activities
  - patient-centered surgical risk assessment and communication
  - perioperative care: selection of prophylactic antibiotic—first- or second-generation cephalosporin
  - perioperative care: VTE prophylaxis when indicated in all patients
  - surgical site infection
  - total knee replacement: preoperative antibiotic infusion with proximal tourniquet,
  - total knee replacement: venous thromboembolic and cardiovascular risk evaluation

Performance improvement activities
- documentation improvements for practice/process improvements
- episodic care management practice improvements
- fall screening and assessment programs
- formal quality improvement methods, practice changes, or other practice improvement processes
- improvements that contribute to more timely communication of test results
- practices/processes for developing regular individual care plans

Note. MACRA QPP = Medicare Access and CHIP Reauthorization Act of 2015 Quality Payment Program; VTE = venous thromboembolism. Data from *MIPS Overview*, by Centers for Medicare & Medicaid Services, 2016b. Retrieved from https://qpp.cms.gov/measures/performance.

Table 4. Examples of Value-Based Care Models

- Accountable Care Organizations
- Patient-Centered Medical Home
- Pay for Performance
- Bundled Payments

this one complication. Orthopaedic nurses play a valuable role in maintaining the four domains of VBP.

Orthopaedic nurses should be aware that VBP is also tied to patient-related factors such as preferences and perception. The factors are tied closely to patient-centered care and patient engagement. According to the Institute for Healthcare Improvement (2015), the next 5 years in healthcare will lead to novel models pertaining to patient and family engagement that focus more on the patient's preferences than the patient's problems. Orthopaedic nurses should keep in mind that the overall purposes for value-based care include improved quality of care, better health outcomes, and lower costs. Table 5 shows examples of these overall purposes.

Hospital-Related VBP

Hospital-related VBP is referred to as an incentive payment program; however, it is not an incentive program in the traditional sense. Simply put, hospitals pay into the incentive program and those with a higher total performance score (TPS) get paid a higher percentage out of the incentive program, potentially even making money, whereas those with a lower TPS risk losing the percentage of funds they put forth. According to CMS (2015), up to 3,500 hospitals risk losing millions in Medicare funds each year. In 2016, the amount hospitals pay into the incentive program will be funded by a 1.75% reduction from the participating hospitals' base operating diagnosis-related group payments for fiscal year 2016 and then the resulting funds are redistributed to hospitals on the basis of their TPSs (CMS, 2015). The amount of funds earned by each hospital will depend on the range and distribution of all the TPSs from eligible and participating hospitals during the fiscal year. Therefore, the possibility exists for a hospital to earn back a value-based incentive payment percentage that is less than, equal to, or more than the 1.75% reduction during the program fiscal year (CMS, 2015). Beginning in the fiscal year 2017 and moving forward, the incentive program will be funded by a 2.0% reduction from the participating hospitals (CMS, 2015). As this percentage increases, hospitals must shift their focus from quantity to quality so that they can remain fiscally sound.

Table 5. Overall Purposes of Value-Based Care With Examples

- Improved quality of care
- Coordination of care
- Interdisciplinary team approach
- Better health outcomes
- Minimize exacerbations of chronic illnesses
- Self-management of disease processes
- Lower costs
- Minimize unnecessary procedures
- Prevention of errors

Conclusion

Orthopaedic nurses must be familiar with these four adverse events that patients with musculoskeletal conditions are at risk for experiencing and how performance measures related to quality and improvement activities can be used in addition to evidence-based preventive nursing practice to minimize the incidence of these four adverse events. The use of evidence-based preventive nursing practices can increase the potential for positive patient outcomes, improve the quality of care, minimize the incidence of adverse events, and promote financial stability of healthcare facilities. As the ACA continues to promote healthcare reforms related to quality and practice improvement activities, orthopaedic nurses will play an instrumental role in supporting the advancement of performance improvement while delivering orthopaedic nursing care.

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