

Centers for Disease Control and Prevention Guideline for the Prevention of Surgical Site Infection, 2017

Sandra I. Berríos-Torres, MD; Craig A. Umscheid, MD, MSCE; Dale W. Bratzler, DO, MPH; Brian Leas, MA, MS; Erin C. Stone, MA; Rachel R. Kelz, MD, MSCE; Caroline E. Reinke, MD, MSHP; Sherry Morgan, RN, MLS, PhD; Joseph S. Solomkin, MD; John E. Mazuski, MD, PhD; E. Patchen Dellinger, MD; Kamal M. F. Itani, MD; Elie F. Berbari, MD; John Segreti, MD; Javad Parvizi, MD; Joan Blanchard, MSS, BSN, RN, CNOR, CIC; George Allen, PhD, CIC, CNOR; Jan A. J. W. Kluytmans, MD; Rodney Donlan, PhD; William P. Schechter, MD; for the Healthcare Infection Control Practices Advisory Committee

IMPORTANCE The human and financial costs of treating surgical site infections (SSIs) are increasing. The number of surgical procedures performed in the United States continues to rise, and surgical patients are initially seen with increasingly complex comorbidities. It is estimated that approximately half of SSIs are deemed preventable using evidence-based strategies.

OBJECTIVE To provide new and updated evidence-based recommendations for the prevention of SSI.

EVIDENCE REVIEW A targeted systematic review of the literature was conducted in MEDLINE, EMBASE, CINAHL, and the Cochrane Library from 1998 through April 2014. A modified Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) approach was used to assess the quality of evidence and the strength of the resulting recommendation and to provide explicit links between them. Of 5487 potentially relevant studies identified in literature searches, 5759 titles and abstracts were screened, and 896 underwent full-text review by 2 independent reviewers. After exclusions, 170 studies were extracted into evidence, evaluated, and categorized.

FINDINGS Before surgery, patients should shower or bathe (full body) with soap (antimicrobial or nonantimicrobial) or an antiseptic agent on at least the night before the operative day. Antimicrobial prophylaxis should be administered only when indicated based on published clinical practice guidelines and timed such that a bactericidal concentration of the agents is established in the serum and tissues when the incision is made. In cesarean section procedures, antimicrobial prophylaxis should be administered before skin incision. Skin preparation in the operating room should be performed using an alcohol-based agent unless contraindicated. For clean and clean-contaminated procedures, additional prophylactic antimicrobial agent doses should not be administered after the surgical incision is closed in the operating room, even in the presence of a drain. Topical antimicrobial agents should not be applied to the surgical incision. During surgery, glycemic control should be implemented using blood glucose target levels less than 200 mg/dL, and normothermia should be maintained in all patients. Increased fraction of inspired oxygen should be administered during surgery and after extubation in the immediate postoperative period for patients with normal pulmonary function undergoing general anesthesia with endotracheal intubation. Transfusion of blood products should not be withheld from surgical patients as a means to prevent SSI.

CONCLUSIONS AND RELEVANCE This guideline is intended to provide new and updated evidence-based recommendations for the prevention of SSI and should be incorporated into comprehensive surgical quality improvement programs to improve patient safety.

JAMA Surg. doi:10.1001/jamasurg.2017.0904
Published online May 3, 2017.

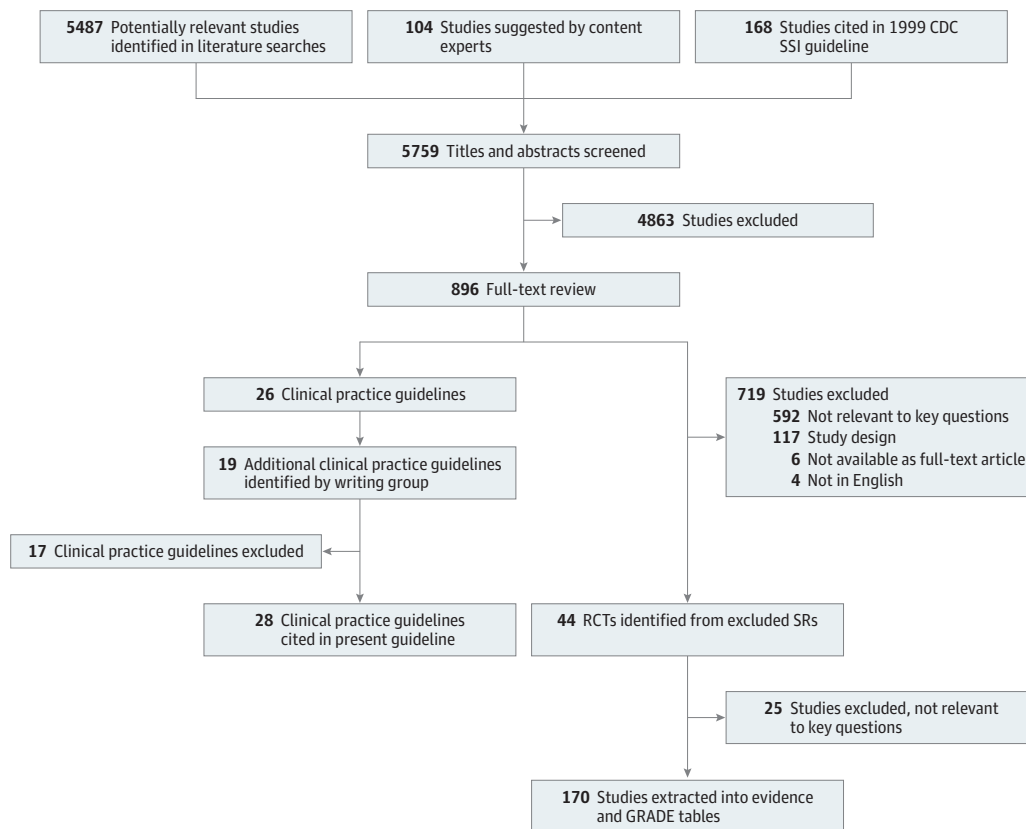
 [Invited Commentary](#)

 [Supplemental content](#)

Author Affiliations: Author affiliations are listed at the end of this article.

Group Information: The Healthcare Infection Control Practices Advisory Committee members are listed at the end of this article.

Corresponding Author: Erin C. Stone, MA, Division of Healthcare Quality Promotion, Centers for Disease Control and Prevention, 1660 Clifton Rd NE, Mail Stop A07 Atlanta, GA 30329 (ecstone@cdc.gov).

Figure. Results of the Study Selection Process

CDC indicates Centers for Disease Control and Prevention; GRADE, Grading of Recommendations, Assessment, Development, and Evaluation; RCTs, randomized controlled trials; SRs, expand; and SSI, surgical site infection.

Surgical site infections (SSIs) are infections of the incision or organ or space that occur after surgery.¹ Surgical patients initially seen with more complex comorbidities² and the emergence of antimicrobial-resistant pathogens increase the cost and challenge of treating SSIs.³⁻⁵ The prevention of SSI is increasingly important as the number of surgical procedures performed in the United States continues to rise.^{6,7} Public reporting of process, outcome, and other quality improvement measures is now required,^{8,9} and reimbursements¹⁰ for treating SSIs are being reduced or denied. It has been estimated that approximately half of SSIs are preventable by application of evidence-based strategies.¹¹

Methods

This guideline focuses on select areas for the prevention of SSI deemed important to undergo evidence assessment for the advancement of the field. These areas of focus were informed by feedback received from clinical experts and input from the Healthcare Infection Control Practices Advisory Committee (HICPAC), a federal advisory committee to the Centers for Disease Control and Prevention (CDC). This guideline was a systematic review of the literature. No institutional review board approval or participant informed consent was necessary.

This guideline's recommendations were developed based on a targeted systematic review of the best available evidence on SSI prevention conducted in MEDLINE, EMBASE, CINAHL, and the Cochrane Library from 1998 through April 2014. To provide explicit links between the evidence and recommendations, a modified Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) approach was used for evaluating the quality of evidence and determining the strength of recommendations.¹²⁻¹⁵ The methods and structure of this guideline were adopted in 2009 by CDC and HICPAC.^{16,17} The present guideline does not reevaluate several strong recommendations offered by CDC's 1999 Guideline for Prevention of Surgical Site Infection¹⁸ that are now considered to be accepted practice for the prevention of SSI. These recommendations are found in eAppendix 1 of the [Supplement](#). A detailed description of the Guideline Questions, Scope and Purpose, and Methods, as well as the Evidence Summaries supporting the evidence-based recommendations, can also be found in eAppendix 1 of the [Supplement](#).

The detailed literature search strategies, GRADE Tables, and Evidence Tables supporting each section can be found in eAppendix 2 of the [Supplement](#). Results of the entire study selection process are shown in the [Figure](#). Of 5487 potentially relevant studies identified in literature searches, 5759 titles and abstracts were screened, and 896 underwent full-text review by 2 independent reviewers.

Full-text articles were excluded if: 1) SSI was not reported as an outcome; 2) all patients included had “dirty” surgical procedures (except for Q2 addressing the use of aqueous iodophor irrigation); 3) the study only included oral or dental health procedures; 4) the surgical procedures did not include primary closure of the incision in the operating room (eg, orthopedic pin sites, thoracotomies, or percutaneous endoscopic gastrostomy [PEG] procedures, or wounds healing by secondary intention); or 5) the study evaluated wound protectors used postincision. Evidence-based recommendations in this guideline were cross-checked with those from other guidelines identified in a systematic search.

CDC completed a draft of the guideline and shared it with the expert panel for in-depth review and then with HICPAC and members of the public at committee meetings (June 2010 to July 2015). CDC posted notice in the *Federal Register* for the following 2 periods of public comment: from January 29 to February 28, 2014, and from April 8 to May 8, 2014. Comments were aggregated and reviewed with the writing group and at another HICPAC meeting. Based on the comments received, the literature search was updated, and new data were incorporated into a revised draft. Further input was provided by HICPAC during a public teleconference in May 2015. Final HICPAC input was provided via a vote by majority rule in July 2015. After final HICPAC input, CDC updated the draft document and obtained final CDC clearance and coauthor approval.

Recommendation Categories

Recommendations were categorized using the following standard system that reflects the level of supporting evidence or regulations:

- Category IA: A strong recommendation supported by high to moderate-quality evidence suggesting net clinical benefits or harms.
- Category IB: A strong recommendation supported by low-quality evidence suggesting net clinical benefits or harms or an accepted practice (eg, aseptic technique) supported by low to very low-quality evidence.
- Category IC: A strong recommendation required by state or federal regulation.
- Category II: A weak recommendation supported by any quality evidence suggesting a trade-off between clinical benefits and harms.
- No recommendation/unresolved issue: An issue for which there is low to very low-quality evidence with uncertain trade-offs between the benefits and harms or no published evidence on outcomes deemed critical to weighing the risks and benefits of a given intervention.

Recommendations

Core Section

In 2006, approximately 80 million surgical procedures were performed in the United States at inpatient hospitals (46 million)⁷ and ambulatory hospital-affiliated or freestanding (32 million) settings.⁶ Between 2006 and 2009, SSIs complicated approximately 1.9% of surgical procedures in the United States.¹⁹ However, the number of SSIs is likely to be underestimated given that approximately 50% of SSIs become evident after discharge.²⁰ Estimated mean attrib-

utable costs of SSIs range from \$10 443 in 2005 US dollars to \$25 546 in 2002 US dollars per infection.^{3-5,11} Costs can exceed \$90 000 per infection when the SSI involves a prosthetic joint implant^{21,22} or an antimicrobial-resistant organism.²³ The Core Section of this guideline (eAppendix 1 of the [Supplement](#)) includes recommendations for the prevention of SSI that are generalizable across surgical procedures, with some exceptions as mentioned below.

Parenteral Antimicrobial Prophylaxis

1A.1. Administer preoperative antimicrobial agents only when indicated based on published clinical practice guidelines and timed such that a bactericidal concentration of the agents is established in the serum and tissues when the incision is made. (Category IB—strong recommendation; accepted practice.)

1A.2. No further refinement of timing can be made for preoperative antimicrobial agents based on clinical outcomes. (No recommendation/unresolved issue.)

1B. Administer the appropriate parenteral prophylactic antimicrobial agents before skin incision in all cesarean section procedures. (Category IA—strong recommendation; high-quality evidence.)

1C. The literature search did not identify randomized controlled trials that evaluated the benefits and harms of weight-adjusted parenteral antimicrobial prophylaxis dosing and its effect on the risk of SSI. Other organizations have made recommendations based on observational and pharmacokinetic data, and a summary of these recommendations can be found in the Other Guidelines section of the narrative summary for this question (eAppendix 1 of the [Supplement](#)). (No recommendation/unresolved issue.)

1D. The search did not identify sufficient randomized controlled trial evidence to evaluate the benefits and harms of intraoperative re-dosing of parenteral prophylactic antimicrobial agents for the prevention of SSI. Other organizations have made recommendations based on observational and pharmacokinetic data, and a summary of these recommendations can be found in the Other Guidelines section of the narrative summary for this question (eAppendix 1 of the [Supplement](#)). (No recommendation/unresolved issue.)

1E. In clean and clean-contaminated procedures, do not administer additional prophylactic antimicrobial agent doses after the surgical incision is closed in the operating room, even in the presence of a drain. (Category IA—strong recommendation; high-quality evidence.)

Nonparenteral Antimicrobial Prophylaxis

2A.1. Randomized controlled trial evidence suggested uncertain trade-offs between the benefits and harms regarding intraoperative antimicrobial irrigation (eg, intra-abdominal, deep, or subcutaneous tissues) for the prevention of SSI. Other organizations have made recommendations based on the existing evidence, and a summary of these recommendations can be found in the Other Guidelines section of the narrative summary for this question (eAppendix 1 of the [Supplement](#)). (No recommendation/unresolved issue.)

2A.2. The search did not identify randomized controlled trials that evaluated soaking prosthetic devices in antimicrobial solutions before implantation for the prevention of SSI. (No recommendation/unresolved issue.)

2B.1. Do not apply antimicrobial agents (ie, ointments, solutions, or powders) to the surgical incision for the prevention of SSI. (Category IB—strong recommendation; low-quality evidence.)

2B.2. Application of autologous platelet-rich plasma is not necessary for the prevention of SSI. (Category II—weak recommendation; moderate-quality evidence suggesting a trade-off between clinical benefits and harms.)

2C. Consider the use of triclosan-coated sutures for the prevention of SSI. (Category II—weak recommendation; moderate-quality evidence suggesting a trade-off between clinical benefits and harms.)

2D. Randomized controlled trial evidence suggested uncertain trade-offs between the benefits and harms regarding antimicrobial dressings applied to surgical incisions after primary closure in the operating room for the prevention of SSI. (No recommendation/unresolved issue.)

Glycemic Control

3A.1. Implement perioperative glycemic control and use blood glucose target levels less than 200 mg/dL in patients with and without diabetes. (Category IA—strong recommendation; high to moderate-quality evidence.)

3A.2. The search did not identify randomized controlled trials that evaluated lower (<200 mg/dL) or narrower blood glucose target levels than recommended in this guideline nor the optimal timing, duration, or delivery method of perioperative glycemic control for the prevention of SSI. Other organizations have made recommendations based on observational evidence, and a summary of these recommendations can be found in the Other Guidelines section of the narrative summary for this question (eAppendix 1 of the [Supplement](#)). (No recommendation/unresolved issue.)

3B. The search did not identify randomized controlled trials that evaluated the optimal hemoglobin A1C target levels for the prevention of SSI in patients with and without diabetes. (No recommendation/unresolved issue.)

Normothermia

1. Maintain perioperative normothermia. (Category IA—strong recommendation; high to moderate-quality evidence.)
2. The search did not identify randomized controlled trials that evaluated strategies to achieve and maintain normothermia, the lower limit of normothermia, or the optimal timing and duration of normothermia for the prevention of SSI. Other organizations have made recommendations based on observational evidence, and a summary of these recommendations can be found in the Other Guidelines section of the narrative summary for this question (eAppendix 1 of the [Supplement](#)). (No recommendation/unresolved issue.)

Oxygenation

6A. Randomized controlled trial evidence suggested uncertain trade-offs between the benefits and harms regarding the administration of increased fraction of inspired oxygen (FIO₂) via endotracheal intubation during only the intraoperative period in patients with normal pulmonary function undergoing general anesthesia for the prevention of SSI. (No recommendation/unresolved issue.)

6B. For patients with normal pulmonary function undergoing general anesthesia with endotracheal intubation, administer increased FIO₂ during surgery and after extubation in the immediate postoperative period. To optimize tissue oxygen delivery, maintain perioperative normothermia and adequate volume replacement. (Category IA—strong recommendation; moderate-quality evidence.)

6C. Randomized controlled trial evidence suggested uncertain trade-offs between the benefits and harms regarding the administration of increased FIO₂ via face mask during the perioperative period in patients with normal pulmonary function undergoing general anesthesia without endotracheal intubation or neuraxial anesthesia (ie, spinal, epidural, or local nerve blocks) for the prevention of SSI. (No recommendation/unresolved issue.)

6D. Randomized controlled trial evidence suggested uncertain trade-offs between the benefits and harms regarding the administration of increased FIO₂ via face mask or nasal cannula during only the postoperative period in patients with normal pulmonary function for the prevention of SSI. (No recommendation/unresolved issue.)

The search did not identify randomized controlled trials that evaluated the optimal target level, duration, and delivery method of FIO₂ for the prevention of SSI. Other organizations have made recommendations based on observational studies, and a summary of these recommendations can be found in the Other Guidelines section of the narrative summary for this question (eAppendix 1 of the [Supplement](#)). (No recommendation/unresolved issue.)

Antiseptic Prophylaxis

8A.1. Advise patients to shower or bathe (full body) with soap (antimicrobial or nonantimicrobial) or an antiseptic agent on at least the night before the operative day. (Category IB—strong recommendation; accepted practice.)

8A.2. Randomized controlled trial evidence suggested uncertain trade-offs between the benefits and harms regarding the optimal timing of the preoperative shower or bath, the total number of soap or antiseptic agent applications, or the use of chlorhexidine gluconate washcloths for the prevention of SSI. (No recommendation/unresolved issue.)

8B. Perform intraoperative skin preparation with an alcohol-based antiseptic agent unless contraindicated. (Category IA—strong recommendation; high-quality evidence.)

8C. Application of a microbial sealant immediately after intraoperative skin preparation is not necessary for the prevention of SSI. (Category II—weak recommendation; low-quality evidence suggesting a trade-off between clinical benefits and harms.)

8D. The use of plastic adhesive drapes with or without antimicrobial properties is not necessary for the prevention of SSI. (Category II—weak recommendation; high to moderate-quality evidence suggesting a trade-off between clinical benefits and harms.)

9A. Consider intraoperative irrigation of deep or subcutaneous tissues with aqueous iodophor solution for the prevention of SSI. Intraperitoneal lavage with aqueous iodophor solution in contaminated or dirty abdominal procedures is not necessary. (Category II—weak recommendation; moderate-quality evidence suggesting a trade-off between clinical benefits and harms.)

9B. The search did not identify randomized controlled trials that evaluated soaking prosthetic devices in antiseptic solutions before implantation for the prevention of SSI. (No recommendation/unresolved issue.)

Randomized controlled trial evidence was insufficient to evaluate the trade-offs between the benefits and harms of repeat application of antiseptic agents to the patient's skin immediately before closing the surgical incision for the prevention of SSI. (No recommendation/unresolved issue.)

Prosthetic Joint Arthroplasty Section

Prevention efforts should target all surgical procedures but especially those in which the human and financial burden is greatest. In 2011, primary total knee arthroplasty accounted for more than half of the 1.2 million prosthetic joint arthroplasty procedures (primary and revision) performed in the United States, followed by total hip arthroplasty and hip hemiarthroplasty.²⁴ Primary shoulder, elbow, and ankle arthroplasties are much less common. By 2030, prosthetic joint arthroplasties are projected to increase to 3.8 million procedures per year.²⁵⁻²⁷

Infection is the most common indication for revision in total knee arthroplasty²⁸ and the third most common indication in total hip arthroplasty.²⁸ By 2030, the infection risk for hip and knee arthroplasty is expected to increase from 2.18%²² to 6.5% and 6.8%, respectively.²⁵ In addition, owing to increasing risk and the number of individuals undergoing prosthetic joint arthroplasty procedures, the total number of hip and knee prosthetic joint infections is projected to increase to 221 500 cases per year by 2030, at a cost of more than \$1.62 billion.^{22,25} The Prosthetic Joint Arthroplasty section contains recommendations that are applicable to these procedures (eAppendix 1 of the Supplement).

Blood Transfusion

11A. Available evidence suggested uncertain trade-offs between the benefits and harms of blood transfusions on the risk of SSI in prosthetic joint arthroplasty. Other organizations have made recommendations on this topic, and a reference to these recommendations can be found in the Other Guidelines section of the narrative summary for this question (eAppendix 1 of the Supplement). (No recommendation/unresolved issue.)

11B. Do not withhold transfusion of necessary blood products from surgical patients as a means to prevent SSI. (Category IB—strong recommendation; accepted practice.)

Systemic Immunosuppressive Therapy

12 and 13. Available evidence suggested uncertain trade-offs between the benefits and harms of systemic corticosteroid or other immunosuppressive therapies on the risk of SSI in prosthetic joint arthroplasty. Other organizations have made recommendations based on the existing evidence, and a summary of these recommendations can be found in the Other Guidelines section of the narrative summary for this question (eAppendix 1 of the Supplement). (No recommendation/unresolved issue.)

For prosthetic joint arthroplasty patients receiving systemic corticosteroid or other immunosuppressive therapy, recommendation

1E applies: in clean and clean-contaminated procedures, do not administer additional antimicrobial prophylaxis doses after the surgical incision is closed in the operating room, even in the presence of a drain. (Category IA—strong recommendation; high-quality evidence.)

Intra-articular Corticosteroid Injection

15 and 16. Available evidence suggested uncertain trade-offs between the benefits and harms of the use and timing of preoperative intra-articular corticosteroid injection on the incidence of SSI in prosthetic joint arthroplasty. Other organizations have made recommendations based on observational studies, and a summary of these recommendations can be found in the Other Guidelines section of the narrative summary for this question (eAppendix 1 of the Supplement). (No recommendation/unresolved issue.)

Anticoagulation

1. Available evidence suggested uncertain trade-offs between the benefits and harms of venous thromboembolism prophylaxis on the incidence of SSI in prosthetic joint arthroplasty. Other organizations have made recommendations based on the existing evidence, and these references can be found in the Other Guidelines section of the narrative summary for this question (eAppendix 1 of the Supplement). (No recommendation/unresolved issue.)

Orthopedic Surgical Space Suit

1. Available evidence suggested uncertain trade-offs between the benefits and harms of orthopedic space suits or the health care personnel who should wear them for the prevention of SSI in prosthetic joint arthroplasty. (No recommendation/unresolved issue.)

Postoperative Antimicrobial Prophylaxis Duration With Drain Use

1. In prosthetic joint arthroplasty, recommendation 1E applies: in clean and clean-contaminated procedures, do not administer additional antimicrobial prophylaxis doses after the surgical incision is closed in the operating room, even in the presence of a drain. (Category IA—strong recommendation; high-quality evidence.)

Biofilm

20A. Available evidence suggested uncertain trade-offs between the benefits and harms regarding cement modifications and the prevention of biofilm formation or SSI in prosthetic joint arthroplasty. (No recommendation/unresolved issue.)

20B. The search did not identify studies evaluating prosthesis modifications for the prevention of biofilm formation or SSI in prosthetic joint arthroplasty. (No recommendation/unresolved issue.)

20C. The search did not identify studies evaluating vaccines for the prevention of biofilm formation or SSI in prosthetic joint arthroplasty. (No recommendation/unresolved issue.)

20D. The search did not identify studies evaluating biofilm control agents, such as biofilm dispersants, quorum sensing inhibitors, or novel antimicrobial agents, for the prevention of biofilm formation or SSI in prosthetic joint arthroplasty. (No recommendation/unresolved issue.)

Conclusions

Surgical site infections are persistent and preventable health care-associated infections. There is increasing demand for evidence-based interventions for the prevention of SSI. The last version of the CDC Guideline for Prevention of Surgical Site Infection¹⁸ was published in 1999. While the guideline was evidence informed, most recommendations were based on expert opinion, in the era before evidence-based guideline methods. CDC updated that version of the guideline using GRADE as the evidence-based method that provides the foundation of the recommendations in this guideline. These

new and updated recommendations are not only useful for health care professionals but also can be used as a resource for professional societies or organizations to develop more detailed implementation guidance or to identify future research priorities. The paucity of robust evidence across the entire guideline created challenges in formulating recommendations for the prevention of SSI. Nonetheless, the thoroughness and transparency achieved using a systematic review and the GRADE approach to address clinical questions of interest to stakeholders are critical to the validity of the clinical recommendations.

The number of unresolved issues in this guideline reveals substantial gaps that warrant future research. A select list of these unresolved issues may be prioritized to formulate a research agenda to advance the field. Adequately powered, well-designed studies that assess the effect of specific interventions on the incidence of SSI are needed to address these evidence gaps. Subsequent revisions to this guideline will be guided by new research and technological advancements for preventing SSIs.

ARTICLE INFORMATION

Accepted for Publication: March 1, 2017.

Published Online: May 3, 2017.

doi:10.1001/jamasurg.2017.0904

Author Affiliations: Division of Healthcare Quality Promotion, Centers for Disease Control and Prevention, Atlanta, Georgia (Berríos-Torres, Stone, Donlan); Center for Evidence-Based Practice, University of Pennsylvania Health System, Philadelphia (Umscheid, Leas, Kelz, Morgan); College of Public Health, The University of Oklahoma Health Sciences Center, Oklahoma City (Bratzler); Carolinas Healthcare System, Charlotte, North Carolina (Reinke); Department of Surgery, University of Cincinnati College of Medicine, Cincinnati, Ohio (Solomkin); Section of Acute and Critical Care Surgery, Washington University School of Medicine in St Louis, Saint Louis, Missouri (Mazuski); American College of Surgeons Representative, University of Washington Medical Center, Seattle (Dellinger); Surgical Infection Society Representative, Veterans Affairs Boston Healthcare System, Boston University and Harvard Medical School, Boston, Massachusetts (Itani); Musculoskeletal Infection Society Representative, Mayo Clinic College of Medicine, Rochester, Minnesota (Berbari); American Academy of Orthopaedic Surgeons Representative, Rush University Medical Center, Chicago, Illinois (Segreti); American Academy of Orthopaedic Surgeons Representative, Rothman Institute, Philadelphia, Pennsylvania (Parvizi); Quality Department, Littleton Adventist Hospital, Denver, Colorado (Blanchard); Association of Perioperative Registered Nurses Representative, New York Methodist Hospital, Brooklyn (Allen); Laboratory for Microbiology and Infection Control, Amphia Hospital, Breda, the Netherlands (Kluytmans); Julius Center for Health Sciences and Primary Care, University Medical Center, Utrecht, the Netherlands (Kluytmans); Department of Surgery, San Francisco General Hospital, University of California, San Francisco (Schechter).

Author Contributions: Dr Umscheid and Ms Stone had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Berríos-Torres, Umscheid, Bratzler, Leas, Stone, Kelz, Morgan, Mazuski, Dellinger, Itani, Berbari, Parvizi, Blanchard, Kluytmans.

Acquisition, analysis, or interpretation of data: Berríos-Torres, Umscheid, Bratzler, Leas, Stone, Kelz, Reinke, Morgan, Solomkin, Mazuski, Dellinger, Segreti, Allen, Kluytmans, Donlan, Schechter.

Drafting of the manuscript: Berríos-Torres, Umscheid, Leas, Stone, Kelz, Reinke, Morgan, Itani, Berbari, Segreti, Blanchard.

Critical revision of the manuscript for important intellectual content: Berríos-Torres, Umscheid, Bratzler, Leas, Stone, Kelz, Reinke, Solomkin, Mazuski, Dellinger, Itani, Berbari, Segreti, Parvizi, Allen, Kluytmans, Donlan, Schechter.

Statistical analysis: Berríos-Torres, Umscheid, Leas.

Administrative, technical, or material support: Berríos-Torres, Bratzler, Leas, Stone, Morgan, Itani, Parvizi.

Study supervision: Berríos-Torres, Umscheid, Bratzler, Stone, Itani, Berbari, Parvizi.

Conflict of Interest Disclosures: Drs Umscheid, Kelz, and Morgan and Mr Leas reported receiving funding from the Centers for Disease Control and Prevention to support the guideline development process. Dr Bratzler reported being a consultant for the Oklahoma Foundation for Medical Quality and for Telligen (a nonprofit Medicaid external quality review organization) and reported that his institution received payment for his lectures, including service on speakers' bureaus from Premier and Janssen Pharmaceuticals. Dr Reinke reported receiving lecture fees from Covidien and reported being a paid consultant for Teleflex. Dr Solomkin reported receiving grants for clinical research from, receiving consulting fees regarding clinical trial data, serving on an advisory board for, or lecturing for honoraria from the following: Merck, Actavis, AstraZeneca, PPD, Tetrphase, Johnson & Johnson, and 3M. Dr Mazuski reported being a paid consultant for Bayer, Cubist Pharmaceuticals, Forest Laboratories, MedImmune, Merck/Merck Sharp and Dohme, and Pfizer; reported receiving lecture fees from Forest Laboratories, Merck/Merck Sharp and Dohme, and Pfizer; and reported that his institution received funding for his consultancy to AstraZeneca and

grants from AstraZeneca, Bayer, Merck/MSD, and Tetrphase. Dr Dellinger reported receiving grants for clinical research from, serving on an advisory board for, or lecturing for honoraria from the following: Merck, Baxter, Ortho-McNeil, Targanta, Schering-Plough, WebEx, Astellas, Care Fusion, Durata, Pfizer, Applied Medical, Rib-X, Affinium, and 3M. Dr Itani reported that his institution received grants from Merck, Cubist, Dr Reddy's, Sanofi Pasteur, and Trius for research trials; reported clinical advisory board membership at Forrest Pharmaceuticals; and reported payment for development of educational presentations for Med Direct and Avid Education. Dr Berbari reported that his institution received a grant from Pfizer for a research trial for which he serves as the principal investigator. Dr Segreti reported receiving lecture fees from Pfizer, Merck, and Forest Laboratories and reported owning stocks in or having stock options from Pfizer. Dr Parvizi reported being a paid consultant for Zimmer, Smith and Nephew, ConvaTec, TissueGene, CeramTech, and Medtronic; reported receiving royalties from Elsevier, Wolters Kluwer, Slack Incorporated, Data Trace Publishing, and Jaypee Brothers Medical Publishers; and reported having stock options with Hip Innovation Technologies, CD Diagnostics, and PRN. Dr Allen reported receiving lecture fees from Ethicon and royalties from Wolters Kluwer as an author for *Infection Control: A Practical Guide for Healthcare Facilities*. Dr Kluytmans reported being a paid consultant for 3M, Johnson & Johnson, and Pfizer. No other disclosures were reported.

Funding/Support: The Centers for Disease Control and Prevention (CDC) supported the development of the guideline. The activities of Drs Umscheid, Kelz, and Morgan and Mr Leas were supported through a short-term detail under contract at CDC (10IPA1004117, 10IPA1004133, 11IPA1106551, 11IPA1106555, and 11IPA1106565).

Role of the Funder/Sponsor: Centers for Disease Control and Prevention conducted the full guideline development process, directing the design and conduct of the systematic reviews; collection, management, analysis, and interpretation of the data; and preparation, review, and approval for submission of the manuscript for publication. Centers for Disease Control and Prevention staff

members were responsible for the overall design and conduct of the guideline and preparation, review, and approval of the manuscript.

Group Information: The Healthcare Infection Control Practices Advisory Committee (HICPAC) members are as follows: Hilary M. Babcock, MD, MPH, Washington University School of Medicine in St Louis; Dale W. Bratzler, DO, MPH, The University of Oklahoma Health Sciences Center; Patrick J. Brennan, MD, University of Pennsylvania Health System; Vickie M. Brown, RN, MPH, WakeMed Health & Hospitals; Lillian A. Burns, MT, MPH, Greenwich Hospital; Ruth M. Carrico, PhD, RN, CIC, University of Louisville School of Medicine; Sheri Chernetsky Tejedor, MD, Emory University School of Medicine; Daniel J. Diekema, MD, University of Iowa Carver College of Medicine; Alexis Elward, MD, Washington University School of Medicine in St Louis; Neil O. Fishman, MD, University of Pennsylvania Health System; Ralph Gonzales, MD, MSPH, University of California, San Francisco; Mary K. Hayden, MD, Rush University Medical Center; Susan Huang, MD, MPH, University of California Irvine School of Medicine; W. Charles Huskins, MD, MSc, Mayo Clinic College of Medicine; Lynn Janssen, MS, CIC, CPHQ, California Department of Public Health; Tammy Lundstrom, MD, JD, Providence Hospital; Lisa Maragakis, MD, MPH, The Johns Hopkins Hospital; Yvette S. McCarter, PhD, University of Florida Health Science Center; Denise M. Murphy, MPH, RN, CIC, Main Line Health System; Russell N. Olmsted, MPH, St Joseph Mercy Health System; Stephen Ostroff, MD, US Food and Drug Administration; Jan Patterson, MD, University of Texas Health Science Center, San Antonio; David A. Pegues, MD, David Geffen School of Medicine at UCLA; Peter J. Pronovost, MD, PhD, The Johns Hopkins University; Gina Pugliese, RN, MS, Premier Healthcare Alliance; Selwyn O. Rogers Jr, MD, MPH, The University of Texas Medical Branch; William P. Schechter, MD, University of California, San Francisco; Barbara M. Soule, RN, MPA, CIC, The Joint Commission; Tom Talbot, MD, MPH, Vanderbilt University Medical Center; Michael L. Tapper, MD, Lenox Hill Hospital; and Deborah S. Yokoe, MD, MPH, Brigham & Women's Hospital.

Ex Officio Members: William B. Baine, MD, Agency for Healthcare Research and Quality; Elizabeth Claverie-Williams, MS, US Food and Drug Administration; David Henderson, MD, National Institutes of Health; Jeannie Miller, RN, MPH, Centers for Medicare & Medicaid Services; Paul D. Moore, PhD, Health Resources and Services Administration; Sheila Murphey, MD, US Food and Drug Administration; and Daniel Schwartz, MD, MBA, Centers for Medicare & Medicaid Services.

Liaisons: Joan Blanchard, RN, BSN, Association of Perioperative Registered Nurses; William A. Brock, MD, Society of Critical Care Medicine; Barbara DeBaun, MSN, RN, CIC, Association of Professionals of Infection Control and Epidemiology, Inc; Kathleen Dunn, BScN, MN, RN, Public Health Agency of Canada; Sandra Fitzer, RN, American Health Care Association; Nancy Foster, American Hospital Association; Janet Franck, RN, MBA, CIC, DNV Healthcare, Inc; Diana Gaviria, MD, MPH, National Association of County and City Health Officials; Jennifer Gutowski, MPH, BSN, RN, CIC, National Association of County and City Health Officials; Holly Harmon, RN, MBA, American Health Care Association; Patrick Horine, MHA, DNV Healthcare, Inc; Michael D. Howell, MD, MPH,

Society of Critical Care Medicine; W. Charles Huskins, MD, MSc, Infectious Diseases Society of America; Marion Kainer, MD, MPH, Council of State and Territorial Epidemiologists; Emily Lutterloh, MD, MPH, Association of State and Territorial Health Officials; Lisa Maragakis, MD, Society for Healthcare Epidemiology of America; Michael McElroy, MPH, CIC, America's Essential Hospitals; Lisa McGiffert, Consumers Union; Silvia Muñoz-Price, MD, America's Essential Hospitals; Shirley Paton, RN, MN, Public Health Agency of Canada; Michael Anne Preas, RN, CIC, Association of Professionals of Infection Control and Epidemiology, Inc; Mark E. Rupp, MD, Society for Healthcare Epidemiology of America; Mark Russi, MD, MPH, American College of Occupational and Environmental Medicine; Sanjay Saint, MD, MPH, Society of Hospital Medicine; Robert G. Sawyer, MD, Surgical Infection Society; Roslyne Schulman, MHA, MBA, American Hospital Association; Rachel Stricof, MPH, Advisory Council for the Elimination of Tuberculosis; Donna Tiberi, RN, MHA, Healthcare Facilities Accreditation Program; Margaret VanAmringe, MHS, The Joint Commission; Stephen Weber, MD, Infectious Diseases Society of America; Elizabeth Wick, MD, American College of Surgeons; Robert Wise, MD, The Joint Commission; and Amber Wood, MSN, RN, CNOR, CIC, CPN, Association of Perioperative Registered Nurses.

Disclaimer: The opinions of the reviewers might not be reflected in all of the recommendations contained in this document.

Additional Information: Before July 2014, Dr Berríos-Torres was employed at Centers for Disease Control and Prevention. She has no affiliation since July 2014. Authors recused themselves from discussions if they had competing interests related to recommendations under discussion. For product-specific recommendation discussions (eg, triclosan-coated sutures), a new declaration of conflicts specific to that topic was requested from each author before his or her input was considered in the formulation of the recommendation.

Additional Contributions: The Centers for Disease Control and Prevention thanks the many individuals and organizations who provided valuable feedback on the guideline during the development process, especially the following experts for their input throughout the process: Rajender Agarwal, MD, MPH (Center for Evidence-Based Practice, University of Pennsylvania Health System, Philadelphia); J. William Costerton, PhD (Center for Genomic Sciences, Allegheny-Singer Research Institute, Pittsburgh, Pennsylvania); Jeffrey C. Hageman, MHS (Division of Healthcare Quality Promotion, Centers for Disease Control and Prevention, Atlanta, Georgia); Thomas Hunt, MD (Department of Surgery, University of California at San Francisco); Bernard Morrey, MD (Department of Orthopedic Surgery, Mayo Clinic, Rochester, Minnesota); Lena M. Napolitano, MD (Division of Acute Care Surgery, University of Michigan Health Systems, Ann Arbor); Douglas Osmon, MD (Department of Infectious Diseases, Mayo Clinic, Rochester, Minnesota); Robin Patel, MD(CM), FRCP(C), D(ABMM) (Infectious Diseases Research Laboratory, Mayo Clinic, Rochester, Minnesota); and Mark Shirtliff, PhD (Department of Microbial Pathogenesis, University of Maryland, Baltimore). None received compensation outside of their usual salary.

REFERENCES

1. National Healthcare Safety Network, Centers for Disease Control and Prevention. Surgical site infection (SSI) event. <http://www.cdc.gov/nhsn/pdfs/pscmanual/9pscscicurrent.pdf>. Published January 2017. Accessed January 25, 2017.
2. Fry DE. Fifty ways to cause surgical site infections. *Surg Infect (Larchmt)*. 2011;12(6):497-500.
3. Anderson DJ, Kirkland KB, Kaye KS, et al. Underresourced hospital infection control and prevention programs: penny wise, pound foolish? *Infect Control Hosp Epidemiol*. 2007;28(7):767-773.
4. Centers for Disease Control and Prevention. The direct medical costs of healthcare-associated infections in U.S. hospitals and the benefits of prevention. http://www.cdc.gov/hai/pdfs/hai/scott_costpaper.pdf. Published 2009. Accessed January 25, 2017.
5. Stone PW, Braccia D, Larson E. Systematic review of economic analyses of health care-associated infections. *Am J Infect Control*. 2005;33(9):501-509.
6. Cullen KA, Hall MJ, Golosinskiy A. Ambulatory surgery in the United States, 2006. National Health Statistics Reports 11. <http://www.cdc.gov/nchs/data/nhsr/nhsr011.pdf>. Revised September 4, 2009. Accessed January 25, 2017.
7. DeFrances CJ, Podgornik MN. 2004 National Hospital Discharge Survey. *Adv Data*. 2006;(371):1-19.
8. US Department of Health and Human Services. National action plan to prevent health care-associated infections: road map to elimination. <https://health.gov/hcq/prevent-hai-action-plan.asp>. Published 2013. Accessed January 25, 2017.
9. Centers for Medicare and Medicaid Services (CMS), HHS. Medicare Program; hospital inpatient prospective payment systems for acute care hospitals and the long-term care hospital prospective payment system changes and FY2011 rates; provider agreements and supplier approvals; and hospital conditions of participation for rehabilitation and respiratory care services; Medicaid program: accreditation for providers of inpatient psychiatric services. Final rules and interim final rule with comment period. *Fed Regist*. 2010;75(157):50041-50681.
10. US Government Printing Office. The Deficit Reduction Act of 2005. <http://www.gpo.gov/fdsys/pkg/BILLS-109s1932enr/pdf/BILLS-109s1932enr.pdf>. Published 2006. Accessed January 25, 2017.
11. Umscheid CA, Mitchell MD, Doshi JA, Agarwal R, Williams K, Brennan PJ. Estimating the proportion of healthcare-associated infections that are reasonably preventable and the related mortality and costs. *Infect Control Hosp Epidemiol*. 2011;32(2):101-114.
12. Guyatt GH, Oxman AD, Kunz R, et al; GRADE Working Group. Going from evidence to recommendations. *BMJ*. 2008;336(7652):1049-1051.
13. Guyatt GH, Oxman AD, Kunz R, Vist GE, Falck-Ytter Y, Schünemann HJ; GRADE Working Group. What is "quality of evidence" and why is it important to clinicians? *BMJ*. 2008;336(7651):995-998.
14. Guyatt GH, Oxman AD, Vist GE, et al; GRADE Working Group. GRADE: an emerging consensus on

rating quality of evidence and strength of recommendations. *BMJ*. 2008;336(7650):924-926.

15. Schünemann HJ, Oxman AD, Brozek J, et al; GRADE Working Group. Grading quality of evidence and strength of recommendations for diagnostic tests and strategies. *BMJ*. 2008;336(7653):1106-1110.

16. Umscheid CA, Agarwal RK, Brennan PJ; Healthcare Infection Control Practices Advisory Committee, Centers for Disease Control and Prevention. Updating the guideline methodology of the Healthcare Infection Control Practices Advisory Committee (HICPAC). http://www.cdc.gov/hicpac/pdf/guidelines/2009-10-29HICPAC_GuidelineMethodsFINAL.pdf. Published 2010. Accessed January 25, 2017.

17. Umscheid CA, Agarwal RK, Brennan PJ; Healthcare Infection Control Practices Advisory Committee. Updating the guideline development methodology of the Healthcare Infection Control Practices Advisory Committee (HICPAC). *Am J Infect Control*. 2010;38(4):264-273.

18. Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR; Centers for Disease Control and Prevention (CDC) Hospital Infection Control Practices Advisory Committee. Guideline for

prevention of surgical site infection, 1999. *Am J Infect Control*. 1999;27(2):97-132.

19. Mu Y, Edwards JR, Horan TC, Berríos-Torres SI, Fridkin SK. Improving risk-adjusted measures of surgical site infection for the National Healthcare Safety Network. *Infect Control Hosp Epidemiol*. 2011;32(10):970-986.

20. McKibben L, Horan T, Tokars JI, et al; Healthcare Infection Control Practices Advisory Committee. Guidance on public reporting of healthcare-associated infections: recommendations of the Healthcare Infection Control Practices Advisory Committee. *Am J Infect Control*. 2005;33(4):217-226.

21. Bozic KJ, Ries MD. The impact of infection after total hip arthroplasty on hospital and surgeon resource utilization. *J Bone Joint Surg Am*. 2005;87(8):1746-1751.

22. Kurtz SM, Lau E, Watson H, Schmier JK, Parvizi J. Economic burden of periprosthetic joint infection in the United States. *J Arthroplasty*. 2012;27(8)(suppl):61-5.e1.

23. Engemann JJ, Carmeli Y, Cosgrove SE, et al. Adverse clinical and economic outcomes attributable to methicillin resistance among

patients with *Staphylococcus aureus* surgical site infection. *Clin Infect Dis*. 2003;36(5):592-598.

24. HCUPnet. Healthcare Cost and Utilization Project, Agency for Healthcare Research and Quality. 2011 Nationwide Inpatient Sample (NIS). <https://www.hcup-us.ahrq.gov/nisoverview.jsp>. Published 2011. Accessed January 25, 2017.

25. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Joint Surg Am*. 2007;89(4):780-785.

26. Kurtz SM, Lau E, Schmier J, Ong KL, Zhao K, Parvizi J. Infection burden for hip and knee arthroplasty in the United States. *J Arthroplasty*. 2008;23(7):984-991.

27. Kurtz SM, Ong KL, Schmier J, Zhao K, Mowat F, Lau E. Primary and revision arthroplasty surgery caseloads in the United States from 1990 to 2004. *J Arthroplasty*. 2009;24(2):195-203.

28. Bozic KJ, Kurtz SM, Lau E, et al. The epidemiology of revision total knee arthroplasty in the United States. *Clin Orthop Relat Res*. 2010;468(1):45-51.