Forced-Air Warming Devices and the Risk of Surgical Site Infections

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Purpose/Goal

To provide knowledge specific to the use of forced-air warming systems and surgical site infections.

Objectives

1. Describe inadvertent perioperative hypothermia.
2. Discuss the use of forced-air warming to maintain normothermia perioperatively.
3. Describe the methodologies used in the studies appraised in this article.
4. Describe the authors' conclusions about the use of forced-air warming systems.

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Melissa D. Kellam, DNAP, CRNA; Loraine S. Dieckmann, PhD; and Paul N. Austin, PhD, CRNA, have no declared affiliations that could be perceived as posing potential conflicts of interest in the publication of this article.

The behavioral objectives for this program were created by Helen Starbuck Pashley, MA, BSN, CNOR, clinical editor, with consultation from Rebecca Holm, MSN, RN, CNOR, clinical editor, and Susan Bakewell, MS, RN-BC, director, Perioperative Education. Ms Starbuck Pashley, Ms Holm, and Ms Bakewell have no declared affiliations that could be perceived as posing potential conflicts of interest in the publication of this article.

Sponsorship or Commercial Support

No sponsorship or commercial support was received for this article.

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http://dx.doi.org/10.1016/j.aorn.2013.08.001

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ABSTRACT

The potential that forced-air warming systems may increase the risk of surgical site infections (SSIs) by acting as a vector or causing unwanted airflow disturbances is a concern to health care providers. To investigate this potential, we examined the literature to determine whether forced-air warming devices increase the risk of SSIs in patients undergoing general, vascular, or orthopedic surgical procedures. We examined 192 evidence sources, 15 of which met our inclusion criteria. Most sources we found indirectly addressed the issue of forced-air warming and only three studies followed patients who were warmed intraoperatively with forced-air warming devices to determine whether there was an increased incidence of SSIs. All of the sources we examined contained methodological concerns, and the evidence did not conclusively suggest that the use of forced-air warming systems increases the risk of SSIs. Given the efficacy of these devices in preventing inadvertent perioperative hypothermia, practitioners should continue to use and clean forced-air warming systems according to the manufacturer's instructions until well-conducted, large-scale trials can further examine the issue. *AORN J* 98 (October 2013) 354-366. © AORN, Inc, 2013. http://dx.doi.org/10.1016/j.aorn.2013.08.001

Key words: *intraoperative hypothermia, normothermia, forced-air warming, surgical site infection.*

Patients often report feeling cold before the induction of general anesthesia or when sedated for surgical procedures. Besides being uncomfortable, inadvertent perioperative hypothermia can be difficult to treat and have undesirable consequences for the patient, including platelet dysfunction and other coagulation defects, delayed postanesthetic recovery, prolonged hospitalization, and surgical site infections (SSIs).[1] Inadvertent perioperative hypothermia, defined as a core body temperature of $\leq$ 36.0° C (96.8° F), is the most common thermal disturbance seen in surgical patients.[1] Reasons for heat loss during operative and invasive procedures include the patient's exposure to the surgical environment and the effects of anesthetic agents and medications that interfere with the body's normal ability to regulate temperature.[1] A major physiological reason for anesthesia-related hypothermia is a redistribution of heat from the core to the periphery of the body because of vasodilation effects caused by volatile anesthetic agents.[1] There is also a similar effect seen with major regional anesthesia (eg, spinal, epidural).[1]

Health care providers often use forced-air warming systems to provide surface warming in the

http://dx.doi.org/10.1016/j.aorn.2013.08.001

OR because these devices are helpful in maintaining normothermia and preventing perioperative hypothermia.[2] However, providers also are concerned that these devices may increase the risk of SSIs by acting as a vector or causing unwanted airflow disturbances over the surgical site. Because of the perceived infection risk, some surgeons request these devices not be turned on until the patient is prepped and draped or that they not be used at all.[2] To investigate this risk, we used the following PICO (ie, population, intervention[s], comparison, outcome) question[3] to guide our search for evidence: Do forced-air warming devices increase the risk of SSIs in patients undergoing general, vascular, or orthopedic surgical procedures?

SEARCH STRATEGY

To answer our question, we examined the literature to determine whether forced-air warming devices increase the risk of SSIs in patients undergoing general, vascular, or orthopedic surgical procedures. We included evidence from high-level sources, including systematic reviews with or without meta-analysis, clinical practice guidelines, and human clinical studies. We also included lower-level studies, which included laboratory and simulation studies, because we suspected that there would be a lack of higher-level evidence to answer our question. We revised our search in an ongoing fashion to refine the search results.

We gathered our evidence by searching PubMed®, Academic Search™ Complete, and the Cochrane Collaboration databases for the period from 1990 to 2012. We used the following search terms alone and in combination: *convection warmer, convection warming, forced air warmer, forced air warming, infection, contamination*, and *complications*.

Our inclusion criteria included full-text articles in English that addressed the PICO question and were published in peer-reviewed journals or on specialty or government web sites. The population of interest included patients of all ages undergoing general, vascular, or orthopedic procedures. We appraised the evidence based on whether it helped answer the PICO question and for methodological quality using the method described by Stetler et al.[4] Two authors (MDK and PNA) evaluated each evidence source, and consensus was reached when there was disagreement. We further scrutinized the reference lists of appraised evidence, including using the "related citations" function in PubMed, to locate further applicable evidence that met our inclusion criteria.

CRITICAL APPRAISAL OF THE LITERATURE

Our search yielded a total of 192 possible sources. Fifteen sources[5-19] remained after we eliminated those that were duplicates or did not meet our inclusion criteria. We did not find any systematic reviews. The investigations we reviewed used four general methods to determine the likelihood of the forced-air warmer causing an SSI, with some studies using more than one method. The direct method was to follow patients who were warmed intraoperatively with a forced-air warmer to determine whether it led to an increased incidence of SSI,[12,14,15] and the three indirect methods were to

- examine the intake, inside, and output hoses of forced-air warming units or the air emitted directly from the forced-air warming unit for bacteria or particles that might harbor bacteria[5-8,10,12];
- evaluate bacterial counts near or on patients, volunteers, or manikins in an OR[12,15,17-19]; and
- examine unwanted airflow disturbances in the OR caused by the forced-air warming device.[9,11,13,14,16,17]

It is important to note that only one of these methods, which was used in three investigations, directly examined the likelihood of an increased incidence of SSIs caused by the intraoperative use of forced-air warmers.[12,14,15] The remaining three methods used by the other investigators indirectly examined the likelihood of forced-air warmers to cause SSIs.

Methodological Concerns

There were numerous methodological concerns with all of the investigations that we reviewed.[5-19] For example, none of the researchers described how they determined the sample size of forced-air warmers or the number of study participants. In addition, none indicated whether the forced-air warmers had been maintained per the manufacturer's instructions. They also did not perform any blinding or random allocation of participants to study groups. An important concern is that five[5,6,9,11,14] of the investigations included an author who was supported or had been supported by a company that manufactures a conductive fiber blanket that was in direct competition with makers of forced-air warming systems. Another study was supported by a forced-air warmer manufacturer.[16] We felt these represented sources of potential bias.

Direct Methods

Three investigations[12,14,15] followed patients who were warmed intraoperatively for SSIs (Table 1). All of these studies were observational studies and were part of other investigations examining bacterial counts near or on patients or manikins. One of the

TABLE 1. Summary of Evidence: Observing Subjects Who Were Warmed Intraoperatively Using a Forced-Air Warmer for Infection

Evidence source[a]	Subjects, procedure, and intervention	Findings and comments[b]
Huang JK, Shah EF, Vinodkumar N, Hegarty MA, Greatorex RA. The Bair Hugger® patient warming system in prolonged vascular surgery: an infection risk? *Crit Care*. 2003;7(3):R13-R16.	■ 16 subjects ■ Aortic surgery with graft ■ Forced-air warming system[c] with upper body cover (mean 234 minutes)	■ No postoperative surgical site infections at six months
McGovern PD, Albrecht M, Belani KG, et al. Forced-air warming and ultra-clean ventilation do not mix: an investigation of theatre ventilation, patient warming and joint replacement infection in orthopaedics. *J Bone Joint Surg Br*. 2011;93(11): 1537-1544.	■ 1,437 subjects ■ Hip or knee replacement ■ Forced-air warming system[c] (n = 1,066 subjects) or conductive fiber blanket[d] (n = 371 subjects)	■ High risk of developing deep infections for subjects warmed with forced-air warming system (odds ratio, 3.8; $P = .024$) ■ No effect of factors such as age or diabetes ■ No records on blood transfusions, incontinency, or overall physical status ■ No control of potentially confounding factors ■ Unknown what effect history played on the results because data were collected during a two-year study period
Moretti B, Larocca AM, Napoli C, et al. Active warming systems to maintain perioperative normothermia in hip replacement surgery: a therapeutic aid or a vector of infection? *J Hosp Infect*. 2009;73(1):58-63.	■ 30 subjects ■ Hip replacement ■ Forced-air warming system[c] (n = 20 subjects) or no forced-air warmer (n = 10 subjects)	■ No postoperative surgical site infections ■ Unknown follow-up period ■ Unknown location of forced-air warmer cover

[a] *All observational studies, Level IV C evidence*
[b] *No mention of randomization, patient selection, sample size calculation, or blinding*
[c] *Bair Hugger®*
[d] *Hot Dog Total Access Warming™*
Bair Hugger is a registered trademark of Arizant Healthcare, Eden Prairie, MN. Hot Dog Total Access Warming is a trademark of Augustine Temperature Management, Eden Prairie, MN.

investigations also looked at the effect of forced-air warmers on unwanted airflow in the OR.[14]

Huang et al[12] included 16 vascular surgery patients but had no control group.[12] Moretti et al[15] examined a total of 30 female patients who underwent hip replacement surgery: 20 who received forced-air warming and 10 who did not. Neither of these studies included a comparison of groups for equivalence. The third direct investigation included 1,437 patients undergoing hip or knee replacement.[14] A forced-air warmer was used with 1,066 patients from July 2008 to March 2010 and a conductive fiber blanket was used with 371 patients from March to June 2010. The authors acknowledged that the presence of potential confounders, such as antibiotic use and thromboprophylaxis, had changed between 2008 and 2010 and could have affected the subjects' risk of SSI.[14] The groups were similar in some respects, including the type of surgery and the presence of diabetes; however, the groups were not compared in terms of other potentially confounding variables, including obesity, incontinence, and fitness for surgery.

McGovern et al[14] described the OR used as being a laminar flow room with ultra-clean air; however, the other studies[12,15] did not describe the type of OR air handling. Because the rooms were functioning ORs, we assumed the air handling met regulative standards. In addition, in one study, the method of following the subjects for SSI was not detailed.[14]

Indirect Methods

The first method that researchers used to indirectly examine whether forced-air warmers are likely to cause SSIs was to look at the incidence of forced-air warmers harboring organisms (Table 2). Six evidence sources[5-8,10,12] examined various locations in or on the forced-air warming device or the air emitted directly from the unit's output hose for bacteria or particles that might harbor bacteria. Methods used to determine this ranged from researchers simply swabbing the interior and exterior of one forced-air warmer, including the inside of the output hose, and culturing the samples in growth media[8] to examining the filtration efficiencies of 25 forced-air warmers from five hospitals.[6]

Albrecht et al[5] compared the filtration efficiency of five new forced-air warmer intake filters with five used intake filters of an older design. Baker et al[8] and Bernards et al[10] examined only a single forced-air warmer. Investigators thoroughly described the methods used to gather air and surface samples. The study by Bernards et al[10] was not a description of an SSI outbreak but of an outbreak of *Acinetobacter baumannii* in an intensive care unit. The strain researchers cultured from affected patients was the same strain cultured from the dust filters of the forced-air warmer used in the affected patient rooms. The authors also noted that staff members were not changing the unit filters per the manufacturer's instructions. The presence of bacteria in or on these devices is a surrogate for SSI incidence; it does not establish a causal relationship to SSIs because the incidence of SSIs in subjects warmed by a forced-air warmer was not examined.

The second indirect method used[12,15,17-19] to determine whether forced-air warmers are likely to cause SSIs was to examine bacterial counts near or on patients[12,15,18] or volunteers[17,19] or near where the site of surgery would most likely be in an empty OR[17] (Table 3). Researchers obtained samples from the surgical site,[12,15,19] near the surgical site,[17] and close to the middle of the OR.[18] The investigators clearly described the methods used to gather samples and culture bacteria. We assumed, but this was not identified in the studies, that all ORs met air handling standards. Only two studies[17,18] described the OR as using "ultra-clean" air handling. Conditions were not standardized. For example, some investigators did not include a surgical team or traffic in the OR,[17,19] and the setting for other studies[12,15] was a working OR during actual procedures.

The final indirect method used to help determine the likelihood of forced-air warmers causing SSIs was to examine unwanted airflow disturbances caused by the air emitted from the forced-air warmer cover placed on the patient (Table 4).[9,11,13,14,16,17]

TABLE 2. Summary of Evidence: Incidence of Forced-Air Warmers Harboring Organisms

Evidence source[a]	Number of devices examined	Culture sites	Findings	Comments[b]
Albrecht M, Gauthier R, Leaper D. Forced-air warming: a source of airborne contamination in the operating room? *Orthop Rev (Pavia)*. 2009;1(2):e28.	■ 25 forced-air warming systems[c,d] from 5 hospitals	■ Air from intake and output hoses, interior of intake and output hoses	■ 8 of 25 forced-air warming systems had lower filtration efficiencies ■ 17 forced-air warming systems had bacteria cultured from inside 71% of intake and 88% of output hoses ■ 9 forced-air warming systems had 89% positive cultures from the liquid from rinsing the inside of the output hose	■ Implied forced-air warming systems emitting internally generated contamination within the size range of free-floating bacteria (< 4 μm)
Albrecht M, Gauthier RL, Belani K, Litchy M, Leaper D. Forced-air warming blowers: an evaluation of filtration adequacy and airborne contamination emissions in the operating room. *Am J Infect Control*. 2011;39(4):321-328.	■ 52 forced-air warming systems[c] ■ 5 new intake filters[c] ■ 5 used intake filters[c]	■ Internal air path surfaces, hose outlet particle counts	■ Newer filters had 93.8% retention efficiency ■ Used filters had 61.3% retention efficiency ■ 92.3% of forced-air warming system blowers had bacteria cultured from internal air path surfaces	■ Increased efficiency of new filters may be because of design change ■ Approximately 58% of forced-air warming blowers were internally generating and emitting airborne contaminants
Avidan MS, Jones N, Ing R, Khoosal M, Lundgren C, Morrell DF. Convection warmers—not just hot air. *Anaesthesia*. 1997;52(11):1073-1076.	■ 10 forced-air warming systems[e] from various ORs	■ Multiple locations	■ 4 out of 10 forced-air warming systems' output hoses harbored potentially pathogenic organisms ■ 10 out of 10 showed no growth from air from the forced-air warming system blanket when perforated ■ The upstream side of the filter showed evidence of colonization	■ Fitting the outlet hose with a filter may prevent emission of bacteria from forced-air warming systems

TABLE 2. *(continued)* Summary of Evidence: Incidence of Forced-Air Warmers Harboring Organisms

Evidence source[a]	Number of devices examined	Culture sites	Findings	Comments[b]
			■ Organisms included *Staphylococcus epidermidis* ■ There was no organism growth when the output hose was fitted with a filter[f]	
Baker N, King D, Smith EG. Infection control hazards of intra-operative forced air warming. *J Hosp Infect*. 2002;51(2):153-154.	■ 1 device[g]	■ The interior and exterior of the forced-air warming systems and the inside of the output hose	■ "Heavy growth" of bacteria was obtained from all sites	
Bernards AT, Harinck HI, Dijkshoorn L, van der Reijden TJ, van den Broek PJ. Persistent *Acinetobacter baumannii*? Look inside your medical equipment. *Infect Cont Hosp Epidemiol.* 2004;25(11): 1002-1004.	■ 1 device[c]	■ The exterior and internal forced-air warming system filters	■ The same strain of *Acinetobacter baumannii* caused an outbreak ■ The organism was not cultured after the dust inside the forced-air warming systems was removed	■ The study was part of an investigation of an *Acinetobacter baumannii* outbreak in a medical intensive care unit
Huang JK, Shah EF, Vinodkumar N, Hegarty MA, Greatorex RA. The Bair Hugger patient warming system in prolonged vascular surgery: an infection risk? *Crit Care.* 2003; 7(3):R13-R16.	■ Unknown number of ORs and unknown number of forced-air warming systems ■ 16 patients undergoing aortic surgery with prosthetic graft (mean 234 minutes, range 180-270 minutes)	■ Forced-air warming systems[c] with upper body cover ■ 6 sites including around the OR, near the axilla, near the wound edge, forced-air warming system[c] filter, and output hose at various times during the procedure	■ Decrease in bacterial counts at all 6 sites	■ No mention of the air handling method used in the OR, but presumably it met standards

[a] *All studies were Level IV C evidence*
[b] *No mention of sample size calculation or whether forced-air warming systems were maintained according to the manufacturer's instructions*
[c] *Bair Hugger®*
[d] *Unknown forced-air warming system manufacturer, forced-air warming systems, or forced-air warmer*
[e] *9 Bair Hugger systems, 1 Warm Touch™*
[f] *DAR Hygrobac filter™ for breathing systems*
[g] *WarmAir®*

Bair Hugger is a registered trademark of Arizant Healthcare, Eden Prairie, MN. Warm Touch and DAR Hygrobac filter are trademarks of Covidien, Mansfield, MA. WarmAir is a registered trademark of Cincinnati Sub-Zero, Cincinnati, OH.

TABLE 3. Summary of Evidence: Bacterial Counts Near or on Patients, Volunteers, or Manikins During Forced-Air Warmer Use

Evidence source[a]	Setting and subjects	Interventions	Sites sampled	Findings	Comments[b]
Huang JK, Shah EF, Vinodkumar N, Hegarty MA, Greatorex RA. The Bair Hugger® patient warming system in prolonged vascular surgery: an infection risk? *Crit Care.* 2003;7(3): R13-R16.	■ Unknown number of ORs	■ 16 patients undergoing aortic surgery with prosthetic graft (ie, mean 234 minutes, range 180-270 minutes) ■ Forced-air warming system[c] with upper body cover	■ 6 sites including around the OR, near the axilla, and near the wound edge ■ Filters and output hoses were sampled at various times during the procedure	■ Significant decrease in colony forming unit (CFU) counts at sites around the OR and near the axilla ■ The forced-air warming system filters and the wound edge were found to be sterile	■ There was no mention of the air handling method used in the OR, although it presumably met standards
Moretti B, Larocca AM, Napoli C, et al. Active warming systems to maintain perioperative normothermia in hip replacement surgery: a therapeutic aid or a vector of infection? *J Hosp Infect*. 2009;73(1):58-63.	■ 3 ORs	■ 30 total patients undergoing hip arthroplasty (ie, mean procedure time: 90 minutes) ■ 20 patients had a forced-air warming system[c] cover placed, but the study did not indicate where	■ 6 sites including around the OR, near the axilla, and near the wound edge ■ Forced-air warming system filter and output hose were sampled at various times during procedure	■ Although bacterial loads increased at some locations near the OR bed with the use of forced-air warming, the increase was comparable to or lower than the load present at the time the patient was placed on the OR bed	■ Validated air sampling method
Sharp RJ, Chesworth T, Fern ED. Do warming blankets increase bacterial counts in the operating field in a laminar-flow theatre? *J Bone Joint Surg Br.* 2002; 84(4):486-488.	■ Laminar flow ultra-clean-air—ventilated OR	■ 12 different conditions ranging from an empty OR to 4 different volunteers on the OR bed covered with the forced-air warming blanket system[d] with the unit on and off	■ 30 cm from a simulated operating site	■ No detectable airborne contamination was detected at the sample site with any condition	■ This pilot study showed low levels of CFU/m^3 ■ 3 of the 4 volunteers had varying degrees of psoriasis ■ There was no surgical team or traffic in the OR
Tumia N, Ashcroft GP. Convection warmers—a possible source of contamination in	■ 2 ultra-clean-air—ventilated ORs	■ 2 collection periods in an empty OR ■ 4 collection periods during orthopedic procedures	■ Close to the middle of the OR, 1 m off of the floor	■ Nonsignificant increase in CFUs with a forced-air warming system on ($P = .48$)	■ Unknown patient characteristics ■ Unknown where the forced-air warming system

TABLE 3. *(continued)* Summary of Evidence: Bacterial Counts Near or on Patients, Volunteers, or Manikins During Forced-Air Warmer Use

Evidence source[a]	Setting and subjects	Interventions	Sites sampled	Findings	Comments[b]
laminar airflow operating theatres? *J Hosp Infect*. 2002; 52(3):171-174.		■ A forced-air warming system cover was applied to the patient		compared with when it was off	cover was applied ■ Unknown forced-air warming system manufacturer, CFUs, forced-air warming system, forced-air warmer, or OR
Zink RS, Iaizzo PA. Convective warming therapy does not increase the risk of wound contamination in the operating room. *Anesth Analg*. 1993;76(1):50-53.	■ 3 ORs	■ 8 draped volunteers as simulated patients ■ Lower body forced-air warming blanket system[c] ■ 2 study periods: 2 hours forced-air warming system off, 2 hours forced-air warming system on	■ Abdomen	■ No difference in total number of bacterial colonies between two study periods ■ More coagulase negative colonies when the forced-air warming system was off ($P < .05$)	■ OR air handling presumably met standards ■ Volunteers had normal skin and were not taking antibiotics ■ Skin was not prepped ■ There was no surgical team or traffic in the OR

[a] *All studies were Level IV C evidence*
[b] *No mention of sample size calculation or whether forced-air warming systems were maintained according to manufacturer instructions*
[c] *Bair Hugger®*
[d] *Warm Touch™*
Bair Hugger is a registered trademark of the Arizant Healthcare, Eden Prairie, MN. Warm Touch™ is a trademark of Covidien, Mansfield, MA.

Forced-air warmers may interrupt the flow of filtered air toward the area of the wound and may allow dust particles containing pathogenic organisms to come into contact with the wound. To study airflow disturbances, the researchers used different methods:

- Sessler et al[16] and Sharp et al[17] examined airflow using smoke,
- Belani et al[9] and McGovern et al[14] used neutral-buoyancy air bubbles,
- Legg et al[13] and Sessler et al[16] used particle counts, and
- Dasari et al[11] and Legg et al[13] measured air temperature at various heights in the OR.

The methods were well described by the investigators, but only two of the investigators[14,16] described methods to detect airflow disturbances that followed an existing standard[16] or used a previously validated method.[14] None of these studies were conducted when a patient was undergoing a procedure but were performed under controlled conditions, including having no traffic in the OR.

DISCUSSION

The evidence we reviewed does not conclusively indicate that forced-air warmers are a cause of SSIs. The lack of conclusive evidence is mainly

TABLE 4. Summary of Evidence: Unwanted Airflow Disturbances in the OR Caused by the Forced-Air Warmer

Evidence source[a]	Setting, subjects, and intervention	Assessment of airflow disturbance	Findings	Comments[b]
Belani KG, Albrecht M, McGovern PD, Reed M, Nachtsheim C. Patient warming excess heat: the effects on orthopedic operating room ventilation performance. *Anesth Analg*. 2013; 117(2):406-411.	■ Downward displacement in ventilated OR ■ Manikin draped for total knee replacement procedure ■ Forced-air warmer[c] with torso cover, torso conductive fiber blanket,[d] or no warming device ■ Experiment repeated once	■ Neutral-buoyancy detergent bubbles were released under the drape near the head of the manikin and sampled over the surgical site	■ There was an increase in average bubble counts over the surgical site with the forced-air warmer (132.5) compared with the conductive fiber blanket (0.48) ($P < .003$)	■ Motionless anesthesia professional at the head of the OR bed ■ No simulated OR team or traffic ■ Use of bubbles to follow airflow
Dasari KB, Albrecht M, Harper M. Effect of forced-air warming on the performance of operating theatre laminar flow ventilation. *Anaesthesia*. 2012;67(3):244-249.	■ Partial-walled, ultra-clean OR ■ Manikin draped for an abdominal procedure ■ Lower body forced-air warmer,[c] over-body conductive fiber blanket,[d] under-body resistive blanket[e]	■ Air temperature measured at 5 heights, including the floor, OR bed, patient, ceiling at 5 locations, and above the surgical site	■ There was a greater increase in temperature over the surgical site with the forced-air warmer: 2.7°C (4.9°F) ($P < .001$) higher than the conductive fabric and 3.6°C (6.5°F) ($P < .001$) higher than the resistive blanket	■ Based on changes in air temperature at various locations, the authors concluded that the forced-air warmer generates convection currents near the surgical site and may produce unwanted airflow disturbances
Legg AJ, Cannon T, Hamer AJ. Do forced air patient-warming devices disrupt unidirectional downward airflow? *J Bone Joint Surg Br*. 2012;94(2): 254-256.	■ Orthopedic OR ■ 1 draped volunteer used to simulate a lower-limb procedure ■ Torso forced-air warmer cover[c] or torso conductive fiber blanket[d]	■ Particle counts (size 0.3, 0.5, 5 μm) 10 cm above the surgical site ■ Air temperature at various locations in the OR	■ Particle counts increased with the forced-air warmer compared with the conductive fiber blanket ($P = .0038$ to .0087)	■ Use of wall extensions to maximize airflow ■ A surgeon with a hood and body exhaust system but no other team members
McGovern PD, Albrecht M, Belani KG, et al. Forced-air warming and ultra-clean ventilation do not mix: an investigation of theatre ventilation, patient warming and joint replacement infection in orthopaedics.	■ Laminar flow ultra-clean-air—ventilated OR ■ Draped manikin simulating hip replacement (repeated once) and draped lumbar spinal procedure (not repeated)	■ Neutral-buoyancy detergent bubbles were released near the manikin's head or near the floor ■ The area near the surgical site was observed	■ Air currents with the forced-air warmer on were more toward the surgical site compared with the conductive fabric	■ Single surgeon and anesthesia professional, but no OR traffic

TABLE 4. *(continued)* Summary of Evidence: Unwanted Airflow Disturbances in the OR Caused by the Forced-Air Warmer

Evidence source[a]	Setting, subjects, and intervention	Assessment of airflow disturbance	Findings	Comments[b]
J Bone Joint Surg Br. 2011;93(11):1537-1544.	■ Upper or lower body forced-air warmer[c] cover or torso conductive fabric blanket[d]			
Sessler DI, Olmsted RN, Kuelpmann R. Forced-air warming does not worsen air quality in laminar flow operating rooms. *Anesth Analg*. 2011; 113(6):1416-1421.	■ Two laminar flow ORs ■ Draped volunteer patient ■ Warmed manikins represented surgical team members ■ Forced-air warmer[c] with upper body cover or under-body blanket	■ Smoke with visual tracer	■ There was no impairment in laminar flow and there were no unwanted airflow disturbances with either the forced-air warmer with upper body cover or under-body blanket.	■ No OR traffic
Sharp RJ, Chesworth T, Fern ED. Do warming blankets increase bacterial counts in the operating field in a laminar-flow theatre? *J Bone Joint Surg Br*. 2002;84(4): 486-488.	■ Laminar flow ultra-clean-air—ventilated OR ■ 12 different conditions ranging from empty OR to 4 different volunteers on OR beds covered with forced-air warmer[f] blankets	■ Smoke test	■ There was no significant effect on OR airflow with the forced-air warmer[b] unit on or off	■ No OR traffic

[a] All studies were Level IV C evidence
[b] No mention of sample size calculation or whether forced-air warmers were maintained according to manufacturer instructions
[c] Warm Touch™
[d] Bair Hugger®
[e] Hot Dog Total Access Warming™
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because of methodological problems in the investigations, such as a general lack of randomization, methods to determine an adequate sample size, and blinding. Only three[12,14,15] of the 15 investigations[5-19] followed patients who were warmed with a forced-air warmer to determine the incidence of SSI. The majority of the investigations indirectly examined the PICO question by determining whether the forced-air warmer harbored organisms, there was an increase in bacteria on or near the surgical site, or the forced-air warmer caused an unwanted airflow disturbance that could lead to an increase in bacteria entering the wound.

Two[12,15] of the three investigations[12,14,15] that followed subjects on whom a forced-air warmer had been used during surgery did not report an increase in SSIs with forced-air warmer use. These investigators reported there were no SSIs in a small

number of patients who underwent major vascular surgery with prosthetic graft use (ie, 16 patients)[12] or patients who underwent hip arthroplasty (ie, 30 patients)[15] regardless of whether a forced-air warmer was used intraoperatively. Serious methodological problems included the lack of a control group[12] and no description of the length of the follow-up period.[15] A third investigation[14] had a respectable sample size of 1,437 patients undergoing major joint replacement surgery, but more than half of the patients were in the forced-air warmer group. These investigators reported there was a greater risk of an SSI in subjects on whom a forced-air warmer was used intraoperatively (odds ratio, 3.8; $P = .024$). However, potentially serious problems with this study included the disclosure that one or more of the authors had been or was supported by a commercial party that manufactures a competing product.

The remaining three methods indirectly examined the PICO question. With the first indirect method, the findings of five[5-8,10] of the six[5-8,10,12] investigations suggested the forced-air warmer could be harboring bacteria or bacteria-containing particles. Typically researchers took swabs from various locations inside of the forced-air warmer, including the filter, air path, and output hose, and transferred the swabs to culture media manually or by blowing air from the unit directly onto culture plates. The investigators cultured bacteria from these sites and concluded that forced-air warmers could be a cause of SSIs. Two of these investigations[5,6] also concluded that there is a risk of the forced-air warmer emitting particles capable of carrying bacteria. In the investigation indicating that the forced-air warmer did not likely harbor bacteria,[12] the investigators reported there were no bacteria cultured from the output hose and filter. The problems with these investigations[5-8,10,12] were that there was no mention of how the forced-air warmers were maintained and researchers established no causal link between the presence of bacteria in the forced-air warmer and SSIs.

Another group of studies[12,15,17-19] looked at the presence of bacteria near or on volunteers, manikins, or patients when using a forced-air warmer, and none conclusively showed an increase in bacteria. Sharp et al[17] found that there was no airborne contamination regardless of whether a forced-air warmer was used. Zink and Iaizzo[19] found that there was no difference in bacteria counts. Tumia and Ashcroft[18] found an insignificant increase. Huang et al[12] found a significant decrease in colony counts when using a forced-air warmer. The fifth group of investigators, Moretti et al,[15] concluded that although the bacterial loads were increased at some locations when using a forced-air warmer, the increase was no higher than the bacterial load seen at the time the patient was assisted onto the OR bed. None of these investigators reported a conflict of interest.

The final indirect method sought to determine whether forced-air warmers cause unwanted airflow disturbances that encourage bacteria to be blown toward the surgical site. None of these investigations were conducted during actual surgical procedures.[9,11,13,14,16,17] Instead, the researchers used highly controlled simulated

AORN Resources

- Clinical FAQs: Hypothermia. AORN, Inc. *http://www.aorn.org/clinicalfaqs.*
- Periop Mastery Program: Preventing unplanned perioperative hypothermia. AORN, Inc. *http://www.aorn.org/periopmasteryprogram.*
- Recommended practices for the prevention of unplanned perioperative hypothermia. In: *Perioperative Standards and Recommended Practices.* Denver, CO: AORN, Inc; 2013:375-386.

Web site access verified August 5, 2013.

scenarios that did not realistically simulate movement and traffic in the OR. Four[9,11,13,14] of the groups of investigators concluded that forced-air warmers were likely to cause these unwanted airflow disturbances. At least one author in all four investigations had been or was currently supported by a company manufacturing a leading competitor to forced-air warmers. No definitive causal link was established between the airflow disturbances and SSIs. Additionally, one study[16] indicating there was no unwanted airflow disturbance was supported, in part, by a forced-air warmer manufacturer; and one of the investigators received support from a forced-air warmer manufacturer.

NURSING IMPLICATIONS

We found no randomized clinical trials examining whether there is an increase in SSIs in subjects on whom a forced-air warmer is used intraoperatively. All of the studies we appraised for this review had major methodological problems, such as the possibility of an inadequate sample size, lack of blinding, and not maintaining the devices according to the manufacturer's instructions. In the three investigations that followed subjects on whom a forced-air warmer had been used during surgery,[12,14,15] only one[14] concluded there was an increase in SSI with forced-air warmer use; however, not only was there no randomization or blinding in that investigation, there was no control of potentially confounding factors, and it is not known what effect history played on the results because the data were collected during the two-year study period.

RECOMMENDATIONS

Although concerns exist about the potential SSI risk from using forced-air warming units, clinicians should continue to use these devices because they are effective for preventing inadvertent perioperative hypothermia.[20] Clinicians should continue to use these devices so long as they are meticulously maintained according to the manufacturer's instructions, including properly replacing filters. Clinicians should take steps to prevent health care–associated infections from the use of forced-air warmers, just as they should when using any medical device. For instance, personnel should routinely and meticulously clean forced-air warmers with manufacturer-approved products, and these devices should be used strictly according to the manufacturer's instructions. Manufacturers should explore designs that allow for convenient cleaning of the surfaces of the airflow path.

FUTURE RESEARCH

The question of forced-air warmers causing SSIs should be examined in large, multicenter, randomized, controlled trials that are free from potential sources of bias such as funding by competing manufacturers. Observers should be blinded as much as possible and sample sizes should be based on the results of existing, albeit flawed, investigations. Investigators should include similar control and treatment groups with similar antibiotic use and surgical techniques. Until the findings of such rigorous studies are reported, clinicians should continue to use forced-air warmers.

CONCLUSION

Forced-air warming devices are an efficacious method of preventing intraoperative hypothermia and its complications (eg, coagulopathy, SSI).[20] Despite this efficacy, there may be provider hesitation in using these devices because of concerns related to these devices acting as vectors of infection or causing unwanted airflow disturbances that result in SSIs.[2]

Our review uncovered no conclusive evidence that the use of forced-air warmers increases the risk of SSIs. Although there is evidence that bacteria may be harbored on the air path surfaces inside the forced-air warmer, the studies that we appraised failed to establish a causal link between this and an increase in SSIs. The evidence also does not support the concern that use of a forced-air warmer may cause an increase in bacteria near or on the patient or cause unwanted airflow disturbances. These findings confirm the AORN

recommendations that forced-air warming is an effective way to prevent unplanned perioperative hypothermia.[20] AORN

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References

1. Sessler DI. Temperature monitoring and perioperative thermoregulation. *Anesthesiology.* 2008;109(2):318-338.
2. Weirich TL. Hypothermia/warming protocols: why are they not widely used in the OR? *AORN J.* 2008;87(2): 333-344.
3. Richardson WS, Wilson MC, Nishikawa J, Hayward RS. The well-built clinical question: a key to evidence-based decisions. *ACP J Club.* 1995;123(3):A12-A13.
4. Stetler CB, Morsi D, Rucki S, et al. Utilization-focused integrative reviews in a nursing service. *Appl Nurs Res.* 1998;11(4):195-206.
5. Albrecht M, Gauthier RL, Belani K, Litchy M, Leaper D. Forced-air warming blowers: an evaluation of filtration adequacy and airborne contamination emissions in the operating room. *Am J Infect Control.* 2011;39(4):321-328.
6. Albrecht M, Gauthier R, Leaper D. Forced-air warming: a source of airborne contamination in the operating room? *Orthop Rev (Pavia).* 2009;1(2):e28.
7. Avidan MS, Jones N, Ing R, Khoosal M, Lundgren C, Morrell DF. Convection warmers—not just hot air. *Anaesthesia.* 1997;52(11):1073-1076.
8. Baker N, King D, Smith EG. Infection control hazards of intraoperative forced air warming. *J Hosp Infect.* 2002; 51(2):153-154.
9. Belani KG, Albrecht M, McGovern PD, Reed M, Nachtsheim C. Patient warming excess heat: the effects on orthopedic operating room ventilation performance. *Anesth Analg.* 2013;117:406-411.
10. Bernards AT, Harinck HI, Dijkshoorn L, van der Reijden TJ, van den Broek PJ. Persistent Acinetobacter baumannii? Look inside your medical equipment. *Infect Cont Hosp Epidemiol.* 2004;25(11):1002-1004.
11. Dasari KB, Albrecht M, Harper M. Effect of forced-air warming on the performance of operating theatre laminar flow ventilation. *Anaesthesia.* 2012;67(3):244-249.
12. Huang JK, Shah EF, Vinodkumar N, Hegarty MA, Greatorex RA. The Bair Hugger patient warming system in prolonged vascular surgery: an infection risk? *Crit Care.* 2003;7(3):R13-R16.
13. Legg AJ, Cannon T, Hamer AJ. Do forced air patient-warming devices disrupt unidirectional downward airflow? *J Bone Joint Surg Br.* 2012;94(2):254-256.
14. McGovern PD, Albrecht M, Belani KG, et al. Forced-air warming and ultra-clean ventilation do not mix: an investigation of theatre ventilation, patient warming and joint replacement infection in orthopaedics. *J Bone Joint Surg Br.* 2011;93(11):1537-1544.
15. Moretti B, Larocca AM, Napoli C, et al. Active warming systems to maintain perioperative normothermia in hip replacement surgery: a therapeutic aid or a vector of infection? *J Hosp Infect.* 2009;73(1):58-63.
16. Sessler DI, Olmsted RN, Kuelpmann R. Forced-air warming does not worsen air quality in laminar flow operating rooms. *Anesth Analg.* 2011;113(6):1416-1421.
17. Sharp RJ, Chesworth T, Fern ED. Do warming blankets increase bacterial counts in the operating field in a laminar-flow theatre? *J Bone Joint Surg Br.* 2002;84 (4):486-488.
18. Tumia N, Ashcroft GP. Convection warmers—a possible source of contamination in laminar airflow operating theatres? *J Hosp Infect.* 2002;52(3):171-174.
19. Zink RS, Iaizzo PA. Convective warming therapy does not increase the risk of wound contamination in the operating room. *Anesth Analg.* 1993;76(1):50-53.
20. Recommended practices for the prevention of unplanned perioperative hypothermia. In: *Perioperative Standards and Recommended Practices*. Denver, CO: AORN, Inc; 2013:375-386.

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EXAMINATION

CONTINUING EDUCATION PROGRAM

3.0 CE

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Forced-Air Warming Devices and the Risk of Surgical Site Infections

PURPOSE/GOAL

To provide knowledge specific to the use of forced-air warming systems and surgical site infections.

OBJECTIVES

1. Describe inadvertent perioperative hypothermia.
2. Discuss the use of forced-air warming to maintain normothermia perioperatively.
3. Describe the methodologies used in the studies appraised in this article.
4. Describe the authors' conclusions about the use of forced-air warming systems.

The Examination and Learner Evaluation are printed here for your convenience. To receive continuing education credit, you must complete the Examination and Learner Evaluation online at *http://www.aorn.org/CE*.

QUESTIONS

1. Inadvertent perioperative hyperthermia is the most common thermal disturbance seen in surgical patients.
a. true *b.* false

2. Reasons for heat loss during operative and invasive procedures include
1. the patient's exposure to the surgical environment.
2. the effects of anesthetic agents and medications that interfere with temperature regulation.
3. redistribution of heat from the core to the periphery of the body.
a. 1 and 2 *b.* 1 and 3
c. 2 and 3 *d.* 1, 2, and 3

3. Health care providers often use forced-air warming systems to provide surface warming in the OR because these devices are helpful in maintaining normothermia and preventing hypothermia.
a. true *b.* false

4. Health care providers are concerned about the use of forced-air warming systems because
a. of the cost that the health care facility must assume to use the units.
b. of the potential for increasing the risk of surgical site infections (SSIs).
c. they are difficult to use and interfere with work flow in the OR.
d. they are noisy and cause distraction in the OR.

5. What were the methodological concerns the authors found in the studies they reviewed for this article?
1. Researchers did not describe how they determined sample sizes of forced-air warmers or the number of study participants.

2. Researchers did not indicate whether the forced-air warmers had been maintained according to the manufacturer's instructions.
3. There was no blinding or random allocation of participants to study groups.
4. In some cases, an author of the study was or had been supported by a company that manufactures a competing product to the forced-air warmer.
5. The statistics had been incorrectly calculated.

a. 4 and 5 *b.* 1, 2, and 3
c. 1, 2, 3, and 4 *d.* 1, 2, 3, 4, and 5

6. In the three investigations that followed patients who were warmed intraoperatively for SSIs, it is unknown whether the groups were similar in confounding variables such as

1. obesity.
2. age.
3. incontinence.
4. fitness for surgery.

a. 1 and 2 *b.* 3 and 4
c. 1, 2, and 3 *d.* 1, 3, and 4

7. The first method that researchers used to indirectly examine whether forced-air warmers are likely to cause SSIs included

1. swabbing the interior and exterior of one forced-air warmer.
2. comparing the filtration efficiency of five new forced-air warmer intake filters with five used filters.
3. culturing *Acinetobacter baumannii* from the nares of patients who would be undergoing surgery with a forced-air warmer.
4. swabbing used patient blankets.

a. 1 and 2 *b.* 3 and 4
c. 1, 2, and 3 *d.* 1, 2, 3, and 4

8. The second indirect method used to determine whether forced-air warmers are likely to cause SSIs was to examine bacterial counts

1. close to the middle of the OR.
2. near the surgical site.
3. on the hands of the anesthesia professional.
4. on or near patients or volunteers.

a. 1 and 2 *b.* 3 and 4
c. 1, 2, and 4 *d.* 1, 2, 3, and 4

9. The evidence reviewed for this article did not conclusively indicate that forced-air warmers are a cause of SSIs because of methodological problems with the investigations.

a. true *b.* false

10. Although concerns exist about the potential SSI risk from using forced-air warming units, clinicians should continue to use these devices so long as

1. the units are meticulously cleaned with manufacturer-approved products.
2. personnel properly replace the filters.
3. clinicians take steps to prevent health care–associated infections.
4. the units are used strictly according to the manufacturer's instructions.

a. 1 and 3 *b.* 2 and 4
c. 1, 2, and 3 *d.* 1, 2, 3, and 4

LEARNER EVALUATION

CONTINUING EDUCATION PROGRAM

3.0 CE

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Forced-Air Warming Devices and the Risk of Surgical Site Infections

This evaluation is used to determine the extent to which this continuing education program met your learning needs. Rate the items as described below.

OBJECTIVES

To what extent were the following objectives of this continuing education program achieved?

1. Describe inadvertent perioperative hypothermia.
Low 1. 2. 3. 4. 5. High

2. Discuss the use of forced-air warming to maintain normothermia perioperatively.
Low 1. 2. 3. 4. 5. High

3. Describe the methodologies used in the studies appraised in this article.
Low 1. 2. 3. 4. 5. High

4. Describe the authors' conclusions about the use of forced-air warming systems.
Low 1. 2. 3. 4. 5. High

CONTENT

5. To what extent did this article increase your knowledge of the subject matter?
Low 1. 2. 3. 4. 5. High

6. To what extent were your individual objectives met? *Low 1. 2. 3. 4. 5. High*

7. Will you be able to use the information from this article in your work setting? *1. Yes 2. No*

8. Will you change your practice as a result of reading this article? (If yes, answer question #8A. If no, answer question #8B.)

8A. How will you change your practice? *(Select all that apply)*

1. I will provide education to my team regarding why change is needed.
2. I will work with management to change/implement a policy and procedure.
3. I will plan an informational meeting with physicians to seek their input and acceptance of the need for change.
4. I will implement change and evaluate the effect of the change at regular intervals until the change is incorporated as best practice.
5. Other: _____

8B. If you will not change your practice as a result of reading this article, why? *(Select all that apply)*

1. The content of the article is not relevant to my practice.
2. I do not have enough time to teach others about the purpose of the needed change.
3. I do not have management support to make a change.
4. Other: _____

9. Our accrediting body requires that we verify the time you needed to complete the 3.0 continuing education contact hour (180-minute) program: _____