Published in final edited form as:

J Arthroplasty. 2016 April ; 31(4): 776–780. doi:10.1016/j.arth.2015.10.039.

Contamination Relative to the Activation Timing of Filtered-Exhaust Helmets

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Abstract

Background—Filtered-exhaust helmet systems are commonplace during total joint arthroplasty, but their ability to limit intraoperative contamination has been questioned. We hypothesized that activation of the airflow system after complete gowning would lead to decreased contamination of the surgical environment.

Methods—Using a fluorescent particle model, the maximal particle spread from a filtered-exhaust helmet and contamination of the surgical environment based on timing of airflow activation through simulated surgical gowning procedures were evaluated.

Results—Helmet airflow analysis revealed particle spread greater than 5 feet in all trials. Activation before gowning resulted in a significantly greater contamination in the control group compared with the experimental group ($P = .014$).

Conclusions—We recommend complete surgical gowning before activation of the airflow system.

Keywords

contamination; filtered-exhaust; space suit; arthroplasty; ultraviolet fluorescent powder

Surgical site infections and periprosthetic joint infections are devastating complications of elective total joint arthroplasty. Despite infection rates of 1%-2%, a substantial burden is placed on both the patient and the health care system when these infections do occur [1,2]. Additional medical treatments, readmissions, and return to the operating room are all potential consequences that cost both time and money [3,4]. As a result, continued efforts have been pursued toward prevention of periprosthetic joint infections.

Contamination in the operating room is a known cause for periprosthetic infections. Investigations into surgical attire, sterile techniques, operating room traffic, and room airflow have proven successful in limiting infection and decreasing infection rates [5-7]. The use of filtered-exhaust surgical helmets and their respective personal protection hoods and/or

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No author associated with this paper has disclosed any potential or pertinent conflicts which may be perceived to have impending conflict with this work. For full disclosure statements refer to <http://dx.doi.org/10.1016/j.arth.2015.10.039>.

suits were developed for this purpose and have become commonplace in many operating rooms during arthroplasty surgery. Often referred to as “space suits,” these devices have an intake valve on top of the helmet that filters air through a disposable hood cover. The air then circulates within the helmet and disperses down toward the surgeon’s face and/or neck and into the gown. Unfortunately, infection prevention while using these filtered-exhaust systems has not yet been supported by the orthopedic literature and these systems are, therefore, more commonly regarded as personal protective equipment [8-10].

A common practice of the orthopedic surgeon and operating room staff is to plug in the helmet battery pack and activate the helmet’s airflow system before the preoperative hand wash. The surgeon then enters the operative suite and proceeds with the sterile gowning process while the helmet continues to circulate air from inside the helmet and out into the surrounding surgical environment. Because the helmets themselves are not part of the sterile processing system and they are often stored in nonsterile locations, there is potential for contaminate spread from within the helmet to the surrounding surgical field, equipment, and staff. As a result, the aim of this study was to evaluate the timing of airflow activation with the use of these helmets in an attempt to use these systems in a more appropriate manner and limit potential contamination. Our first hypothesis was that airflow from the filtered-exhaust helmet would lead to widespread dispersion of fluorescent particles in a surgical draping scenario. Our second hypothesis was that activation of the airflow system on a filtered-exhaust helmet before complete surgical gowning would lead to increased contamination of the surrounding surgical environment. To our knowledge, no prior study in the orthopedic literature has investigated a relationship between helmet airflow timing and contamination.

Material and Methods

For both parts of the study, we used an ultraviolet (UV) fluorescent powder (Glitterbug Powder; Brevis Corporation, Salt Lake City, UT) to represent skin particles and various air contaminants as a potential source of contamination. Several recent studies in the orthopedic literature have used similar fluorescent particle models to demonstrate the contamination potential [11-13]. The powder is near invisible to the naked eye on application and is detected through use of UV-A. The specific filtered-exhaust system evaluated in this study was the T5 Personal Protection System (Stryker Instruments, Kalamazoo, MI). This system is the most commonly used one at our institution, and we believe that its airflow design is similar to other models on the market. Each trial performed was conducted with a full battery charge. Surgical gowns used for part 2 of the study were a standard 2-piece system, consisting of a separate head covering and gown. The same operative environment was used for each study. Laminar airflow was not used.

Part 1: Airflow Spray Pattern

The surgical helmet was positioned on a stand at a standard height and surrounded by sterile surgical drapes. One tablespoon of UV fluorescent powder was placed into the air intake valve located on the top of the helmet. The helmet airflow was activated for 30 seconds at maximal strength to ensure a steady state of airflow. On deactivation, particle settling was allowed for 30 minutes. UV-A was then used to observe fluorescent particle accumulation on

the surgical drapes. Distance was measured from the base of the stand (Fig. 1). This portion of the study was repeated 3 times.

Part 2: Airflow Activation During a Surgical Gowning

A standard sterile surgical gowning procedure was replicated in a closed operating theater. The setup consisted of 2 orthopedic residents simulating the role of a surgeon and surgical technician. A filtered-exhaust helmet was secured in place on the surgeon's head and 1 tablespoon of UV fluorescent powder was administered into the air intake valve located on the top of helmet. Safety precautions for the surgeon wearing the helmet included a head covering, goggles, and facemask. Before the start of the gowning procedure, both the surgeon and the surgical technician were analyzed with UV-A light to ensure no particle contamination. Subsequently, the surgeon performed a standard sterile gowning procedure with assistance from the surgical technician. This process included application of the helmet face shield, surgical gown, and surgical gloves. Two orthopedic surgeons who were not participating in the gowning observed the procedure for any errors or nonsterile techniques.

In the early airflow activation (control) group, the helmet's airflow was activated before the initiation of the gowning procedure. In the late airflow activation (experimental) group, an identical procedure was performed with one key difference: the helmet airflow was not activated until after the gowning procedure was completed. Specifically, the helmet was not plugged into the battery pack until the face shield, gown, and gloves had been applied. After the helmet was plugged in, final tying of the surgical gown occurred. On completion of gowning, UV-A light was used to observe fluorescent particles on both the surgeon and scrub technician in both groups (Fig. 2).

A standard scoring system was developed based on a 0-6 scale that corresponded to 6 separate body regions. These regions consisted of the right hand, left hand, right arm, left arm, chest and/or abdomen, and head and/or neck (Fig. 3). One point was assigned if any fluorescent particles were observed within the specified region. A higher overall score represented increased contamination potential. Four trials were completed for each group resulting in 8 total trials. Compressed air was used in between trials to remove excess fluorescent powder from the helmet with UV light being used to confirm removal on the outside of the helmet.

Descriptive statistical analysis was used to evaluate the data. A one-sided Wilcoxon rank-sum test was performed comparing the experimental group (late airflow activation) to the control group (early airflow activation). Statistical significance was set at $P < .05$.

Results

Airflow Spray Pattern

Activation of the helmet airflow system resulted in substantial particle spread among the drapes. The drapes were positioned in a 5-foot diameter from the base of the stand and particle coverage extended to the edge of the drapes (Fig. 4). Although specific quantification of the powder could not be performed, we noted that particle spread was greater in the front of the helmet as compared to the rear.

Airflow Activation During Surgical Gowning

A total of 8 gowning trials were completed; 4 control trials with early airflow activation before gowning; and 4 experimental trials with late airflow activation after completion of gowning Tables 1 and 2. In the control group, UV-A light demonstrated a mean contamination potential score of 6/6 (standard deviation = 0) on the surgical technician after gowning. Contamination potential was maximal, with fluorescent particles seen in all six body regions throughout all trials. In the experimental group, UV-A light demonstrated a mean contamination potential score of 0/6 (standard deviation = 0) on the scrub technician after gowning. Contamination potential was minimal, with no fluorescent particles seen in any of the 6 body regions throughout all trials (Fig. 5). These differences were statistically significant ($P = .014$).

Although not part of our original hypothesis, we documented a large amount of contamination on the surgeon wearing the filtered-exhaust helmet. In the control group, the fluorescent particles were documented in 6 of 6 body regions using the same standard scoring system. This group also had a large amount of fluorescent particles that were drawn back into the air intake valve on the top of the helmet. In the experimental group, the fluorescent particles were contained within the surgeon's face shield and gown, thus not entering the surrounding surgical field and contributing to the contamination potential.

Discussion

Our study results showed that there was a statistically significant difference in contamination potential based on the timing of airflow activation for a filtered-exhaust surgical helmet. In the first part of the study, we documented the airflow pattern which resulted in substantial particle spread, specifically toward the front of the person wearing the helmet in distances that exceeded 5 feet. In the second part of the study, particle contamination of both the surgeon and the surgical technician was statistically larger when airflow was activated before the gowning process. This increased contamination potential may lead to increased infection rates; however, infection rate evaluation was beyond the scope of this study. Delaying airflow activation until after complete surgical gowning is a simple step that requires minimal alteration of current practices.

Filtered-exhaust helmet systems are commonly used during arthroplasty surgery to not only protect the surgeon but also for the theoretical decrease of operative site contamination. Although the early body-exhaust systems developed by Charnley resulted in decreased infection rates in conjunction with laminar room airflow, the use of modern filtered-exhaust systems have not yet been proven to decrease infection in the orthopedic literature [14,15]. A study by Shaw et al evaluated air samples in 48 total hip arthroplasty (THA) and total knee arthroplasty (TKA) cases. Groups were divided into filtered-exhaust helmet systems and conventional paper gowns. Air samples taken from the surgical field showed similar particle counts regardless of filtered-helmet exhaust use. This lack of decreased contamination has been replicated in other studies [9,10]. Another study by Hooper et al reviewed space suit use in conjunction with laminar flow operating rooms of 51,485 THAs and 36,826 TKAs over a 10-year period. Their data revealed no benefit of using surgical space suits and even showed increased infection rates with their use [8].

Despite the lack of evidence supporting their use, filtered-exhaust helmet systems continue to be a common fixture in the operating room. As a result, several studies have attempted to evaluate their limitations. A study by Singh et al evaluated the intraoperative bacterial contamination of the helmet face shield during 11 THAs and 29 TKAs. They demonstrated a contamination rate as high as 80% with *Staphylococcus aureus* being the most prevalent organism cultured [16]. A similar study by Kearns et al [17] showed contamination of the surgical hood in 48 of 102 (47%) of cases. Perhaps most comparable with our study was a recent investigation by Young et al, in which a similar mock surgical gowning procedure was performed with fluorescent powder on the surgeon's hands to simulate normal squamous cells. On gowning, they demonstrated that the positive air pressure generated by the filtered-exhaust helmet within the gown caused particle migration from the surgeon's hands onto the forearm region. Their conclusions were that surgical helmets are a potential source of contamination, and they recommended using sealant tape around the inner glove [12].

Although we believe that our study does have practical applications, there are several limitations that should be noted. First, our goal was to evaluate contamination potential from inside the filtered-exhaust helmet using a fluorescent particle model. We did not investigate actual bacterial contamination or particle counts and, therefore, cannot derive any conclusions of the effect of this technique on clinical infection rates. Second, all trials were conducted in a controlled operating theater that was designed to simulate operative conditions. The use of a nonlaminar airflow room may be viewed as a limitation as laminar flow may have decreased the amount of potential airborne contamination; however, our goal was to represent a worst-case scenario. This included maximal air speed, high contamination, and no laminar flow. In addition, although there is a theoretical advantage of laminar airflow rooms in reducing reduce particle load in the operating room, the current literature has yet to fully support this technology [8]. Third, we used one type of filtered-exhaust helmet during our study because it is the most commonly used helmet at our institution. We acknowledge that other surgical helmets may have different designs and airflow strengths; however, our experience has shown that most helmets share similar airflow patterns. Fourth, we understand that intraoperative infection is a multifactorial issue; however, the aim of our study was to evaluate one specific source of contamination.

Conclusions

In summary, the results of this study support our hypothesis that there is an increase in contamination potential from activation of the surgical helmet in the operating room before complete gowning. To our knowledge, this is the first study in the orthopedic literature to investigate the timing of helmet airflow activation in this regard and also demonstrates that altering a simple step in the gowning process may limit contamination. Future studies should focus on particle counts, bacterial culturing, and prospective clinical trials to determine infection rates between early and late airflow activation.

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Fig. 1.
Particle spread measurement.

Fig. 2.
Airflow timing activation during surgical gowning procedure.

Fig. 3.
Contamination scoring system.

Fig. 4.
Particle dispersion from helmet.

Fig. 5.
Comparison of particle contamination on sleeve under ultraviolet light (control vs study groups).

Table 1

Gowning Trial Results.

Trial	Contamination Score (Surgeon) ^a	
	Control Group (Early Activation)	Study Group (Late Activation)
1	6	0
2	6	0
3	6	0
4	6	0

^aLowest contamination potential = 0; highest contamination potential = 6.

Table 2

Gowning Trial Results.

Trial	Contamination Score (Assistant) ^a	
	Control Group (Early Activation)	Study Group (Late Activation)
1	6	0
2	6	0
3	6	0
4	6	0

^aLowest contamination potential = 0; highest contamination potential = 6.