

CURRENT GUIDELINES AND PRACTICE RECOMMENDATIONS TO PREVENT HOSPITAL-ACQUIRED CONDITIONS AFTER MAJOR ORTHOPAEDIC SURGERIES

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Abstract

» In 2016, a total of 48,771 hospital-acquired conditions (HACs) were reported in U.S. hospitals. These incidents resulted in an excess cost of >\$2 billion, which translates to roughly \$40,000 per patient with an HAC.

» Current guidelines for the prevention of venous thromboembolism and surgical site infection consist primarily of antithrombotic prophylaxis and antiseptic technique, respectively.

» The prevention of catheter-associated urinary tract infection (CA-UTI) and in-hospital falls and trauma is done best via education. In the case of CA-UTI, this consists of training staff about the indications for catheters and their timely removal when they are no longer necessary, and in the case of in-hospital falls and trauma, advising the patient and family about the patient's fall risk and communicating the fall risk to the health-care team.

» Blood incompatibility is best prevented by implementation of a pretransfusion testing protocol. Pressure ulcers can be prevented via patient positioning, especially during surgery, and via postoperative skin checks.

Hospital-acquired conditions (HACs), or those that emerge during a hospital stay that were not present on admission, include common pathologies despite their so-called “never event” (i.e., preventable) status. In 2016, a total of 48,771 HACs were reported in U.S. hospitals. These incidents resulted in an excess cost of >\$2 billion, which translates to roughly \$40,000 per patient with an HAC. In this article, we review HACs as a result of common musculoskeletal procedures: total hip arthroplasty (THA), which has an HAC prevalence of 2.8%; total knee arthroplasty (TKA), 3.4%; and spinal fusion and laminectomy, 3.3% collectively¹. In a previous

study², we explored the most common HACs that occur following these procedures, as well as the risk factors associated with their occurrence.

The U.S. Centers for Medicare & Medicaid Services (CMS) has identified 14 HAC-defining events: a foreign object retained after surgery, air embolism, blood incompatibility, stage-III and IV pressure injuries, falls and trauma, manifestations of poor glycemic control, catheter-associated urinary tract infection (CA-UTI), vascular catheter-related infection, surgical site infection (SSI), deep vein thrombosis (DVT) or pulmonary embolism (PE), and iatrogenic pneumothorax with venous catheterization^{1,3}. Several of these HACs

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have been defined by CMS as being reasonably preventable on the basis of the application of published, evidence-based guidelines, and thus have become the target for payment reduction programs aimed at reducing their prevalence. The purpose of this article was to present current guidelines specifically aimed at preventing and mitigating all 14 HACs as defined by the CMS.

Materials and Methods

Protocol

This study followed the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) checklist⁴ and guidelines of the Cochrane Handbook for Systematic Reviews of Interventions⁵.

Search Methodology

A literature search was conducted for all the relevant guidelines and recommendations via several online databases: Google Scholar, PubMed, MEDLINE, Web of Science, Cochrane, and ScienceDirect. For conditions with no available guidelines, we identified evidence-based recommendations and practices to prevent these conditions. Because of wide variability in practices published internationally, we included only articles published in the United States. References of available studies were manually examined for studies meeting inclusion criteria to ensure inclusion of all available and relevant evidence. Two independent authors (A.I.H. and A.P.) searched titles, abstracts, and full text for eligibility with respect to the inclusion criteria.

Inclusion Criteria

Our approach to identifying evidence-based guidelines for each HAC entailed screening for the following inclusion criteria: (1) the current guideline directly addressed the HAC of interest; (2) the guideline was developed in the U.S., or internationally if U.S. guidelines could not be located; and (3) the current guideline included information on actions to be taken to prevent the HAC of interest. Of the 14 HACs identified

by CMS, 4 were subtypes of SSIs, and as such were combined into 1 category, bringing the total number of HAC categories to 11.

The Strength of Evidence

The GRADE (Grading of Recommendations Assessment, Development and Evaluation) criteria⁶ were applied to guidelines and recommendations to determine the strength of the evidence. GRADE is a widely used and accepted method of classifying the strength of recommendations on the basis of the risk of bias, consistency, directness, precision, and publication bias. Only those recommendations with high (++++) or moderate (+++) GRADE scores were included.

Results

The current guidelines on HAC prevention following common orthopaedic procedures are provided below according to the 11 HAC categories identified by CMS.

Venous Thromboembolism (VTE)

Prevalence

The overall prevalence of VTE has been reported to range from approximately 0.24% to 1.60% in patients undergoing THAs and from 0.45% to 5.30% following TKA⁷⁻¹³. In patients undergoing elective spine surgery, the rate of VTE has varied among the studies (1.0% to 31%)¹⁴. Therefore, the North American Spine Society (NASS) concluded that the rate of postoperative VTE is not clearly understood¹⁵.

Prevention Guidelines and Practice Recommendations

In 2019, the American Society of Hematology set forth guidelines for perioperative VTE management¹⁶. Recommendations included choosing direct oral anticoagulants over vitamin K antagonists unless otherwise contraindicated (renal insufficiency, liver disease, or antiphospholipid syndrome), as well as choosing a shorter course of antithrombotic therapy (3 to 6 months) for primary treatment over a longer course

(6 to 12 months)¹⁶. The remaining moderate or high-grade recommendations pertained to long-term treatment and prevention not necessarily pertinent to the perioperative setting.

The American Academy of Orthopaedic Surgeons (AAOS) also published guidelines, albeit earlier in 2012, to prevent the development of VTE following total joint arthroplasties (TJAs)¹⁷. Of the 10 recommendations made in the report, the only 1 rated as "strong" by the AAOS was the recommendation against routine postoperative duplex ultrasonography screening of patients who undergo elective TJA¹⁷.

Since the AAOS guidelines did not release evidence-based recommendations for or against any specific VTE prophylactic regimen, Lieberman and Heckmann¹⁸ recommended that it is important for the orthopaedic surgeon to be aware of all available options and understand their risks and benefits. The most used VTE chemoprophylaxis agents include low-molecular-weight heparins (LMWHs), warfarin, aspirin, apixaban, rivaroxaban, dabigatran, and fondaparinux.

The American College of Chest Physicians (ACCP) also published guidelines in 2012 directed at the prevention of VTE specifically following orthopaedic surgeries¹⁹. Notable recommendations included using antithrombotic prophylaxis or an intermittent pneumatic compression device (IPCD) for a minimum of 10 to 14 days, as well as using apixaban or dabigatran for patients who decline injections¹⁹.

In several studies²⁰⁻²³, aspirin has been proposed as a safe and efficacious VTE prophylaxis after TJA. Additionally, aspirin is endorsed by the latest guidelines from the AAOS²⁴ and ACCP²⁵ for preventing VTE. However, these recommendations did not endorse a specific dose of aspirin. There is wide variation in terms of the dose and duration of aspirin use for VTE prophylaxis. The dose varies from 75 to 650 mg twice a day²⁶.

Kepler et al.²⁷ proposed VTE prophylaxis recommendations for

spinal surgery. In addition to encouraging early mobilization after surgery, external compression devices such as IPCDs and sequential compression devices (SCDs) should be used, as there is evidence to suggest that they can prevent DVT and they are easy to apply. Another means of mechanical intervention, inferior vena cava filters, have been shown to be effective in the prevention of PE in patients with known DVT who are not candidates for pharmacological intervention or in patients who are at higher risk for VTE. These forms of mechanical prophylaxis may reduce the rate of VTE by 60% to 66%²⁸⁻³⁰. Adjunctive therapy with chemoprophylaxis, including antiplatelet agents, warfarin, LMWHs, factor Xa inhibitors, and thrombin inhibitors, may reduce the risk by an additional 30% to 74%³¹⁻³⁴. However, there is no widely accepted, definitive literature providing evidence or guidelines for VTE prophylaxis³⁵.

In 2021, Vint et al.³⁶ proposed a VTE prophylaxis regime and tested it in 200 patients undergoing anterior lumbar interbody fusion surgery. This regimen included LMWH, tinzaparin (4, 500 units administered subcutaneously on the evening before surgery and then daily for 3 to 5 days), and then 150 mg of aspirin daily plus 30 mg of lansoprazole daily for 4 weeks postoperatively. All patients had intermittent pneumatic compression of their calves and thighs intraoperatively and for 24 hours postoperatively, and then they were managed with early mobilization and thromboembolism-deterrent stockings for 6 weeks. This regimen was associated with 0% rate of any symptomatic VTE (Table I).

Surgical Site Infection

Prevalence

It is estimated that SSI accounts for almost 20% of all nosocomial infections in the orthopaedic setting³⁷. These infections can lead to serious adverse effects, as they prolong hospital stays by 12 to 20 days, double rehospitalization

rates, and increase health-care costs by >300%³⁸⁻⁴⁰.

Prevention Guidelines and Practice Recommendations

The U.S. Centers for Disease Control and Prevention (CDC) most recently published guidelines in 2017 for the prevention of SSI⁴¹. Relevant topics included parenteral and nonparenteral microbial prophylaxis, glycemic control, maintenance of normothermia, oxygenation, antiseptic prophylaxis, blood transfusions, drain use, and biofilms.

Antiseptic prophylaxis entails advising patients to shower or bathe with soap or antiseptic agents at least the night before the operation. During surgery, intraoperative irrigation of tissues with aqueous iodophor solution should be considered. It has not been deemed necessary to apply antimicrobial agents to the surgical incision for the prevention of SSI or to administer parenteral antibiotics after surgical incision closure for clean and clean-contaminated procedures⁴¹.

Patients should maintain glycemic control as measured by a blood glucose target of <200 mg/dL. Perioperative normothermia, as well as proper oxygenation, can help to prevent SSI. It is recommended that an increased fraction of inspired oxygen be administered both during surgery and in the immediate postoperative period. Patients should also have adequate fluid replacement to combat blood loss during surgery. If necessary, patients should receive blood transfusion, and transfusion of blood products should not be avoided with the intention of preventing SSI⁴¹.

The AAOS has published recommendations for SSI prevention with the use of local modalities⁴². Methicillin-resistant *Staphylococcus aureus* (MRSA) screening via nasal swab or polymerase chain reaction (PCR) testing prior to surgery is recommended. If necessary, MRSA decolonization can be done with nasal mupirocin and chlorhexidine wipes before surgery. Incisional negative pressure wound therapy has been found to be beneficial as well, but there is no

clear evidence regarding optimal duration of use and pressure. Lastly, there is evidence to suggest that silver dressings are effective, particularly following arthroplasty⁴².

The Second International Consensus Meeting (ICM) on Musculoskeletal Infection convened in July 2018 to discuss issues regarding infection in orthopaedic patients⁴³. One subspecialty group that was focused on the spine recommended that the optimal prophylactic antibiotic be a first or second-generation cephalosporin given intravenously within 60 minutes prior to the first incision. In patients with a contraindication, vancomycin and/or clindamycin can be used as an alternative. Additionally, the Infectious Diseases Society of America (IDSA) guidelines for redosing should be followed. These include prophylactic antibiotic administration in procedures lasting longer than twice the half-life of an antibiotic or if there is excessive blood loss (1,500 mL). It is recommended that vancomycin powder be applied to the wound during spinal surgery. Previous data have suggested that the use of a perioperative aminoglycoside is effective, but the ICM did not deem this necessary on the basis of gathered evidence (Table I).

Hospital-Acquired Pressure Injury Prevalence

The frequency of hospital-acquired pressure injury (HAPI) has been reported to range from 2.5% to 66%⁴⁴⁻⁴⁸, and the rate after orthopaedic surgeries has been reported to be up to 11.8%⁴⁷. The risk of pressure ulcer development in patients with medical devices is reportedly 2.4 times greater than that in other patients⁴⁹.

Prevention Guidelines and Practice Recommendations

The Royal Children's Hospital Melbourne in Victoria, Australia, has published guidelines on the prevention of HAPI⁵⁰. Notably, patients at increased risk are those with long operations, those who become hypotensive or

TABLE I Recommendations for the Prevention of VTE, SSI, Pressure Injuries, and CA-UTI*

VTE	GRADE†	SSI	GRADE†	Pressure Injury	GRADE†	CA-UTI	GRADE†
Choose anticoagulants over vitamin K antagonists ¹⁶	+++	Patients should shower or bathe with soap or antiseptic agents at least the night before the operation ⁴¹	++++	Use high-density pressure-redistributing foam on operating tables ⁵⁰	++++	Use urinary catheters in operatively managed patients only when necessary, rather than routinely ⁵⁸	++++
Choose a shorter course of antithrombotic therapy (3-6 mo) for primary treatment over a longer course (6-12 mo) ¹⁶	+++	Perform intraop. skin preparation with alcohol-based antiseptic agent, unless contraindicated ⁴¹	++++	Elevate heels off table and slightly flex knees ⁵⁰	++++	Avoid prolonged use of indwelling catheter unless indicated ⁵⁸	++++
Routine postop. duplex ultrasonography screening is not recommended ¹⁷	++++	Antimicrobial should only be administered when indicated ⁴¹	++++	Perform comprehensive postop. skin assessment ⁵⁰	++++	Only properly trained personnel should insert urinary catheters, using sterile equipment and aseptic technique, and must perform hand hygiene before and after insertion ⁵⁸	++++
Patients not at elevated risk should receive pharmacologic agents and/or mechanical devices during the periop. period ¹⁷	+++	Patients should maintain glycemic control as measured by a blood glucose target of <200 mg/dL ⁴¹	++++	Use prophylactic dressings (i.e., semipermeable films, hydrocolloids, and foams) during procedures in which osseous prominences are exposed	+++		
Patients should be encouraged to mobilize early after surgery ²⁷	++++	Maintain periop. normothermia and adequate volume replacement ⁴¹	++++	For procedures with patient in supine position: • Flex the patient's knees 5°-10° • Place pillow beneath knees • Lift heels off the bed to improve circulation	++++		
External compression devices (IPCD or SCD) should be used ²⁸⁻³⁰	+++	Administer increased FiO ₂ for patients with normal pulmonary function undergoing general anesthesia with endotracheal intubation ⁴¹	++++	For prone position procedures: • Minimize time in this position • Elevate the head above the heart to reduce venous congestion and cerebral ischemia • Have a gurney readily accessible for immediate supine positioning if necessary	+++		
Use antithrombotic	+++	Screen for MRSA via nasal swab or PCR	+++				

continued

TABLE I (continued)

VTE	GRADE†	SSI	GRADE†	Pressure Injury	GRADE†	CA-UTI	GRADE†
prophylaxis or an IPCD for a minimum of 10-14 days ¹⁹		testing preoperatively ⁴²					
Use apixaban or dabigatran for patients who decline injections ¹⁹	+++	Use chlorhexidine wipes the night before and morning of surgery ⁴²	+++				
		Use incisional negative pressure wound therapy ⁴²	++++				
		Use silver dressings ⁴²	+++				
		Use first- or second-generation cephalosporin intravenously within 60 min prior to first incision (vancomycin for contra-indicated patients) ⁴³	+++				
		Apply vancomycin powder to wound during spine surgery ⁴³	+++				
*VTE = venous thromboembolism, SSI = surgical site infection, CA-UTI = catheter-associated urinary tract infection, IPCD = intermittent pneumatic compression device, SCD = sequential compression device, FiO₂ = fraction of inspired oxygen, MRSA = methicillin-resistant <i>Staphylococcus aureus</i>, and PCR = polymerase chain reaction. †According to the GRADE (Grading of Recommendations Assessment, Development and Evaluation) criteria⁶, + + + + indicates recommendations with high GRADE scores for the strength of evidence and + + + indicates those with moderate scores.							

hypothermic during surgery, those with reduced mobility on the first postoperative day, and those with prolonged placement of complex equipment such as a head frame for neurosurgery.

To combat some of these issues, their institution has implemented a few interventions. First, the operating tables have been fitted with high-density pressure-redistributing foam. They advise that the patient be repositioned preoperatively and postoperatively in positions different from that used during the surgery. A skin assessment should be done postoperatively to assess for any pressure injuries. Orthopaedic patients are at even higher risk for injury because of the use of external hardware such as casts and braces, and these should be monitored carefully.

The Association of periOperative Registered Nurses (AORN) also specifically discussed the importance of prophylactic dressings as well as the risks of injury in both the prone and supine positions⁵⁰. During procedures in which osseous prominences are exposed, they recommend the use of prophylactic dressings, such as semipermeable film dressings, hydrocolloid dressings, and foam dressings, as a supplement to current positioning interventions⁵⁰. For patients in the supine position, the AORN recommends flexing the patient's knees 5° to 10° and placing a pillow under them, as well as lifting the patient's heels off the bed to improve circulation. For patients in the prone position, the AORN recommends minimizing time in this position, ele-

vating the head above the heart in a midline position to reduce venous congestion and the risk of cerebral ischemia, and having a gurney readily accessible in case the patient needs to be placed in the supine position emergently⁵⁰ (Table I).

Catheter-Associated Urinary Tract Infection

Prevalence

UTIs represent 13% of all health-care-associated infections in the U.S., resulting in prolonged hospital stays, elevated health-care expenditures, and increased mortality⁵¹. The prevalence of postoperative UTIs specific to TJA has been cited to be as high as 3.26%⁵². UTIs in the postoperative setting have been linked to adverse events such as periprosthetic infection, implant failure, and subsequent

revision procedures, resulting in prolonged and costly hospital stays⁵³⁻⁵⁷.

Prevention Guidelines and Practice Recommendations

The CDC has published guidelines for CA-UTI prevention⁵⁸, which state that only properly trained personnel, using sterile equipment and aseptic technique, should insert urinary catheters, and they must perform hand hygiene before and after insertion. Additionally, it is recommended that urinary catheters be used in the operative setting only when necessary, and only for as long as necessary and not longer⁵⁸.

The American Urological Association released a 2020 best practice statement on urologic procedures and antimicrobial prophylaxis⁵⁹. Citing a systematic review by Marschall et al.⁶⁰, in which a significantly lower prevalence of symptomatic UTIs was observed after antimicrobial prophylaxis was given, the statement recommended the use of single-dose antimicrobial prophylaxis at the time of catheter removal (Table I).

In-Hospital Falls and Trauma Prevalence

In-hospital falls have been reported to occur in 2% to 17% of patients during short-term hospitalization⁶¹. Studies have identified an association between higher fall rates and an age of >80 years (23.4%)⁶². Studies have also shown that patients with in-hospital falls had hospital stays that were 6.3 days longer, and the average cost of a fall injury was approximately \$14,000⁶³.

Prevention Guidelines and Practice Recommendations

The Joint Commission has established a list of actions that they recommend in order to prevent falls and fall-related injury in hospitals⁶³. The first of 6 steps is to raise awareness about fall prevention, which includes the incorporation of safety precautions through principles, tools, adequate staffing, and alarms. Establishing an interdisciplinary fall prevention team is also recommended, in addition to using a standardized, vali-

dated tool that identifies patient risk factors for falls, as well as the development of individualized plans of care for at-risk patients. Standardized hand-off communication of a patient's risk of falls between caregivers and the education of each patient by trained health professionals have been demonstrated as effective and are recommended. Last, having a post-fall management system (post-fall huddles, transparent reporting, and analysis of falls) is recommended⁶³.

Performing risk factor interventions for all patients regardless of their fall risk is recommended by the Institute for Clinical Systems Improvement (ICSI)⁶¹. It also recommends testing patients for cognitive dysfunction such as dementia or delirium, assessment of mobility function, a medication check, and performing an environmental safety assessment. This would include the use of visual communication tools, informing the patient and their family of fall risks, patient education, and the communication of a patient's fall risk to all members of the health-care team (Table II).

Unintended Retention of a Foreign Object Prevalence

The unintended retention of a foreign object (URFO) substantially adds to the cost of patient care, and the Pennsylvania Patient Safety Authority estimated the average cost of care related to an URFO to be about \$166,000⁶⁴. The most common causes of URFOs include the absence of policies and procedures, failure to convey relevant patient information in communications among physicians and staff, and failure to comply with existing policies.

Prevention Guidelines and Practice Recommendations

The Joint Commission has developed risk-reduction strategies and recommendations to help organizations prevent the occurrence of a URFO⁶⁴. These strategies include creating a reliable counting system through a multidisci-

plinary approach that includes all members in the surgical room, ensuring that all surgical items are accounted for. The surgeon should also verbally verify the results of the counting procedure. Appropriate documentation of surgical items or instruments is also a recommended practice. Assistive safe technologies, such as radiofrequency-detectable sponge systems and bar-coded sponge systems, can also be used as potential strategies to augment the reliability of the manual counting and prevent the URFOs. The Joint Commission guidelines also mention incorporating effective communication through team briefings and debriefings during surgical procedures⁶⁴.

Both the AORN and the American College of Surgeons support the following prevention recommendations for URFOs: surgical counts should be consistently performed according to national standards and facility policy; only radiographically detectable sponges, towels, and instruments should be used in the surgical wound; and a methodical wound exploration should be conducted before wound closure⁶⁵. Since inadequate counting practices are often due to human error associated with distractions, the incorporation of these practices into the workplace is likely to improve the patient's likelihood of not experiencing a URFO⁶⁶. The AORN also provides guidance on the timing of sponge counts, as detailed in Table III⁶⁶.

The ICSI has detailed recommendations for both when and how surgical counts should be performed to minimize the likelihood of a URFO, which are outlined in Table III⁶⁷. Although new technology has been introduced that can assist with the count process, the ICSI does not recommend that it take the place of a manual 2-person count⁶⁷ (Table III).

Venous Air Embolism Prevalence

The rate of venous air embolism (VAE) in patients who undergo cervical spine surgery in the sitting or semi-sitting position is approximately 7% to 8%⁶⁸.

TABLE II Recommendations for the Prevention of IHFT, VAE, ADR, and MPGC*

IHFT	GRADE†	VAE	GRADE†	ADR	GRADE†	MPGC	GRADE†
Establish an interdisciplinary fall prevention team ⁶³	+++	Screen for patent foramen ovale ⁷²	++++	Assess patient risk factors for ADR and drug-disease and drug-drug interactions ⁸¹	++++	Begin insulin therapy at blood glucose level of ≥ 180 mg/dL and target 140-180 mg/dL range ⁸⁹	++++
Develop personalized plans of care for individuals at risk for falls ⁶³	++++	Consider closure of patent foramen ovale if sitting position is preferred approach ⁷²	+++	Ensure correct medication dosage before prescribing a new medication ⁸¹	++++	Assess the patient for changes in glucose measures, illness severity, and nutritional status when making insulin dosing changes ⁸⁹	++++
Standardize communication procedures about fall risk and provide ample opportunity for patient education at the bedside ⁶³	+++			Document and monitor medication orders, and consider the use of handheld devices for ordering ⁸¹	++++	Standardize glucose monitoring as part of preop., intraop., and postop. care ⁶⁷	++++
Implement a post-fall management system, including post-fall huddles, transparent reporting of events, and retrospective analysis of falls ⁶³	+++			Optimize patient drug regimen by ensuring health benefits outweigh potential risks, including risk of morbidity and mortality from falls	++++	Assess patient for poor glycemic control ⁶⁷	++++
Perform risk factor interventions for all patients regardless of fall risk ⁶¹	+++			Document: • Initiation of new drug therapy • Responses to therapy • Any need for ongoing treatment • Evaluation of comorbidities • Maintain current medication list ⁸¹	+++	Implement protocol for patients with hypoglycemia (<70 mg/dL) ⁶⁷	++++
				When pharmacogenomic testing has been done or is available, consider combining results with screening for: • Drug-drug interactions • Drug-gene interactions • Drug-drug-gene interactions ⁸²	+++	Do not give oral diabetic agents or short-acting insulin preoperatively ⁶⁷	++++
						Reduce patient's normal regimen of long-acting insulin by up to 50% preoperatively ⁶⁷	++++
						Provide glycemic control aimed at blood glucose level range of 140-180 mg/dL; avoid range of 80-110 mg/dL ⁶⁷	++++

*IHFT = in-hospital fall or trauma, VAE = venous air embolism, ADR = adverse drug reaction, and MPGC = manifestations of poor glycemic control. †According to the GRADE (Grading of Recommendations Assessment, Development and Evaluation) criteria⁶, +++ indicates recommendations with high GRADE scores for the strength of evidence and +++ indicates those with moderate scores.

There have been several reported cases of patients managed in the prone position during lumbar and thoracic laminectomy and fusions who experienced VAE^{69,70}. Clinically important VAE is rare in patients undergoing cervical surgery in the prone position, and the case of only 1 patient has been reported previously⁶⁸. Patients with patent foramen ovale (PFO) are at a higher risk for VAE. However, under the proper anesthesia management, patients with PFO can be operatively managed in the semi-setting position and have a low risk of VAE⁷¹.

Prevention Guidelines and Practice Recommendations

There are no current guidelines in place for the prevention of air embolism in surgical patients. Mirski et al. provided a list of recommendations for the assessment of a patient's risk of VAE and the implementation of monitoring and treatment strategies for planned invasive procedures in an attempt to prevent air embolism events; however, none of the recommendations were of moderate or high grade⁷² (Table II).

Blood Incompatibility

Prevalence

The rate of blood transfusions has been reported to range from 3.5% to 18.5% in TKA and from 5.4% to 26.2% in THA, and is negatively associated with hospital procedure volume⁷³. Procedural risks include the potential for blood-borne infection, incompatibility, allergic reaction, and transfusion reactions⁷⁴⁻⁷⁶.

Prevention Guidelines and Practice Recommendations

The British Committee for Standards in Haematology developed a set of guidelines for pretransfusion compatibility procedures⁷⁷. These guidelines emphasize the need to create a pretransfusion testing protocol, as well as to establish written policies for fulfilling blood transfusion requests and collecting blood samples used for pretransfusion compatibility testing⁷⁷ (Table III).

Adverse Drug Reaction

Prevalence

The rate of adverse drug reactions (ADRs) due to nonsteroidal anti-inflammatory drugs (NSAIDs) in orthopaedic inpatients has been reported to range from 16% to 26%^{78,79}. The majority of ADRs are assessed as mild and can be prevented⁸⁰. It has been reported that diclofenac accounts for the highest number of ADRs^{78,79}. Improved identification of ADRs, and the drugs causing them, can help to minimize the number of prolonged hospitalizations, costs of treatment, and rates of morbidity and mortality resulting from ADRs.

Guidelines and Practice Recommendations for ADRs

The Hartford Institute for Geriatric Nursing developed a set of recommendations for the reduction of ADRs in older patients⁸¹. These guidelines recommend the assessment of risk factors for ADRs, potential drug-disease and drug-drug interactions, and correct dosage before the initiation of new medication. Medication orders should be monitored and the use of handheld technological devices such as a personal digital assistant should be considered to reduce ADRs in patients. Awad et al. found that pharmacogenomic testing combined with early detection of drug-drug-gene interactions before the initiation of pain management can reduce adverse drug interactions⁸² (Table II).

Manifestations of Poor Glycemic Control

Prevalence

Hyperglycemia has been reported to delay collagen synthesis⁸³ and impair phagocytosis⁸⁴. These factors translate into a higher risk of various infections and poorer wound healing after any surgical procedure in diabetic patients^{85,86}. Furthermore, strategies aimed at reducing postoperative morbidity by tightly controlling blood glucose levels in the postoperative setting have been highly successful, in both diabetic and nondiabetic patients^{87,88}.

Prevention Guidelines and Practice Recommendations

The American Diabetes Association (ADA) has recommendations for diabetes care in the hospital setting, which include the monitoring and treatment of glucose levels⁸⁹. Patients should be educated prior to discharge on the appropriate skills regarding medication dosage, glucose monitoring, and the recognition and treatment of hypoglycemia. The ADA also recommends consulting with an endocrine specialist when caring for a diabetic patient.

The ADA recommends beginning insulin therapy for the treatment of hyperglycemia at ≥ 180 mg/dL and targeting a range between 140 and 180 mg/dL. Clinical judgment should be used in conjunction with the assessment of a patient for changes in glucose measures, illness severity, and nutritional status when making insulin dosing decisions for the patient⁸⁹.

The ICSI has recommended that oral diabetic agents and short-acting insulins should not be taken preoperatively, while long-acting insulin dosages may be decreased by up to 50% preoperatively⁶⁷. The ICSI also recommends that glycemic control be aimed at achieving blood glucose levels of 140 to 180 mg/dL and that tighter targets of 80 to 110 mg/dL be avoided. Inpatient diabetes management recommendations from the ICSI include having a protocol that can be utilized for patients with hypoglycemia (<70 mg/dL) (Table II).

Catheter-Related Bloodstream Infection

Prevalence

Catheter-related bloodstream infections (CRBSIs) have the tendency to substantially increase the length and cost of hospital stays but not affect rates of mortality⁹⁰. Central venous catheters (CVCs) pose a higher risk of device-related infections, mortality, and morbidity than any other medical device⁹¹. CVCs are considered to be the main source of bacteremia and septicemia in hospitalized patients, with the risk of CRBSI being up

TABLE III Recommendations for the Prevention of CRBSI, BGI, and URFO*

CRBSI	GRADE†	BGI	GRADE†	URFO	GRADE†
Emphasize training and education of personnel who insert and maintain vascular catheters • Ensure adherence to appropriate infection control measures • Periodically assess personnel knowledge of guidelines⁹⁰	++++	Create pretransfusion testing protocol that includes quality management system with clearly defined procedures ⁷⁷	++++	Create a counting system inclusive of all surgical room staff ⁶⁴	++++
Ensure maximal sterile precautions are taken when inserting a vascular catheter • Use a cap and mask as well as sterile gown, gloves, full body drape, and sleeve to protect pulmonary artery catheters • Skin should be cleaned with >0.5% chlorhexidine prep. with alcohol	++++	Establish written protocols for fulfilling blood transfusion requests as well as collection of blood samples used for pretransfusion testing ⁷⁷	++++	Document results of counts of surgical items and instruments ^{64,65}	++++
Do not routinely replace CVCs or perform guidewire exchanges for non-tunneled catheters	++++			Document that all broken instruments and verification that all broken pieces are accounted for ^{66,67} Sponge counts should be done: • If additional sponges are added to the sterile field • Before closure of incision or cavity • After closure of incision or cavity • At time of relief of scrub tech or circulating nurse • Immediately before completion of surgery	++++

*CRBSI = catheter-related bloodstream infection, BGI = blood group incompatibility, URFO = unintended retention of foreign object, and CVC = central venous catheter. †According to the GRADE (Grading of Recommendations Assessment, Development and Evaluation) criteria⁶, +++++ indicates recommendations with high GRADE scores for the strength of evidence and +++ indicates those with moderate scores.

to 64 times greater with CVCs than with peripheral venous catheters⁹¹.

Prevention Guidelines and Practice Recommendations

The CDC issued guidelines in an attempt to eliminate CRBSI cases from all patient-care areas⁹⁰. These guidelines emphasize the education and training of health-care personnel who insert and maintain catheters. They also recommend that maximal sterile precautions be taken during the insertion of central venous catheters. These guidelines also recommend against the routine replacement of CVCs or doing guide-

wire exchanges routinely for non-tunneled catheters in order to prevent infection⁹⁰ (Table III).

Discussion

Patients undergoing any of the 4 most common inpatient orthopaedic surgeries (TKA, THA, spinal fusion, or laminectomy) have been noted to experience HACs at a rate of 1.3% to 5.4%⁹²⁻⁹⁷. The most common HACs among this population are SSI, VTE, CA-UTI, and an inpatient fall or trauma, as reported in our previous article².

Although guidelines that have shown efficacy in preventing these

adverse events have been put into place, these guidelines exist independently, many times published by different governing bodies and under varying definitions and evidence. As such, we compiled an updated and comprehensive resource with accompanying tables for reference, guided only by published guidelines supported by strong evidence using the GRADE criteria. We therefore hope that this resource will be of benefit for care providers seeking to reduce the prevalence of HACs, irrespective of specialty.

Our review is not without limitations. Language bias may be one of these limitations in this review because we

included only guidelines published in the English language. However, there is no evidence of a systematic bias as a result of the language restrictions in medical meta-analyses^{98,99}. We believe that by using these guidelines in combination with identifying the risk factors for HACs reported in our previous article², the orthopaedic community needs to establish a clinical dashboard with the purpose of further preventing HACs.

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