



## Original Research

## Examination of Surgical Helmet and Surgical Hood Application Methods in Reducing Contamination in Arthroplasty Surgery

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## ABSTRACT

**Background:** Contamination of the surgeon during gowning is a possible risk factor for prosthetic joint infection in arthroplasty surgery. Surgical helmets are a common form of personal protective equipment used during this type of surgery. Increasingly, there is a focus on the methods of application of the surgical hood and gown while wearing these helmets.

**Methods:** Ultraviolet fluorescent powder was used to represent air-borne contaminant and applied through the airflow inlet of the surgical helmet. Seven methods of helmet and surgical gown application methods were examined. A ultraviolet torch was used to determine the level of contamination across 11 body regions. A single body region with less than 10 particles was classified as minor contamination, and over 10 particles as major contamination.

**Results:** Early activation of the surgical helmet resulted in significant level of contamination across the majority of body regions. Major contamination also affected the scrub nurse when applying the surgical hood to the surgeon's helmet. Late activation of helmet system resulted in only minor level of contamination to the surgeon's shoulders and forearms. Adhesive wrist wraps over the inner gloves did not decrease contamination when added to late activation of the helmet.

**Conclusion:** It is our recommendation that the surgical hood should be applied by an unsterile theater assistant and that the surgical helmet system should be activated after the surgeon has applied inner gloves to minimize the level of contamination to the surgeon's gown.

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## Introduction

As the number of hip and knee joint replacements implanted increases yearly in Australia [1], there is an ever-growing concern for the burden of prosthetic joint infection (PJI) [2]. The original Charnley whole body exhaust-ventilated suit was designed to reduce contamination of the surgical field using a negative pressure inflow-outflow system. Owing to the cumbersome nature of the inflow-outflow tubes associated with exhaust-ventilated suit, the modern surgical helmet was invented. These devices draw in air through a fan on the superior aspect of the helmet which is then circulated within the confines created by a disposable hood cover and the surgical gown [3].

A large randomized control trial in 1982 found that combined with ultraclean air ventilation systems, the use of body exhaust suits reduced the incidence of PJI by 25% [4]. However, subsequent studies have disputed the result. A 10-year period analysis of New Zealand joint registry showed there is increased early infection for total knee and hip replacements associated with usage of surgical helmets [5]. A systematic review has further demonstrated no reduction in wound contamination with surgical helmets [6]. Despite this, surgical helmets have remained commonly used as personal protective equipment (PPE). Activation of the surgical helmet fan after the surgeon is completely gowned and gloved may reduce the risk of contamination [7].

In our institution, it is common for the surgeon to wear the surgical helmet, activate the fan, wash their hands, and enter the theater. The sterile scrub nurse applies the surgical hood to the surgeon in an attempt to keep the head shield as sterile as possible. The surgeon will then don a surgical gown and a pair of inner gloves. The sterile scrub nurse then applies a sterile band of

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adhesive tape around the inner gloves to avoid contamination at the gown-glove interface.

The aim of the study is to examine 7 modes of surgical helmet and sterile shield application methods commonly used in arthroplasty surgery and measure the level of contamination of this process.

## Material and methods

As with other similar studies, ultraviolet (UV) fluorescent powder (Glitterbug Powder; Brevis Corporation, Salt Lake City, UT) was used to represent airborne contaminants such as skin-flakes [8]. The surgical helmet used in this study was the T5 Personal Protection System (Stryker Instruments, Kalamazoo, MI). A full battery was used for each trial run to ensure no interruption to the functioning of the surgical helmet. A standard one-piece surgical gown (SecurePlus, PlusMedical, AU), 2 pairs of gloves (Protexis Hydrogel; Cardinal Health, Dublin, OH), and surgical hood (Steri-shield; Stryker Instruments, Kalamazoo, MI) completed the rest of the PPE.

Two orthopedic registrars simulated the role of a surgeon and surgical assistant. A third registrar acted as an observer for any errors and for photo-taking. The surgeon applied all standard PPE which included scrubs, safety goggles, surgical balaclava, and face mask. These were removed and changed between each trial. The helmet was placed and secured by the observer on the surgeon's head, and 1 teaspoon of Glitterbug (Glitterbug, ONSOLUTION, AU) was placed into the fan well at the top of the helmet. Before any gowning procedure, the UV torch was used to ensure there was no presence of pre-existing Glitterbug on the surgeon. Afterward, the scrub nurse would apply the surgical hood with the surgeon donning the surgical gown and 2 pairs of gloves.

Seven methods of filtered-exhaust helmet and surgical gown application were examined in this study:

1. Early activation of helmet (before applying surgical hood, surgical gown, and gloves);
2. Late activation of helmet (after applying surgical hood, surgical gown, and gloves) measurement taken at 5 minutes
3. Late activation of helmet and the use of adhesive wrist bands over inner gloves (after applying surgical hood, surgical gown, and gloves) with measurement taken at 5 minutes
4. Late activation of helmet (after applying surgical hood, surgical gown, and gloves) with measurement taken at 30 minutes;
5. Late activation of helmet and the use of adhesive wrist bands over inner gloves (after applying surgical hood and surgical gown) with measurement taken at 30 minutes;
6. Early activation of helmet (before applying surgical hood, surgical gown, and gloves) being applied by scrub nurse in sterile gown
7. Late activation of helmet (after applying surgical hood, surgical gown, and gloves) being applied by scrub nurse in sterile gown.

The surgical helmet was plugged to the power source before sterile gowning for all the early activation methods. The late activation methods involved the surgeon applying the surgical gown and both set of gloves before the assistant connected the helmet to the power supply. For method 4 and 5, the surgeon would be handling surgical tools to emulate performing arthroplasty surgery for 30 minutes before contamination measurement. To seal the wrist with adhesive tape, IOBAN adhesive film (3M, Maplewood, MN) was cut into 5-cm strips and wrapped circumferentially over the end of the inner gloves before the outer gloves were applied. For the last 2 methods, the scrub nurses would don their own surgical gown and gloves using an aseptic technique before

applying the surgical hood to the surgeon (Fig. 1). The contamination level measurement for method 6 and 7 were performed on the scrub nurse and not the surgeon.

Eleven separate body regions were examined for Glitterbug including the head, shoulders, forearms, outer gloves, inner gloves, chest, and abdomen (Fig. 2). This was performed with the gown left in situ on the surgeon or scrub nurse using a Glitterbug UV torch. Less than 10 particles in a single body region were classified as minor contamination, and over 10 particles as major contamination. Three trials were performed for each gowning method, resulting in a total of 21 trials.

Compressed air was used between trials to remove Glitterbug particles from the helmet which were visible to naked eye. The outer gloves were removed by the observer using sterile gloves, and this was done before measuring the contamination of the inner glove.

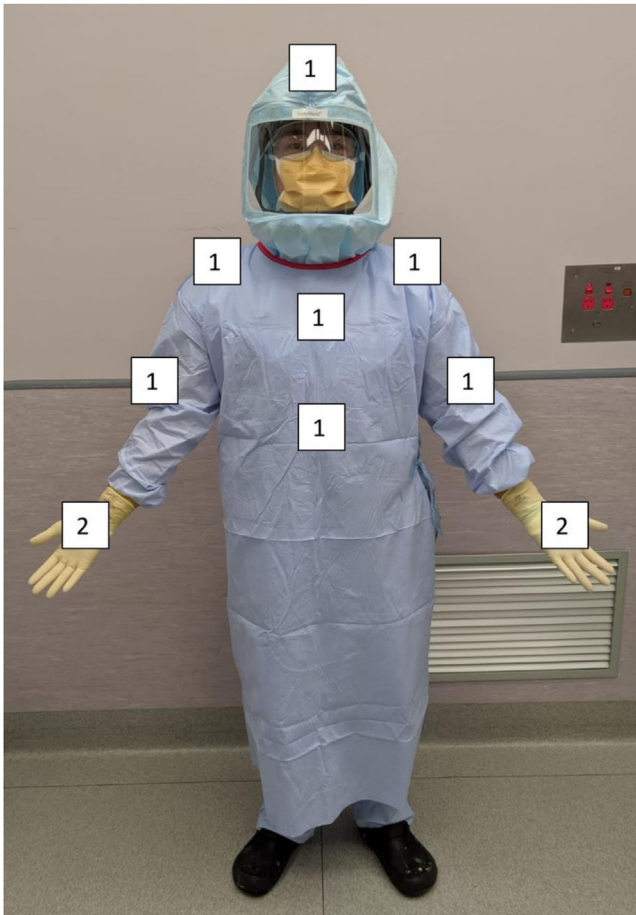
## Results

*Early activation of surgical helmet (before applying surgical hood, surgical gown, and gloves)*

Early activation of surgical helmet resulted in significant contamination across majority of body regions (Fig. 3). Of the 3 trials, major level of contaminations was noted in all 7 body regions



**Figure 1.** Application of the surgical hood by a scrub nurse.



**Figure 2.** Eleven body regions analyzed for contamination.

(Table 1). Minor levels of contamination were observed on the top gloves for 2 trial runs. No contamination was seen on the inner gloves.

*Late activation of surgical helmet (after applying surgical hood and surgical gown) with measurement taken at 5 minutes*

Late activation of the surgical helmet demonstrated minor levels of contamination over bilateral shoulders and forearms in trials 1 and 3 (Table 1). In all 3 trials, the head, chest, abdomen, and both top and bottom layer gloves were free of contamination. One trial run resulted in no contamination at all.

*Late activation of surgical helmet and the use of adhesive wrist bands over inner gloves (after applying surgical hood and surgical gown) with measurement taken at 5 minutes*

Late activation of filtered-exhaust helmet, with adhesive wrist seal, yielded similar results to late activation alone. Again, no contamination was noted for head, chest, abdomen, and gloves (Table 1). In all 3 trial runs, minor contamination was seen over bilateral shoulders and forearms.

*Late activation of surgical helmet (after applying surgical hood and surgical gown) with measurement taken at 30 minutes*

This method incorporating extended time before measurement demonstrated increased level of contamination in comparison to method 2. There is contamination to head region in 2 of the 3 trial runs. All levels of contamination are noted to be minor.



**Figure 3.** An example of major contamination on a surgical hood.

*Late activation of surgical helmet and the use of adhesive wrist bands over inner gloves (after applying surgical hood and surgical gown) with measurement taken at 30 minutes*

Similarly, the extended time before measurement demonstrated head contamination in 2 of the 3 trials. Again, all levels of contamination are deemed minor.

*Early activation of helmet (before applying surgical hood, surgical gown, and gloves) being applied by scrub nurse in sterile gown*

This method resulted in major levels of contamination to the scrub nurse in 7 of 11 zones in all trials (Fig. 1). Minor contamination of the outer gloves was noted on each run. Inner gloves remained uncontaminated throughout.

*Late activation of helmet (after applying surgical hood, surgical gown, and gloves) being applied by scrub nurse in sterile gown*

The late activation method demonstrated minor contamination to both shoulders and forearms of the scrub nurse in all trials.

## Discussion

PJI is a devastating complication of arthroplasty surgery and is a major cause of revision surgery [9]. Early infections are presumed to be secondary to iatrogenic contamination, and one study has demonstrated that 98% of bacteria within the wound are due to airborne contamination [10]. Modern surgical helmets may act as a potential source of airborne contamination.



**Table 1**  
Summary of contamination level from all gowning methods.

Methods	E1	E2	E3	5L1	5L2	5L3	5W1	5W2	5W3	30L1	30L2	30L3	30W1	30W2	30W3	ESN1 <sup>a</sup>	ESN2 <sup>a</sup>	ESN3 <sup>a</sup>	LSN1 <sup>a</sup>	LSN2 <sup>a</sup>	LSN3 <sup>a</sup>
Head	MJ	MJ	MJ	–	–	–	–	–	–	–	mn	mn	mn	mn	–	MJ	MJ	MJ	–	–	–
Chest	MJ	MJ	MJ	–	–	–	–	–	–	–	–	–	–	–	–	MJ	MJ	MJ	–	–	–
Abdomen	MJ	MJ	MJ	–	–	–	–	–	–	–	–	–	–	–	–	MJ	MJ	MJ	–	–	–
Shoulder (R)	MJ	MJ	MJ	mn	–	mn	mn	mn	mn	mn	mn	mn	–	mn	mn	MJ	MJ	MJ	mn	mn	mn
Shoulder (L)	MJ	MJ	MJ	mn	–	mn	mn	mn	mn	mn	mn	mn	–	mn	mn	MJ	MJ	MJ	mn	mn	mn
Forearm (R)	MJ	MJ	MJ	mn	–	mn	mn	mn	mn	mn	mn	mn	–	mn	mn	MJ	MJ	MJ	mn	mn	mn
Forearm (L)	MJ	MJ	MJ	mn	–	mn	mn	mn	mn	mn	mn	mn	–	mn	mn	MJ	MJ	MJ	mn	mn	mn
Outer glove (R)	Mn	–	mn	–	–	–	–	–	–	–	–	–	–	–	–	mn	mn	mn	–	–	–
Outer glove (L)	Mn	–	mn	–	–	–	–	–	–	–	–	–	–	–	–	mn	mn	mn	–	–	–
Inner glove (R)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Inner glove (L)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total	9	7	9	4	0	4	4	4	4	4	5	5	1	5	4	9	9	9	4	4	4

5L, late activation measured at 5 minutes after gowning; 5W, late activation with adhesive wrist seal on inner gloves measured at 5 minutes after gowning; 30L, late activation measured at 30 minutes after gowning; 30W, late activation with adhesive wrist seal on inner gloves measured at 30 minutes after gowning; E, early activation; ESN, early activation with scrub nurse applying surgical hood; LSN, late activation with scrub nurse applying surgical hood; MJ, major contamination (particles > 10); mn, minor contamination (particles equal or less than 10).

<sup>a</sup> For ESN and LSN, the contamination measurements were carried out on the scrub nurse, not the surgeon.

Our study confirmed that the timing of airflow activation for the surgical helmet system had a significant influence on the level of contamination on the surgical gown and surgical hood. In particular, early activation of surgical helmet has been associated with major contamination for both the surgeon and the scrub nurse. This is consistent with a study performed by Hanselman et al [7]. Although another study did not demonstrate bacterial contamination of the surgical hood immediately after it was applied, there was no mention in this article about the timing of fan activation [8].

Interestingly, our experiments found that over time, there was an egress of fluorescent particles with a predilection for this to occur on the surgical hood. We assume that this occurs because of the positive pressure forcing air to escape at the hood-gown interface. This may be another cause of contamination of the surgical field and supports previous work suggesting that the surgical hood does not remain sterile for the duration of surgery [8]. This contamination may be reduced through the use of a single-piece hood and gown such as a zippered toga system [3]. Despite previous well-designed studies demonstrating egress of fluorescent particles at the gown-glove interface [11], we did not find that adhesive wraps at the gown-glove interface altered this outcome. This may be because the gowns we used were soft and less rigid, preventing egress through this mechanism.

The findings of our study also support the hypothesis that when the surgical helmet is activated early, the scrub nurse may be contaminated by placing the surgical hood on the surgeon. This does not appear to have been examined previously in the literature and may play a significant role in the contamination of surgical staff and equipment during surgery.

### Recommendations

We recommend that the fan on the surgical helmet should be activated after the surgeon dons their inner gloves. Second, the surgical hood should be applied by an unscrubbed staff member to reduce contamination of staff in sterile gowns.

We cannot make any recommendations for or against adhesive wraps at the gown-glove interface. Even though it did not prevent the egress of fluorescent particles in our study, it may have other benefits including preventing the inner gloves from slipping down to an unsterile area of the gown's sleeve.

### Limitations

The major limitation of our study and other studies similar to this one is that contamination of surgical gowns and helmets with

Glitterbug powder does not represent bacterial contamination. Used as a surrogate marker of bacterial contamination, it seems logical that decreased contamination must be beneficial for the patient; however, no link can be drawn between Glitterbug contamination and PJI.

Other limitations include that only one brand of surgical hood system, gown, and gloves was used. At least one previous study has demonstrated varying amounts of contamination depending on the type of gown used [11]. As such, the findings from this study are limited to these brands.

Although previous studies have demonstrated that reducing airborne contamination from staff wearing whole body suits decreases PJI rates [4], a large randomized control trial using modern surgical helmets is needed.

### Conflict of Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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