Forced-air warming discontinued: periprosthetic joint infection rates drop

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Abstract

Several studies have shown that the waste heat from forced-air warming (FAW) escapes near the floor and warms the contaminated air resident near the floor. The waste heat then forms into convection currents that rise up and contaminate the sterile field above the surgical table. It has been shown that a single airborne bacterium can cause a periprosthetic joint infection (PJI) following joint replacement surgery. We retrospectively compared PJI rates during a period of FAW to a period of air-free conductive fabric electric warming (CFW) at three hospitals. Surgical and antibiotic protocols were held constant. The pooled multicenter data showed a decreased PJI rate of 78% following the discontinuation of FAW and a switch to air-free CFW (n=2034; P=0.002). The 78% reduction in joint implant infections observed when FAW was discontinued suggests that there is a link between the waste FAW heat and PJIs.

Introduction

It is now generally recognized that in the absence of active warming, most surgical patients will become clinically hypothermic. It has also been shown that mild perioperative hypothermia is detrimental to a variety of outcomes including increased soft tissue infections (SSI),

bleeding and transfusion requirements,

increased risk of morbid cardiac events,

prolonged recovery and prolonged hospital stays.1 As a result of these studies and others like them, FAW has become a standard of care for most surgical procedures.

In 2009, we reported the results of our laboratory research showing that the waste air from FAW is not simply benign waste air, but is almost 1000 watts of waste heat (www.Heat-rises.blogspot.com). In some circumstances, the waste heat and air escapes from under the surgical drape near the floor, which it warms the contaminated air normally resident near the floor. The contaminated warm air forms into convection currents that rise along the sides of the surgical table, mobilizing the floor bacteria into the sterile surgical field above the patient. In other circumstances, the waste heat radiates through the surgical drape, inducing a tornado-like vortex near the anesthesia screen. This tornado-like vortex has been shown to vacuum contaminants from the floor and deposit them into the sterile surgical field.

The fact that waste FAW heat causes contamination of the sterile surgical field has been corroborated by seven peer-reviewed, published studies.2-7 One study by Legg et al., for example, showed that there are 2000 times more contaminating particles above the surgical site when FAW is used than with air-free CFW.7

It has been shown that the concentration of contaminants in the air of the sterile surgical field has been shown to vacuum contaminants from the floor and deposit them into the sterile surgical field.8-11 The contaminated warm air forms into convection currents that rise along the sides of the surgical table, mobilizing the floor bacteria into the sterile surgical field above the patient. In other circumstances, the waste heat radiates through the surgical drape, inducing a tornado-like vortex near the anesthesia screen. This tornado-like vortex has been shown to vacuum contaminants from the floor and deposit them into the sterile surgical field.

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Materials and Methods

This study is designed to investigate periprosthetic joint infection (PJI) rates while using FAW (Bair Hugger®, 3M, St. Paul, MN, USA) compared with air-free CFW (HotDog®, Augustine Temperature...
Management, Eden Prairie, MN, USA). The measured outcome in each of these studies is PJI. This multicenter retrospective outcome study consists of data reported by three hospitals.

Each hospital report shares a study design similar to the McGovern study. In each study, a baseline PJI rate was determined for the FAW control group over a one-year period of time ($t_{FAW}$). FAW was then discontinued, and the hospital switched to air-free CFW warming. Any infections occurring during the first two months after the switch in warming technologies were disregarded. Given that PJIs do not necessarily occur in the immediate postoperative period, it would be impossible to know if an infection occurring during the washout period came from the FAW or CFW time period. Starting with month three of the CFW period, the PJI rate was determined for the following 6-24 months of data collection ($t_{CFW}$). The changes in PJI rates from $t_{FAW}$ to $t_{CFW}$ were then determined.

Only hospitals reporting that no other significant changes were made to their surgical and antibiotic prophylaxis protocols during the study period qualified to be part of this study. No effort was made to standardize surgical protocols, the assumption being that the averaging of the multicenter data would offset minor variations in protocols. No effort was made to control for demographic variables, with the assumption being that the average patient population using a given hospital for total joint replacement surgery does not change appreciably from year to year.

Model selection and parameter significance tests were performed by comparing differences in model deviance to the expectation value under the $\chi^2$ distribution (likelihood ratio test), 0.5 was added to each cell using Haldane correction for sparse observations. A paid, independent statistician performed statistical calculations.

### Table 1. Periprosthetic joint infection results.

| Patient warming device | Developing infection, n (%) | Not developing infection, n (%) | Odds ratio (95% confidence interval) | P |
|------------------------|----------------------------|-------------------------------|-------------------------------------|----|
| **Center #1**          |                            |                               |                                     |    |
| Conductive fabric      | 2 (0.3)                    | 675 (99.7)                    | 1.0                                 | 0.029\* |
| Forced air             | 6 (1.5)                    | 382 (98.5)                    | 4.59 (1.06, 19.85)                  |    |
| **Center #2**          |                            |                               |                                     |    |
| Conductive fabric      | 0 (0.0)                    | 218 (100)                     | 1.0                                 | 0.031* |
| Forced air             | 4 (2.3)                    | 171 (97.7)                    | 11.47 (0.61, 214.43)                |    |
| **Center #3**          |                            |                               |                                     |    |
| Conductive fabric      | 2 (1.0)                    | 192 (99.0)                    | 1.0                                 | 0.70\* |
| Forced air             | 6 (1.6)                    | 376 (98.4)                    | 1.33 (0.31, 5.78)                   |    |
| **Multicenter pooled results** |                  |                               |                                     |    |
| Conductive fabric      | 4 (0.4)                    | 1085 (99.6)                   | 1.0                                 | 0.002\* |
| Forced air             | 16 (1.7)                   | 929 (98.3)                    | 4.28 (1.50, 12.19)                  |    |

### Table 2. Chain of infection analysis.

| Chain of infection methodology | HCD | FAW |
|--------------------------------|-----|-----|
| **1. Infectious agent**       | Biofilm producing *Mycobacterium chimaera* | Biofilm producing skin bacteria, especially *Staphylococcus* |
| **2. Reservoir**              | The inaccessible internal airflow pathway of the HCD | i) The inaccessible internal airflow pathway of the FAW blower; ii) the skin of the surgical staff |
| **3. Portal of exit**         | Aerosolized into and exhausted with the heated cooling air | i) Aerosolized into and exhausted with the heated air; ii) skin cells and bacteria shed into the air of the OR from the surgical staff |
| **4. Mode of transmission**   | i) Waste heat rises outside the ventilation flow field and is then entrained into the downward ventilation airflow; ii) The waste heat from the HCD is blown inside the ventilation flow field near floor. Much like the waste heat from FAW, it then rises | The waste FAW hot air escapes from under the lower edge of the surgical drape near the floor inside the ventilation flow field. It warms the contaminated air that is normally resident near the floor. The waste heat and the warmed contaminated floor air then rise alongside the surgical table and end up in the sterile surgical field above the patient |
| **5. Portal of entry**        | Cardiac surgery | Orthopedic surgery |
| **6. Susceptible host**       | The surgical patient receiving implanted foreign materials | The surgical patient receiving implanted foreign materials |

HCD, heat-cutter device; FAW, forced air warming.
Discussion

This is a multicenter observational outcome study investigating the possible relationship between FAW and PJI in hip and knee total joint replacement surgery. The data were collected retrospectively at three hospitals. The switch from FAW to air-free conductive fabric warming was the only independent variable identified during the study period. It is axiomatic that warming by convection is inefficient; resulting in the release of waste heat.23 The most common brand of FAW was used by all three hospitals in this study. However, it must be noted that all other brands of FAW also release approximately the same amount of waste heat, thereby causing the same surgical contamination risks. The pooled multicenter data from the three hospitals reported in this study showed a decreased PJI rate of 78% following the discontinuation of FAW and a switch to air-free CFW. This pooled result corroborates the findings of the McGovern study, which reported a 74% decrease in PJI rates when FAW was discontinued and CFW was initiated.8 Assuming that there were no other unreported significant changes in the surgical or antibiotic protocols during the study period, the significant drop in the PJI rates must be attributed to the discontinuation of FAW until proven otherwise.

The suggestion that FAW could simultaneously be causing PJIs and reducing soft tissue SSIs seems to be contradictory. However, this apparent contradiction is explained by the presence or absence of biofilm.24 Biofilm is a coating of exopolysaccharide material that protects the bacterium from antibodies and antibiotics, effectively allowing it to hibernate for up to one year before sprouting into a full infection. Many bacteria can form biofilm coatings in the presence of implanted foreign materials, but cannot form effective biofilm in soft tissue.25 The result is that the infectious process is fundamentally different in joint replacement surgery, where a single bacterium can cause an infection, compared to soft tissue surgery, where an inoculum of more than one million bacteria is usually required to cause an infection.16-18 Patients receiving implants, especially orthopedic implants, are especially susceptible to infection because bacteria can form biofilm on the implant.

The often-referenced studies showing that FAW reduces SSIs were investigating soft tissue surgery (colon, breast and hernia), where effective biofilm cannot be formed.1,2 With soft tissue surgery, maintaining normothermia by any means of active warming seems to lower the infection rate. Even heavily contaminated air cannot introduce the inoculum of more than one million bacteria into a wound, the quantity required for a soft tissue infection. In contrast, the results of this study suggest that FAW should not be used during joint replacement surgery, where a single bacterium is adequate to cause the PJI.15-18

There is a striking similarity between the waste heat and air from HCD causing heart valve infections and the waste heat and air from FAW causing PJIs after hip and knee replacement surgery. Using the CDC’s chain of infection methodology, the similarities between HCD infections and FAW infections can be appreciated (Table 2).

The similarity between these infections and the equipment causing them supports the CDC’s broad recommendation to not use any equipment that blows air in the operating room. Nothing that blows air should be in an operating theater, if possible and ...it is important not to blow air in the operating theater.24

In summary, seven published studies have documented the contamination of the sterile surgical field by the rising waste FAW heat.7,11 Now, there are two retrospective outcome studies investigating the linkage between the rising waste FAW heat and deep PJI in joint replacement surgery. Both of these studies show significant decreases in PJI rates when the use of FAW is discontinued. Discontinuing the use of FAW in this multicenter retrospective trial resulted in a reduction of the PJI rates of 78%, which is consistent with the 74% reduction reported by McGovern et al.1 In both of these studies, the lower infection rates were achieved while using air-free CFW.

According to the American Academy of Orthopedic Surgeons, the incidence of periprosthetic joint infection after primary hip or knee arthroplasty is over 2% among the Medicare population.29 Therefore, the approximately one million of these procedures performed annually in the US should result in 20,000 PJIs per year. 20,000 catastrophic, permanently disabling PJI infections per year would seem to qualify as a public health crisis if they have a common etiology. This study suggests that more than 15,000 of these infections (78%) may be caused by FAW and are thus preventable.

Given the current FAW contamination and infection research and the CDC’s recent admonition against blowing air in the operating room, it may be that a randomized controlled trial (RCT) would be unethical at this point. Therefore, retrospective outcome studies are the most robust clinical information that is likely to be available on this topic, and additional studies should be encouraged.

Conclusions

Based on these data it seems prudent that hospitals and clinicians avoid using forced-air warming on patients during surgeries involving implanted materials, especially joint replacements, until it is proven to be safe.

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