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Full Length Research Article

COMPARATIVE EFFICACY ASSESSMENT OF DIFFERENT SURGICAL CAPS IN THE OPERATING ROOM

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ABSTRACT

Background: Infectious agents have a strong correlation with peri-operative and post-operative complications[1]. Previous studies suggest that operating room staff sheds a large number of bacteria normally associated with skin particles into the air[2]. In the current study we attempted to analyze the efficacy of 4 different surgical caps that are most commonly used in the operating rooms today. The primary objective of this study was to determine the type of surgical cap that would most effectively contain bacteria contamination and prevent dispersion. Secondary object was to assess overall effectiveness of the surgical caps in containing and preventing dispersion of bacteria.
Methods: A mannequin head with wig was used to imitate the head of a healthcare professional. Talc was dispersed evenly on the wig to mimic bioburden of the head and neck region. The head was subsequently covered with four different surgical caps and repositioned to facilitate talc spread. Photos of the dispersed talc under the black light and fluorescent light were taken after each observation. The amount of the talc dispersion was analyzed using histogram in Adobe Photoshop 7.0™.
Results: All digital photos were subsequently modified with Adobe Photoshop 7.0™ to narrow the frequency range to the upper band beyond the bulk of the image data in order to enhance perception of the talc dispersion. By adjusting visual frequency range to the darker limit of the spectrum we were able to improve visibility of the white color in the images. After narrowing the spectrum range we used histogram function to mathematically analyze the amount of the talc dispersion on the black paper.
Conclusions: It has been concluded from this modeling study that bouffant reusable type of the surgical cap is the most effective in terms of the prevention of potential microbial contamination of the surgical field from the skin area of the head by the caregiver's debris. Skull design of the surgical caps showed very similar results in terms of effectiveness in both reusable and disposable designs. From our experiment we concluded that bouffant reusable design of the surgical cap reduced the efficacy of the bacterial and epidermal bioburden spread. Further studies in the operating room using microbiological techniques are much needed.

INTRODUCTION

Bacterial contamination of the surgical wound in the operating room can lead to increase in the number of postsurgical complications such as infection, inflammation, delay in healing, and wound dehiscence (Whyte *et al*., 1982). These complications can potentially lead to a prolonged hospital stay, which not only increases financial costs for the patient but also furthers the increasing risk of nosocomial infections. Infectious agents have a strong correlation with peri-operative and post-operative complications, morbidity and mortality. It has been accepted for some time that operating room staff shed a large number of bacteria normally associated with skin particles into the air (Whyte *et al*., 1976). Studies have shown that different areas of the human body have various degree of microbial contamination (Table 1). Literature suggests that areas of the head and neck regions are some of the most concerning in terms of transmission of bacteria (Howard and Simmons, 1995). This fact is further exacerbated by the relative accessibility of these regions comparatively to others. (Howard and Simmons, 1995) Even more concerning is the well-established fact that the most common pathogens that colonize human skin and mucous membranes i.e. Gram positive cocci (Staphylococcus sp., Streptococcus sp., Moraxella sp.), Gram negative rods (including anaerobes) are also the ones that are most commonly

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Table 1. Predominant Human Microbial Flora[3,4]

Type of bacteria	Body site				Bacterial size µm
	Skin	Conjunctiva	Nasopharynx	Oral cavity	
Aerobic and facultative					
Staphylococcus species (sp.)	+	+	+	+	$\frac{1}{2}$ - $1\frac{1}{2}$
Streptococcus sp.	+	+	+	+	< 2
Moraxella catarrhalis				+	$\frac{1}{2}$ - $1\frac{1}{2}$
Anaerobic Veilonella sp.				+	$\frac{3}{10}$ - $2\frac{1}{2}$
Peptostreptococcus	+	+	+	+	$\frac{3}{10}$ - 2
Actinomyces sp.				+	$\frac{3}{10}$ - 2
Bifidobacterium				+	$\frac{3}{10}$ - 2
Eubacterium sp.				+	$\frac{3}{10}$ - 2
Propionibacterium	+	+	+		$\frac{3}{10}$ - 2
Fusobacterium sp.				+	$\frac{3}{10}$ - $2\frac{1}{2}$
Bacteroides sp.				+	$\frac{3}{10}$ - $2\frac{1}{2}$
Prevotella sp.				+	$\frac{3}{10}$ - $2\frac{1}{2}$
Porphyromonas sp.				+	$\frac{3}{10}$ - $2\frac{1}{2}$

Table 2. Summary data after analysis of the photographs in the Adobe Photoshop 7.0™

Digital photography type	Mean value	SD	Median	Pixels
1. Control photograph representing blank black paper under the black and electric light sources	0.01	0.38	0	8992000
2. Control photograph representing talc dispersion without any type of the surgical cap under the black and fluorescent light.	0.36	7.78	0	8992000
3. Photograph representing talc dispersion after the use of the bouffant disposable cap.	0.10	3.37	0	8992000
4. Photograph representing talc dispersion after the use of the bouffant reusable cap.	0.01	0.88	0	8992000
5. Photograph representing talc dispersion after the use of the skull disposable cap.	0.01	0.97	0	8992000
6. Photograph representing talc dispersion after the use of the skull reusable cap.	0.02	1.60	0	8992000

Figure 1. Image A: Bouffant disposable (Convertors® Blue Comfort™ Bouffant Cap, Large24 Inch, Latex Free)
Figure 1. Image B.Bouffant reusable (Blue Sky Scrubs™, Cotton and polyester)
Figure 1. Image C.Skull type disposable (Convertors® Blue Easy- Tie™ Cap, Latex Free)
Figure 1. Image D.Skull type reusable (With drug logo, cotton and polyester)

und
11).

Attempts to reduce the risk from bacteria dispersed from personnel in the operating rooms have been of two kinds; diluting the organisms given off by improving the design of operating room ventilation (Howard and Hanssen, 2007; Hambraeus *et al*., 1977), or improving the design of operating-room clothing (Whyte *et al*., 1976; Whyte *et al*., 1983 and Bergman *et al*., 1985). Control of bacteria dispersed into the environment by the use of ventilation has been well documented and implemented (Howard and Simmons, 1995; Hambraeus *et al*., 1977). Most modern operating rooms utilize laminar flow ventilation systems that are well maintained.

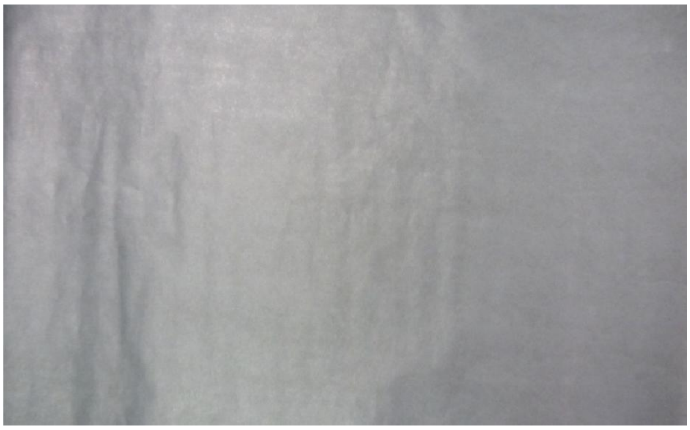


Photo 1. Photograph representing blank black paper under the black and electric light sources (baseline arm). Gross analysis

Luminosity Histogram
Mean: 0.01
SD: 0.38
Median: 0
Pixels: 8992000

Photo 2. Photograph representing blank black paper under the black and electric light sources after the narrowing spectrum range (baseline arm)

However, normal operating-room clothing does little to prevent the dispersal of bacteria particles by the operating team. Studies have shown significantly reduced bacterial dispersion by use of surgical gowns made of certain materials and fits. (Whyte *et al*., 1976; Whyte *et al*., 1983 and Bergman *et al*., 1985) However, there seems to be an absence of similar studies on the efficacy of surgical caps and we continue to see 4 to 5 different variations of materials and fits in the operating rooms. Since peri-operative infections remain a major concern for modern operating rooms, there is need to further investigate and minimize sources of bacterial exposure. In the current study we attempt to analyze the efficacy of 4 different surgical caps that are most commonly used in the operating rooms today. The primary objective of this study was to determine the type of surgical cap that would most effectively contain bacteria contamination and prevent dispersion. Secondary object was to assess overall effectiveness of the surgical caps in containing and preventing dispersion of bacteria.

MATERIALS AND METHODS

This modeling study aimed to represent bacterial contamination in the operating room. 4 different types of the surgical caps were assessed (Photos 1-4). The mannequin head with a wig consisting of artificial hair (polyester strands) was used to represent primary surgical caregiver. Microbiological literature[4] suggests that particle sizes of the most of the bacterial contaminants found on the area of the head (typically protected by the surgical cap) falls between 0.3 – 2.5 micron range (Table 1). However, it has been proven that infectious agents are usually transmitted in colonies (Hardin, 1994) (with the sizes >5 microns) rather than individually. In order to simulate bacterial agents talc powder with the particle size of 10 microns has been used (Natural Pigments, USA). The source of the ultraviolet light (Mood Lites™) was implemented to enhance the detection of the talc. Digital camera (Canon SX 230 HS™) was used to take sample pictures of the talc dispersion with subsequent analysis by Adobe Photoshop 7.0™.

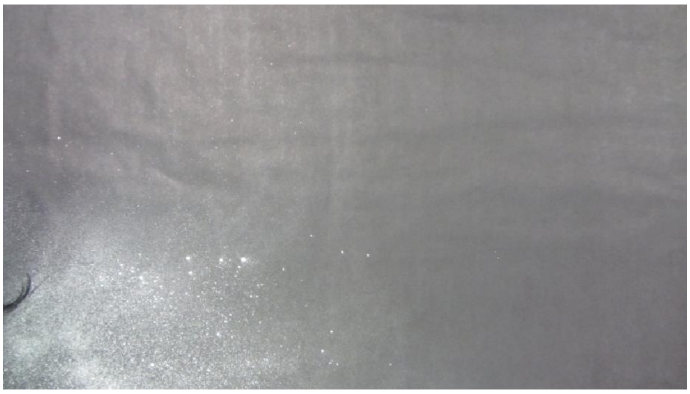


Photo 3. Photograph representing talc dispersion without any type of the surgical cap under the black and fluorescent light (Control arm). Gross analysis

Photo 4. Photograph representing talc dispersion without any type of the surgical cap under the black and fluorescent light after the narrowing spectrum range (Control arm)

Photo 5. Photograph representing talc dispersion after the use of the bouffant disposable cap. Gross analysis

Luminosity Histogram
Mean: 0.10
SD: 3.37
Median: 0
Pixels: 8992000

Photo 6. Photograph representing talc dispersion after the use of the bouffant disposable cap after the narrowing spectrum range

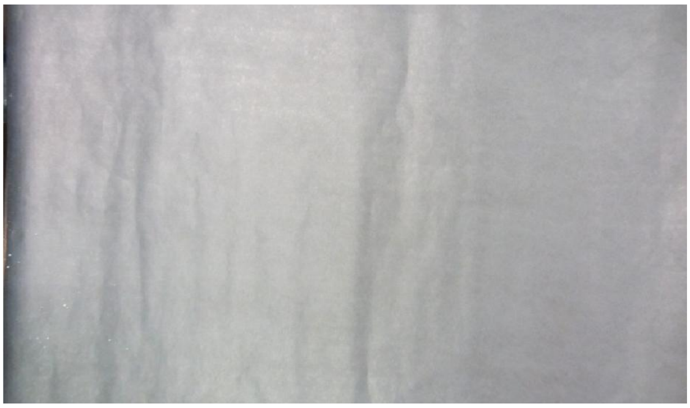


Photo 7. Photograph representing talc dispersion after the use of the bouffant reusable cap. Gross analysis

This study was conducted in the enclosed room without the windows. Two types of light sources were used: black light and fluorescent light.The mannequin head with the wig was permanently positioned at all times. The area under the mannequin head representing the position of the patient during the surgery was covered with the black sheet of paper in order to detect the presence of the talc powder. The digital camera was permanently positioned at all times above the black paper to ensure accurate coverage of the field. A fixed amount of the talc (5 ml) was evenly dispersed on top of the mannequin head with the wig. In order to eliminate the possibility of some of the talc powder remaining from the previous observations, a brand new wig was used for each run.

Luminosity Histogram
Mean: 0.01
SD: 0.88
Median: 0
Pixels: 8992000

Photo 8. Photograph representing talc dispersion after the use of the bouffant reusable cap after the narrowing spectrum range

The mannequin head with dispersed talc on it was subsequently covered by different types of the surgical caps (bouffant disposable, bouffant reusable, scull type disposable and skull type reusable). The mannequin head was then repositioned at a 45º angle and subsequently dropped freely to imitate movement of anesthesiologist and to facilitate talc spread. The source of ultraviolet light was used in order to enhance the detection of the talc particles on the black paper. Photos of the dispersed talc under the black light and electric light were taken after each observation.

Total of 6 digital photographs were taken during the study:

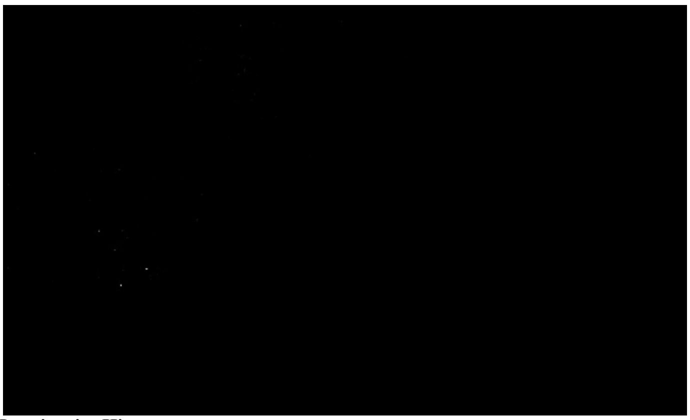
(1) Black paper – Baseline arm.
(2) Photograph representing talc dispersion without the use of a surgical cap – Control arm.
(3) Photograph representing talc dispersion after the use of the bouffant disposable cap.
(4) Photograph representing talc dispersion after the use of the bouffant reusable cap.
(5) Photograph representing talc dispersion after the use of the skull disposable cap.
(6) Photograph representing talc dispersion after the use of the skull reusable cap.

Adobe Photoshop 7.0™ was used in order to assess degree of the talc dispersion in at all observations. Two types of the analysis of the talc dispersion were used: gross visual analysis and digital one. In order for the research team to precisely quantify the amount of the talc dispersion digital photograph was analyzed as histogram in Adobe Photoshop 7.0™. A histogram illustrates characteristics of pixels in an image distribution by graphing the number of pixels at each color intensity level. The histogram shows detail in the shadows (shown in the left part of the histogram), midtones (shown in the middle), and highlights (shown in the right part). A histogram can help one to determine whether an image has enough detail to make a good correction.

The histogram also gives a quick picture of the tonal range of the image, or the image key type. A low-key image has detail concentrated in the shadows. A high-key image has detail concentrated in the highlights, and an average-key image has detail concentrated in the midtones. An image with full tonal range has some pixels in all areas. Identifying the tonal range helps determine appropriate tonal corrections. The Histogram panel offers many options for viewing tonal and color information about an image. The panel displays the following statistical information below the histogram:

- Mean represents the average intensity value.
- Standard deviation represents how widely intensity values vary.
- Median shows the middle value in the range of intensity values.
- Pixels represent the total number of pixels used to calculate the histogram.
- Level displays the intensity level of the area underneath the pointer.
- Count shows the total number of pixels corresponding to the intensity level underneath the pointer.
- Percentile displays the cumulative number of pixels at or below the level underneath the pointer. This value is expressed as a percentage of all the pixels in the image, from 0% at the far left to 100% at the far right.

Photo 9. Photograph representing talc dispersion after the use of the skull disposable cap. Gross analysis



Luminosity Histogram
Mean: 0.01
SD: 0.97
Median: 0
Pixels: 8992000

Photo 10. Photograph representing talc dispersion after the use of the skull disposable cap after the narrowing spectrum range

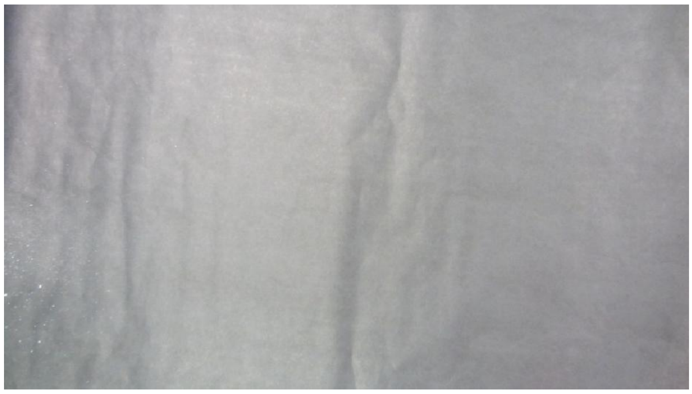


Photo 11. Photograph representing talc dispersion after the use of the skull reusable cap. Gross analysis

Mean: 0.02
SD: 1.60
Median: 0
Pixels: 8992000

Photo 12. Photograph representing talc dispersion after the use of the skull reusable cap after the narrowing spectrum range

RESULTS AND DISCUSSION

In order to assess the effectiveness of the different types of the surgical caps by the amount of the dispersed talc on the black paper both gross visual analysis and Adobe Photoshop 7.0™ were used. All digital photographs taken were subsequently adjusted using the *levels* option in Adobe Photoshop 7.0™. By narrowing the analyzed frequency range to the upper band beyond the bulk of the image data we excluded aberrant colors from the study. Excluded range was not pertinent to the talc particle detection; moreover by doing so we received enhancement of the white color on the image. After narrowing the spectrum range we used histogram function to mathematically analyze the amount of the talc dispersion (Photos 5-16).

Total of 6 digital photographs were taken during the study: (1) Black paper – Baseline arm, (2) No surgical cap – Control arm, (3) bouffant disposable cap, (4) Photograph representing talc dispersion after the use of the bouffant reusable cap, (5) Photograph representing talc dispersion after the use of the skull disposable cap, (6) Photograph representing talc dispersion after the use of the skull reusable cap. All 6 above mentioned digital photos were subsequently modified with Adobe Photoshop 7.0™ to narrow the frequency range to the upper band beyond the bulk of the image data in order to enhance perception of the talc dispersion. By adjusting visual frequency range to the darker limit of the spectrum we were able to eliminate unnecessary black color and improve visibility of the white color in the images. Expectantly we received enhancement of the perception of the white talc particles. After narrowing the spectrum range we used histogram function to mathematically analyze the amount of the talc dispersion on the black paper. The histogram option transformed all the digital pictures taken into distribution of the colors in the spectrum. Dim photographs were displaying the shift of the distribution towards the darker side of the spectrum with the lower mean whereas brighter photos tended to shift the distribution towards the lighter spectrum side with the greater nominal values of the mean. The actual values of the means were compared to the controls (the photograph representing blank black paper under the black and electric light sources was used as baseline and had lowest mean value; photograph representing talc dispersion without any type of the surgical cap under the black and fluorescent light was referred as to have the highest mean value among others). The idea behind it was that talc added white color to the digital photograph and shifted the histogram to the lighter side of the spectrum rising mean value. Means, standard deviations, medians and pixels from the histograms representing the digital photographs of the black paper covered with talc were further analyzed (Table 2). According to our histographic data, the order of best to worst with respect to prevention of particle dispersal was the bouffant reusable > skull disposable > skull reusable > bouffant disposable. This pattern is also appreciable using visual analysis.

Conclusions

The implementation of the disposable caps in the intensive care units, operating rooms and postoperative care units has been taking place in the last decade by most healthcare facilities, including the facility in which the authors practice. As such, single use caps have become the standard of care in most hospitals. Furthermore, healthcare professionals are prohibited from wearing reusable caps as the part of operating room policy at some institutions. This study gives insight into the validity of the policies regarding surgical cap usage. Bacterial contamination was imitated by the talc particles with the size comparable to the microbial aggregations and epidermal bioburden. Mathematical data obtained with the aid of the Adobe Photoshop 7.0™ was supplemented by the visual analysis of the digital photographs from the black paper after talc dispersion using different types of the surgical caps as a dispersion prevention tool. It has been concluded from this modeling study that bouffant reusable type of the surgical cap is the most effective in terms of the prevention of potential microbial contamination of the surgical field from the skin area of the head by the caregiver's debris (histogram derived mean, median and pixel values are similar to control photo representing blank black paper without any talc). Skull design of the surgical caps showed very similar results in terms of effectiveness from prevention bacterial dispersion in both reusable and disposable designs. This may be due to the fact that the wig used was better contained in the bouffant reusable cap versus the disposable with the aid of the combination of cotton and polyester fabrics. The investigators did not use short hair wigs in order to maximize the clinical risk of spillage in each group. Presumably, shorter hair would yield a lower result in field contamination under identical experimental conditions. From our experiment we conclude that bouffant reusable design of the surgical cap had maximal efficacy of prevention of simulated bacterial and epidermal bioburden spread from the head. Further studies in the operating room using microbiological techniques are much needed to implement specific headwear during surgeries that require additional care to prevent contamination of the surgical wound. The authors would like to thank Dr. Carin Hagberg and the Department of Anesthesiology for the use of their facilities for the conduct of this experiment.

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