Infection Prevention and Control Guidelines for Anesthesia Care

Chapter XX: Role of the CRNA in Reducing Ventilator-Associated Pneumonia and Surgical Site Infection

Introduction

Ventilator-Associated Pneumonia (VAP) and Surgical Site Infection (SSI) are two significant healthcare-associated infections (HAIs) that can lead to increased morbidity, mortality, and healthcare costs. There are other HAIs that may pose a risk to patients, this chapter will focus on VAP and SSI as these infections are ones that anesthesia providers can directly mitigate. The following section outlines key prevention strategies for anesthesia professionals to mitigate the risk of these adverse events.

Purpose

The purpose of this chapter is to outline key prevention strategies for anesthesia professionals to mitigate the risk of VAP and SSI.

Audience

This resource is intended for Certified Registered Nurse Anesthetists (CRNAs), also known as nurse anesthesiologists or nurse anesthetists, resident registered nurse anesthetists, other anesthesia providers, members of the interdisciplinary team, administrators involved in policy developed and implementation, quality assurance professionals, and other interested stakeholders.

Ventilator-Associated Pneumonia

VAP is hospital-acquired pneumonia that develops 48 hours or longer in patients who have been mechanically ventilated by endotracheal tube (ETT) or tracheostomy.[1-3] VAP is reported to affect 5 to 40% of patients receiving invasive mechanical ventilation for more than 2 days, with large variations depending upon the country, ICU type, and criteria used to identify VAP.[1,2]

VAP is a serious healthcare-associated infection that can lead to significant morbidity, mortality, and increased healthcare costs.[4-9] Clinical signs of VAP include purulent tracheal discharge, fevers, and respiratory distress in the presence of microorganisms.[10] Studies have attempted to quantify the economic burden of VAP and have reported costs ranging from $10,000 to $40,000 per patient treated.[4,5,7-9]

Implementing the following ventilator bundle compliance prevention strategies may reduce the burden of VAP and improve patient outcomes.[2,11-22]

- Practice hand hygiene before and after patient care.
- Use noninvasive ventilation when possible to avoid intubation and associated risks.
- Extubate as early as possible to minimize duration of invasive ventilation.
- Prevent aspiration by:
  - Maintaining semirecumbent position (30-40 degrees) if possible.
  - Avoiding gastric overdistention.
  - Avoiding unplanned extubation and reintubation.
  - Using cuffed endotracheal tubes with subglottic suctioning.
  - Maintaining cuff pressure of ≥ 20cm H_2O.
- Avoid nasotracheal intubation.
- Avoid acid suppressive therapy (i.e., H2 blockers, proton pump inhibitors), if possible, due to risk increases bacterial colonization of the aerodigestive tract. If clinically indicated, use the lowest possible dose and duration of acid suppressive therapy to reduce risk of bacterial colonization.
- Perform regular oral care with an antiseptic solution.
- Eliminate potential contamination risk to equipment:

- Using sterile water to rinse reusable equipment.
- Removing condensate from ventilator circuits.
- Changing circuits only when visibly soiled.
- Using sterile suction catheters.

Surgical Site Infection

SSI is an infection occurring at or near the surgical site within 30 days of the surgical procedure or within 90 days of implantation of prosthetic materials.[23] SSIs can be classified as superficial or deep, involving tissues beneath the skin, surrounding organs, or implanted materials.[23] SSIs can be caused by a myriad of bacteria, including the patient's own endogenous flora. SSIs are costly and pose a risk to patient safety. SSIs account for 20% or more of all HAIs and affect up to 3% of all surgical patients, with variation based on type of surgery, patient co-morbidities, length of operation, increasing mortality 2- to 10-fold.[24-29] SSIs are the most costly HAI with an estimated annual cost of $3.3 billion, and extend hospital length of stay by 9.7 days, with cost of hospitalization increased by more than $20,000 per admission.[7,26,27,29]

It is estimated that over half of SSIs are preventable by the use of evidence-based measures.[30] CRNAs can play an active role in SSI mitigation by deploying an SSI prevention bundle, which includes performing enhanced SSI surveillance to determine the source, extent, and potential solutions to the problem.

Hand Hygiene

Hand hygiene interrupts the transmission of pathogens between healthcare providers, patients, and contaminated surfaces/fomites in the patient's environment.[31-34] While studies demonstrate that hand hygiene plays an important role in reducing healthcare acquired infections, compliance rates among anesthesia professionals is poor.[32,35-37] Strategic placement of alcohol-based hand sanitizer dispensers near the anesthesia work area is recommended to improve hand hygiene compliance and facilitate SSI prevention.[38,39]

Equipment and Environment Cleaning

Cross-transmission of bacteria can occur in the anesthesia work area on surfaces like equipment (e.g., IV poles), anesthesia carts, anesthesia machines, and computers.[34,40,41] Proper cleaning, disinfection, and sterilization, as appropriate, of anesthesia equipment and the anesthesia machine are important to prevent SSIs.[40,41] Recommended precautions include:

- Cleaning and then disinfecting anesthesia machine surfaces, knobs, and high-touch areas like keyboards between cases and at the end of the day with an appropriate germicide.
- Taking protective measures to prevent contamination of materials stored on the anesthesia machine from becoming inadvertently contaminated by airborne debris (e.g., blood).[40]

Maintenance of Normothermia

Perioperative hypothermia is defined as the reduction in body temperature to less than 36°C in the perioperative period.[42] Prevention of intraoperative hypothermia has been shown to significantly reduce the incidence of SSIs.[43-45] Hypothermia triggers vasoconstriction and tissue hypoxia, which can impair wound healing and increase SSI risk.[43] Hypothermia can also impair the function of neutrophils, further reducing the body's protection against infection.[46,47]

CRNAs should maintain normothermia for the patient during surgery.[43-45] The method of maintaining normothermia is patient and procedure dependent, and may include passive warming measures (e.g., blankets, surgical drapes) or active warming measures (e.g. forced air warming devices, underbody warming mattresses, fluid warmers for intravenous and irrigation fluids, radiant warmers). There continues to be debate regarding forced air warming and its relationship to SSIs, therefore each anesthesia professional must determine what is more appropriate for their patient and follow relevant facility policies and protocols for patient warming.[48-66]

Document measures taken to maintain patient normothermia, including the warming method used, warming device identifier, and temperature settings when applicable.[67]

Strict Glycemic Control

Hyperglycemia is associated with a higher risk of developing SSIs.[44,68-70] Surgical stress triggers the release cortisol, leading to hyperglycemia and insulin resistance.[70] Hyperglycemia impairs neutrophil function and immune response, increasing susceptibility to infections.[71,72] During the perioperative period, short-term strict glycemic control has been shown to be more important than long-term glycemic management in reducing SSI risk.[27,68-70,73] Recommendations range from blood glucose levels less than 200 mg/dL to as low as 110-150 mg/dL.[27,30,68-71,74-76] For cardiac patients, the target is less than 180 mg/dL or lower.[71,77-79]

More information about perioperative glycemic control can be found in the AANA *Enhanced Recovery After Surgery, Considerations for Pathway Development and Implementation*.

Fluid Management – Normovolemia

Perioperative fluid therapy helps maintain adequate tissue perfusion and oxygenation, which is important for wound healing and preventing SSIs.[71,80,81] Both hypovolemia and hypervolemia can impair wound healing and increase SSI risk.[80-83] Specifically, hypovolemia can cause vasoconstriction and a reduction in perfusion, resulting in decreased oxygen delivery to organs and peripheral tissues.[80,81,84] Hypervolemia results in tissue edema, local inflammation, and impaired collagen synthesis, which can lead to infection and wound dehiscence.[80,81,84] Current recommendations include adherence to goal-directed fluid therapy protocols rather than standard fluid management calculations.[81,83]

Perioperative Antibiotic Administration

Optimizing perioperative antimicrobial dosing, timing, and selection of the appropriate antibiotic agent typically fall under the anesthesia professional's responsibilities.[85] Most guidelines recommend administering prophylactic antibiotics within 60 minutes prior to surgical incision and 120 minutes prior to incision for antibiotics like vancomycin and fluoroquinolones that have longer infusion times.[86-89] Studies suggest administering cephalosporin antibiotics (e.g., cefazolin) ≤ 30 minutes prior to incision, which may be more effective in reducing SSI risk compared to the 60 minutes prior.[86,88,89]

Blood Loss Prevention

Blood transfusions have been associated with an increased risk of developing SSIs due to their immunosuppressive effects.[74,90] It is important for anesthesia providers to take steps to reduce the need for transfusion. However, blood products should never be withheld if clinically indicated, as inadequate tissue oxygenation from undertransfusion can also impair wound healing and increase infection risk.[74,90]

References

1. Belay CM, Zewale TA, Amlak BT, Abebe TG, Hailu G. Incidence and Predictors of Ventilator-Associated Pneumonia Among Adult Intubated Patients in Bahir Dar Specialized Hospitals, 2021: A Retrospective Follow-Up Study. *Int J Gen Med*. 2022;15:8173-8182. doi:10.2147/ijgm.S380301
2. Papazian L, Klompas M, Luyt CE. Ventilator-associated pneumonia in adults: a narrative review. *Intensive Care Med*. May 2020;46(5):888-906. doi:10.1007/s00134-020-05980-0
3. Amanullah S, Posner DH. Ventilator-Associated Pneumonia. Medscape. Accessed Jul 9, 2024, https://emedicine.medscape.com/article/304836-overview
4. Restrepo MI, Anzueto A, Arroliga AC, et al. Economic burden of ventilator-associated pneumonia based on total resource utilization. *Infect Control Hosp Epidemiol*. May 2010;31(5):509-15. doi:10.1086/651669
5. Luckraz H, Manga N, Senanayake EL, et al. Cost of treating ventilator-associated pneumonia post cardiac surgery in the National Health Service: Results from a propensity-matched cohort study. *J Intensive Care Soc*. May 2018;19(2):94-100. doi:10.1177/1751143717740804
6. Raycheva R, Rangelova V, Kevorkyan A. Cost Analysis for Patients with Ventilator-Associated Pneumonia in the Neonatal Intensive Care Unit. *Healthcare (Basel)*. May 25 2022;10(6)doi:10.3390/healthcare10060980
7. Zimlichman E, Henderson D, Tamir O, et al. Health care-associated infections: a meta-analysis of costs and financial impact on the US health care system. *JAMA Intern Med*. Dec 9-23 2013;173(22):2039-46. doi:10.1001/jamainternmed.2013.9763
8. Kollef MH, Hamilton CW, Ernst FR. Economic impact of ventilator-associated pneumonia in a large matched cohort. *Infect Control Hosp Epidemiol*. Mar 2012;33(3):250-6. doi:10.1086/664049
9. Safdar N, Dezfulian C, Collard HR, Saint S. Clinical and economic consequences of ventilator-associated pneumonia: a systematic review. *Crit Care Med*. Oct 2005;33(10):2184-93. doi:10.1097/01.ccm.0000181731.53912.d9

10. Kohbodi GNA, Rajasurya V, Noor A. Ventilator-Associated Pneumonia. [Updated 2023 Sep 4]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK507711/.
11. Klompas M, Branson R, Cawcutt K, et al. Strategies to prevent ventilator-associated pneumonia, ventilator-associated events, and nonventilator hospital-acquired pneumonia in acute-care hospitals: 2022 Update. *Infect Control Hosp Epidemiol*. Jun 2022;43(6):687-713. doi:10.1017/ice.2022.88
12. Klompas M. Potential Strategies to Prevent Ventilator-associated Events. *Am J Respir Crit Care Med*. Dec 15 2015;192(12):1420-30. doi:10.1164/rccm.201506-1161CI
13. Guidelines for the management of adults with hospital-acquired, ventilator-associated, and healthcare-associated pneumonia. *Am J Respir Crit Care Med*. Feb 15 2005;171(4):388-416. doi:10.1164/rccm.200405-644ST
14. Alp E, Voss A. Ventilator associated pneumonia and infection control. *Ann Clin Microbiol Antimicrob*. Apr 6 2006;5:7. doi:10.1186/1476-0711-5-7
15. Modi AR, Kovacs CS. Hospital-acquired and ventilator-associated pneumonia: Diagnosis, management, and prevention. *Cleve Clin J Med*. Oct 1 2020;87(10):633-639. doi:10.3949/ccjm.87a.19117
16. Mastrogianni M, Katsoulas T, Galanis P, Korompeli A, Myrianthefs P. The Impact of Care Bundles on Ventilator-Associated Pneumonia (VAP) Prevention in Adult ICUs: A Systematic Review. *Antibiotics (Basel)*. Jan 20 2023;12(2)doi:10.3390/antibiotics12020227
17. Da Rocha Gaspar MD, Antunes Rinaldi EC, Guetter Mello R, et al. Impact of evidence-based bundles on ventilator-associated pneumonia prevention: A systematic review. *J Infect Dev Ctries*. Feb 28 2023;17(2):194-201. doi:10.3855/jidc.12202
18. Plata-Menchaca EP, Ferrer R. Current treatment of nosocomial pneumonia and ventilator-associated pneumonia. *Rev Esp Quimioter*. Oct 2022;35 Suppl 3(Suppl 3):25-29. doi:10.37201/req/s03.06.2022
19. Su KC, Kou YR, Lin FC, et al. A simplified prevention bundle with dual hand hygiene audit reduces early-onset ventilator-associated pneumonia in cardiovascular surgery units: An interrupted time-series analysis. *PLoS One*. 2017;12(8):e0182252. doi:10.1371/journal.pone.0182252

20. Li F, Liu H, Zhang L, et al. Effects of Gastric Acid Secretion Inhibitors for Ventilator-Associated Pneumonia. *Front Pharmacol*. 2022;13:898422. doi:10.3389/fphar.2022.898422
21. Whitman C, Patel J, Patel B, Vito K, Gerber D. 884: Ventilator-associated pneumonia risk between proton pump inhibitors and histamine antagonists. *Critical Care Medicine*. 2013;41(12):A221. doi:10.1097/01.ccm.0000440122.51535.21
22. Grindlinger GA, Cairo SB, Duperre CB. Pneumonia prevention in intubated patients given sucralfate versus proton-pump inhibitors and/or histamine II receptor blockers. *J Surg Res*. Dec 2016;206(2):398-404. doi:10.1016/j.jss.2016.08.028
23. Borchardt RA, Tzizik D. Update on surgical site infections: The new CDC guidelines. *Jaapa*. Apr 2018;31(4):52-54. doi:10.1097/01.Jaa.0000531052.82007.42
24. Prielipp RC, Birnback DJ. Health Care-Associated Infections: A Call to Anesthesia Professionals. *APSF Newsletter*. 2019;34(2)
25. Davis CH, Kao LS, Fleming JB, Aloia TA. Multi-Institution Analysis of Infection Control Practices Identifies the Subset Associated with Best Surgical Site Infection Performance: A Texas Alliance for Surgical Quality Collaborative Project. *J Am Coll Surg*. Aug 16 2017;doi:10.1016/j.jamcollsurg.2017.07.1054
26. Centers for Disease Control and Prevention. National Healthcare Safety Network. Surgical Site Infection Event (SSI). . Accessed July 2, 2024, https://www.cdc.gov/nhsn/pdfs/pscmanual/9pscssicurrent.pdf
27. Ban KA, Minei JP, Laronga C, et al. American College of Surgeons and Surgical Infection Society: Surgical Site Infection Guidelines, 2016 Update. *J Am Coll Surg*. Jan 2017;224(1):59-74. doi:10.1016/j.jamcollsurg.2016.10.029
28. Awad SS. Adherence to surgical care improvement project measures and post-operative surgical site infections. *Surg Infect (Larchmt)*. Aug 2012;13(4):234-7. doi:10.1089/sur.2012.131
29. Zhang Y, Li J. Perioperative Infection Risks. OpenAnesthesia. Accessed July 2, 2024, https://www.openanesthesia.org/keywords/perioperative-infection-risks/
30. Berríos-Torres SI, Umscheid CA, Bratzler DW, et al. Centers for Disease Control and Prevention Guideline for the Prevention of Surgical Site Infection, 2017. *JAMA Surg*. Aug 1 2017;152(8):784-791. doi:10.1001/jamasurg.2017.0904

31. Sickbert-Bennett EE, DiBiase LM, Schade Willis TM, Wolak ES, Weber DJ, Rutala WA. Reducing health care-associated infections by implementing a novel all hands on deck approach for hand hygiene compliance. *Am J Infect Control*. May 2 2016;44(5 Suppl):e13-6. doi:10.1016/j.ajic.2015.11.016
32. Baier C, Tinne M, von Lengerke T, Gossé F, Ebadi E. Compliance with hand disinfection in the surgical area of an orthopedic university clinic: results of an observational study. *Antimicrob Resist Infect Control*. 2022/01/31 2022;11(1):22. doi:10.1186/s13756-022-01058-2
33. Tanner J, Dumville JC, Norman G, Fortnam M. Surgical hand antisepsis to reduce surgical site infection. *Cochrane Database Syst Rev*. Jan 22 2016;2016(1):Cd004288. doi:10.1002/14651858.CD004288.pub3
34. Sharma A, Fernandez PG, Rowlands JP, Koff MD, Loftus RW. Perioperative Infection Transmission: the Role of the Anesthesia Provider in Infection Control and Healthcare-Associated Infections. *Curr Anesthesiol Rep*. 2020/09/01 2020;10(3):233-241. doi:10.1007/s40140-020-00403-8
35. Koff MD, Loftus RW, Burchman CC, et al. Reduction in intraoperative bacterial contamination of peripheral intravenous tubing through the use of a novel device. *Anesthesiology*. May 2009;110(5):978-85. doi:10.1097/ALN.0b013e3181a06ec3
36. Biddle C, Shah J. Quantification of anesthesia providers' hand hygiene in a busy metropolitan operating room: what would Semmelweis think? *Am J Infect Control*. Oct 2012;40(8):756-9. doi:10.1016/j.ajic.2011.10.008
37. Loftus RW, Muffly MK, Brown JR, et al. Hand contamination of anesthesia providers is an important risk factor for intraoperative bacterial transmission. *Anesth Analg*. Jan 2011;112(1):98-105. doi:10.1213/ANE.0b013e3181e7ce18
38. Munoz-Price LS, Riley B, Banks S, et al. Frequency of interactions and hand disinfections among anesthesiologists while providing anesthesia care in the operating room: induction versus maintenance. *Infect Control Hosp Epidemiol*. Aug 2014;35(8):1056-9. doi:10.1086/677154
39. Tartari E, Weterings V, Gastmeier P, et al. Patient engagement with surgical site infection prevention: an expert panel perspective. *Antimicrob Resist Infect Control*. 2017;6:45. doi:10.1186/s13756-017-0202-3
40. Munoz-Price LS, Bowdle A, Johnston BL, et al. Infection prevention in the operating room anesthesia work area. *Infect Control Hosp Epidemiol*. Jan 2019;40(1):1-17. doi:10.1017/ice.2018.303

41. Loftus RW, Koff MD, Burchman CC, et al. Transmission of pathogenic bacterial organisms in the anesthesia work area. *Anesthesiology*. Sep 2008;109(3):399-407. doi:10.1097/ALN.0b013e318182c855

42. Brooks C, Bosserman Matulewicz S. Understanding the Dangers of Perioperative Hypothermia. Outpatient Surgery Magazine. Accessed Jul 9, 2024,

43. WHO Best Practices for Injections and Related Procedures Toolkit. Geneva: World Health Organization; 2010 Mar 2, Best Practices for Injection. Available from: https://www.ncbi.nlm.nih.gov/books/NBK138495/.

44. Forbes SS, McLean RF. Review article: the anesthesiologist's role in the prevention of surgical site infections. *Can J Anaesth*. Feb 2013;60(2):176-83. doi:10.1007/s12630-012-9858-6

45. Yamada K, Nakajima K, Nakamoto H, et al. Association Between Normothermia at the End of Surgery and Postoperative Complications Following Orthopedic Surgery. *Clin Infect Dis*. Jan 16 2020;70(3):474-482. doi:10.1093/cid/ciz213

46. Torikoshi Y, Yokota A, Kamio N, et al. Impact of Hypothermia on Differentiation and Maturation of Neutrophils. *Blood*. 2018;132(Supplement 1):2393-2393. doi:10.1182/blood-2018-99-114651

47. Fröhlich D, Wittmann S, Rothe G, Sessler DI, Vogel P, Taeger K. Mild hyperthermia down-regulates receptor-dependent neutrophil function. *Anesth Analg*. Jul 2004;99(1):284-292. doi:10.1213/01.Ane.0000117142.28174.98

48. Kellam MD, Dieckmann LS, Austin PN. Forced-air warming devices and the risk of surgical site infections. *AORN J*. Oct 2013;98(4):354-66; quiz 367-9. doi:10.1016/j.aorn.2013.08.001

49. Annis K, Coates C, Renehan K, Ridgway B, Jasinski D. Examination of Hospital Policies Regarding Certified Registered Nurse Anesthetist Attire in the Operating Room. *Aana j*. Dec 2017;85(6):410-416.

50. Oregon Health and Science University. Office of Clinical Integration and Evidence-Based Practice. Evidence-Based Practice Summary Forced Air Warming Devices Effect on Patient Outcomes. Accessed July 2, 2024, https://www.ohsu.edu/sites/default/files/2021-07/Evidence%20Brief%20on%20Forced%20Air%20Warming%20Devices%20for%20Surgical%20Use.pdf

51. Wood AM, Moss C, Keenan A, Reed MR, Leaper DJ. Infection control hazards associated with the use of forced-air warming in operating theatres. *J Hosp Infect*. Nov 2014;88(3):132-40. doi:10.1016/j.jhin.2014.07.010
52. Augustine SD. Forced-Air Warming Discontinued: Periprosthetic Joint Infection Rates Drop. *Orthop Rev (Pavia)*. Jun 23 2017;9(2):6998. doi:10.4081/or.2017.6998
53. Nieh HC, Su SF. Meta-analysis: effectiveness of forced-air warming for prevention of perioperative hypothermia in surgical patients. *J Adv Nurs*. Oct 2016;72(10):2294-314. doi:10.1111/jan.13010
54. Al-Dardery NM, Abdelwahab OA, El-Samahy M, Seif AM, Mouffokes A, Khaity A. Self-warming blankets versus active warming by forced-air devices for preventing hypothermia: A systematic review and meta-analysis. *Medicine (Baltimore)*. May 5 2023;102(18):e33579. doi:10.1097/md.0000000000033579
55. da Silva LL, Almeida A, Possari JF, Poveda VB. Forced Air Warming System: Evaluation of Internal System Contamination. *Surg Infect (Larchmt)*. Apr 2019;20(3):215-218. doi:10.1089/sur.2018.152
56. Wang J, Fang P, Sun G, Li M. Effect of active forced air warming during the first hour after anesthesia induction and intraoperation avoids hypothermia in elderly patients. *BMC Anesthesiol*. Feb 7 2022;22(1):40. doi:10.1186/s12871-022-01577-w
57. Haeberle HS, Navarro SM, Samuel LT, et al. No Evidence of Increased Infection Risk with Forced-Air Warming Devices: A Systematic Review. *Surg Technol Int*. Dec 22 2017;31:295-301.
58. Lange VR. Forced air contamination risk in the OR. *Ann Med Surg (Lond)*. Jan 2022;73:102976. doi:10.1016/j.amsu.2021.102976
59. Kümin M, Deery J, Turney S, et al. Reducing Implant Infection in Orthopaedics (RIIiO): Results of a pilot study comparing the influence of forced air and resistive fabric warming technologies on postoperative infections following orthopaedic implant surgery. *J Hosp Infect*. Dec 2019;103(4):412-419. doi:10.1016/j.jhin.2019.08.019
60. Lee Y, Kim K. Optimal Application of Forced Air Warming to Prevent Peri-Operative Hypothermia during Abdominal Surgery: A Systematic Review and Meta-Analysis. *Int J Environ Res Public Health*. Mar 3 2021;18(5)doi:10.3390/ijerph18052517

61. Kümin M, Jones CI, Woods A, et al. Resistant fabric warming is a viable alternative to forced-air warming to prevent inadvertent perioperative hypothermia during hemiarthroplasty in the elderly. *J Hosp Infect*. Dec 2021;118:79-86. doi:10.1016/j.jhin.2021.10.005
62. Coetzee GJ. Eliminating protein from reusable laryngeal mask airways. A study comparing routinely cleaned masks with three alternative cleaning methods. *Anaesthesia*. Apr 2003;58(4):346-53. doi:10.1046/j.1365-2044.2003.03084.x
63. Gemayel A, Flikkema K, Fritz G, Blascak D. Are Intra-operative Forced Air Warming Devices a Possible Source for Contamination During Hand Surgery? *Cureus*. Sep 2023;15(9):e46287. doi:10.7759/cureus.46287
64. Shirozu K, Takamori S, Setoguchi H, Yamaura K. Effects of forced air warming systems on the airflow and sanitation quality of operating rooms with non-laminar airflow systems. *Perioper Care Oper Room Manag*. Dec 2020;21:100119. doi:10.1016/j.pcorm.2020.100119
65. Shirozu K, Setoguchi H, Araki K, Ando T, Yamaura K. Impact of air-conditioner outlet layout on the upward airflow induced by forced air warming in operating rooms. *Am J Infect Control*. Jan 2021;49(1):44-49. doi:10.1016/j.ajic.2020.06.202
66. Brock-Utne JG, Ward JT, Jaffe RA. Potential sources of operating room air contamination: a preliminary study. *J Hosp Infect*. Jul 2021;113:59-64. doi:10.1016/j.jhin.2021.04.020
67. Croke L. Guideline for prevention of hypothermia. *AORN J*. Jul 2019;110(1):P8-p10. doi:10.1002/aorn.12761
68. Takesue Y, Tsuchida T. Strict glycemic control to prevent surgical site infections in gastroenterological surgery. *Ann Gastroenterol Surg*. Apr 2017;1(1):52-59. doi:10.1002/ags3.12006
69. Wang Y-y, Hu S-f, Ying H-m, et al. Postoperative tight glycemic control significantly reduces postoperative infection rates in patients undergoing surgery: a meta-analysis. *BMC Endocrine Disorders*. 2018/06/22 2018;18(1):42. doi:10.1186/s12902-018-0268-9
70. Lai J, Li Q, He Y, Zou S, Bai X, Rastogi S. Glycemic Control Regimens in the Prevention of Surgical Site Infections: A Meta-Analysis of Randomized Clinical Trials. *Front Surg*. 2022;9:855409. doi:10.3389/fsurg.2022.855409

71. Soule B. *Evidence-Based Principles and Practices for Preventing Surgical Site Infections*. Joint Commission International; 2018.
72. Jafar N, Edriss H, Nugent K. The Effect of Short-Term Hyperglycemia on the Innate Immune System. *Am J Med Sci*. Feb 2016;351(2):201-11. doi:10.1016/j.amjms.2015.11.011
73. Domingos CM, Iida LI, Poveda VB. Glycemic control strategies and the occurrence of surgical site infection: a systematic review. *Rev Esc Enferm USP*. Sep-Oct 2016;50(5):868-874. doi:10.1590/s0080-623420160000600022
74. Calderwood MS, Anderson DJ, Bratzler DW, et al. Strategies to prevent surgical site infections in acute-care hospitals: 2022 Update. *Infect Control Hosp Epidemiol*. May 2023;44(5):695-720. doi:10.1017/ice.2023.67
75. Duggan EW, Carlson K, Umpierrez GE. Perioperative Hyperglycemia Management: An Update. *Anesthesiology*. 2017;126(3):547-560. doi:10.1097/aln.0000000000001515
76. American Association of Nurse Anesthesiology. Enhanced Recovery after Surgery, Considerations for Pathway Development and Implementation. 2017;
77. Umpierrez G, Cardona S, Pasquel F, et al. Randomized Controlled Trial of Intensive Versus Conservative Glucose Control in Patients Undergoing Coronary Artery Bypass Graft Surgery: GLUCO-CABG Trial. *Diabetes Care*. 2015;38(9):1665-1672. doi:10.2337/dc15-0303
78. Siddiqui KM, Asghar MA, Khan MF, Khan FH. Perioperative Glycemic Control and its Outcome in Patients following Open Heart Surgery. *Annals of Cardiac Anaesthesia*. 2019;22(3):260-264. doi:10.4103/aca.ACA_82_18
79. Thongsuk Y, Hwang NC. Perioperative Glycemic Management in Cardiac Surgery: A Narrative Review. *J Cardiothorac Vasc Anesth*. Jan 2024;38(1):248-267. doi:10.1053/j.jvca.2023.08.149
80. Voldby AW, Brandstrup B. Fluid therapy in the perioperative setting—a clinical review. *Journal of Intensive Care*. 2016/04/16 2016;4(1):27. doi:10.1186/s40560-016-0154-3
81. Miller TE, Myles PS. Perioperative Fluid Therapy for Major Surgery. *Anesthesiology*. May 2019;130(5):825-832. doi:10.1097/aln.0000000000002603

82. Jonsson K, Jensen JA, Goodson WH, 3rd, et al. Tissue oxygenation, anemia, and perfusion in relation to wound healing in surgical patients. *Ann Surg*. Nov 1991;214(5):605-13. doi:10.1097/00000658-199111000-00011
83. Yuan J, Sun Y, Pan C, Li T. Goal-directed fluid therapy for reducing risk of surgical site infections following abdominal surgery - A systematic review and meta-analysis of randomized controlled trials. *Int J Surg*. Mar 2017;39:74-87. doi:10.1016/j.ijsu.2017.01.081
84. Kendrick JB, Kaye AD, Tong Y, et al. Goal-directed fluid therapy in the perioperative setting. *J Anaesthesiol Clin Pharmacol*. Apr 2019;35(Suppl 1):S29-s34. doi:10.4103/joacp.JOACP_26_18
85. Heuer A, Kossick MA, Riley J, Hewer I. Update on Guidelines for Perioperative Antibiotic Selection and Administration From the Surgical Care Improvement Project (SCIP) and American Society of Health-System Pharmacists. *AANA J*. Aug 2017;85(4):293-299.
86. de Jonge SW, Gans SL, Atema JJ, Solomkin JS, Dellinger PE, Boermeester MA. Timing of preoperative antibiotic prophylaxis in 54,552 patients and the risk of surgical site infection: A systematic review and meta-analysis. *Medicine*. 2017;96(29):e6903. doi:10.1097/md.0000000000006903
87. Berrondo C, Carone M, Katz C, Kenny A. Adherence to Perioperative Antibiotic Prophylaxis Recommendations and Its Impact on Postoperative Surgical Site Infections. *Cureus*. Jun 2022;14(6):e25859. doi:10.7759/cureus.25859
88. Sommerstein R, Troillet N, Harbarth S, et al. Timing of Cefuroxime Surgical Antimicrobial Prophylaxis and Its Association With Surgical Site Infections. *JAMA Netw Open*. Jun 1 2023;6(6):e2317370. doi:10.1001/jamanetworkopen.2023.17370
89. Bratzler DW, Dellinger EP, Olsen KM, et al. Clinical practice guidelines for antimicrobial prophylaxis in surgery. *Am J Health Syst Pharm*. Feb 1 2013;70(3):195-283. doi:10.2146/ajhp120568
90. Aeschbacher P, Nguyen TL, Dorn P, Kocher GJ, Lutz JA. Surgical Site Infections Are Associated With Higher Blood Loss and Open Access in General Thoracic Practice. *Front Surg*. 2021;8:656249. doi:10.3389/fsurg.2021.656249

The *Infection Control Guide for Certified Registered Nurse Anesthetists* was adopted by the AANA Board of Directors in 1992 and revised in 1993, 1997, November 2012. In February 2015, the AANA Board of Directors archived the guide and adopted the *Infection Prevention and Control Guidelines for Anesthesia Care*.