



Theatre shoes – a link in the common pathway of postoperative wound infection?

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ABSTRACT

INTRODUCTION Operating department staff are usually required to wear dedicated theatre shoes whilst in the theatre area but there is little evidence to support the beneficial use of theatre shoes.

PATIENTS AND METHODS We performed a study to assess the level of bacterial contamination of theatre shoes at the beginning and end of a working day, and compared the results with outdoor footwear.

RESULTS We found the presence of pathogenic bacterial species responsible for postoperative wound infection on all shoe groups, with outdoor shoes being the most heavily contaminated. Samples taken from theatre shoes at the end of duty were less contaminated than those taken at the beginning of the day with the greatest reduction being in the number of coagulase-negative staphylococcal species grown. Studies have demonstrated that floor bacteria may contribute up to 15% of airborne bacterial colony forming units in operating rooms. The pathogenic bacteria we isolated have also been demonstrated as contaminants in water droplets spilt onto sterile gloves after surgical scrubbing.

CONCLUSIONS Theatre shoes and floors present a potential source for postoperative infection. A combination of dedicated theatre shoe use and a good floor washing protocol controls the level of shoe contamination by coagulase-negative staphylococci in particular. This finding is significant given the importance of staphylococcal species in postoperative wound infection.

KEYWORDS

Shoes – Contamination – Theatre – Operation – Outdoor – Wound infection

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Operating department staff are usually required to wear dedicated theatre shoes whilst in the theatre area. Many studies have assessed the effects of laminar flow,^{1–5} prophylactic antibiotics,⁶ surgical drapes and theatre staff attire^{7–15} but there is little evidence to support the use of theatre shoes.

Previous studies have noted that a proportion of the airborne bacteria within theatres are redispersed floor bacteria.¹⁴ Modern operating theatres with laminar flow and high air turnover rates minimise this risk. However, airborne wound contamination remains a concern in those receiving implants where the sequelae of infection are disastrous. The clean appearance of theatre shoes has been shown to be an unreliable indication of bacterial contamination.¹⁵

We conducted a study to assess bacterial contamination of 100 shoes used by theatre staff. Of the shoes tested, half were everyday shoes used by staff outside the theatre com-

plex, the remainder comprised designated theatre shoes tested at the beginning and end of a working day.

In our institution, with an infection incidence of 1% for primary lower limb arthroplasty,^{16,17} no specific shoe-cleaning protocol exists and staff are responsible for cleaning their shoes when they see fit. Theatre shoes are prohibited from being worn outside the theatre complex but outdoor shoes are worn by staff in the main theatre corridor and reception to gain access to the changing rooms. Once wearing theatre shoes, staff are obliged to walk through these areas again to get to the operating theatres.

We, therefore, had two main hypotheses: (i) there would be no significant difference between the bacterial contamination of outdoor and indoor shoes; and (ii) theatre shoes were likely to become more contaminated towards the end of a working day.

Patients and Methods

The setting for the study was the Avon Orthopaedic Centre where elective orthopaedic procedures, predominantly joint arthroplasty, are performed. No emergency or out-of-hours work is performed. Staff with a contract exceeding 1 year are provided with dedicated theatre shoes. Temporary staff provide their own shoes or use those designated for visitors.

Ward staff and theatre porters are not required to change from outdoor shoes when accompanying a patient into the anaesthetic room adjacent to the operating theatre. Overshoes are not used.

An initial pilot study with three sub-groups of 10 was performed to assess the data set required to achieve statistical significance. Four weeks later the remaining data (three sub-groups of 40) were collected using the same methodology. Theatre staff were not informed of the study to prevent bias from altered shoe cleaning practices.

Shoes were chosen at random from theatre changing rooms at the beginning of a working day. Outdoor shoes and theatre shoes were selected and a microbiological swab (APTACA Sterile Transport Swab) taken from the sole. Swabs were taken directly to the microbiology department for processing. That evening once theatres had closed, swabs were taken again from these theatre shoes having been used by staff during the day. These samples were taken directly to the microbiology department.

Microbiology staff were blinded as to the source of the swabs. Swabs were put onto a half dish of blood agar (Oxoid, Basingstoke, UK) and spread using a loop. After 18-h incubation at 37°C in air, colony counts were taken, macroscopic appearances noted and suspected staphylococcal colonies tested for the presence of coagulase. Antibiotic sensitivities were not assessed.

The chi-square test for contingency tables was employed to analyse the data.

Results

The outside shoes had the greatest bacterial contamination with the majority of specimens (88%) positive for at least two bacterial species (Table 1). Coagulase-negative staphylococci made up the majority of the isolates followed by *Bacillus* and coliform species. *Diphtheroid*, *Neisseria* and *Micrococci* species were also isolated (Table 2). One shoe swab demonstrated no growth.

Among the morning theatre shoe samples, 52% (16/50) demonstrated no bacterial growth. The majority, however, (48%) were positive for at least one bacterial species. Coagulase-negative staphylococci were the commonest isolate followed by coliform and *Bacillus* species. *Diphtheroid* species were isolated on one shoe.

Table 1 Number of bacterial species per shoe in each sample group

Number of species isolated	Outside shoes	Theatre shoes	
		Morning	End-of-day
No growth	1	16	22
1	5	24	25
2	24	9	3
3	15	1	0
> 3	5	0	0

The end-of-day theatre shoes swabs were the least contaminated of the three sample groups with 44% (22/50) of shoes returning no bacterial growth. Of those with positive cultures, 50% (25/50) grew one bacterial species with Gram-negative *Bacilli* species being the commonest isolate, followed by coagulase-negative staphylococci. *Diphtheroid* species were found on two shoes.

Contamination was found on 98% of outdoor shoes, 68% of morning theatre shoes, and 56% of end-of-day theatre shoes. The difference of the contamination level between the outdoor shoes and morning theatre shoes was statistically significant ($P = 0.000065$) as was the difference of outdoor and end-of-day theatre shoes ($P = 0.00001$). However, with the current number of samples, no meaningful difference was seen between morning and end-of-day theatre shoes ($P = 0.22$).

Discussion

Postoperative infection is of concern in all surgery but particularly operations such as joint arthroplasty where the

Table 2 Total number of each bacterial species isolated per sample group

Bacterial species isolated	Outside shoes	Theatre Shoes	
		Morning	End-of-day
Coagulase-negative			
<i>Staphylococcus</i>	35	22	11
Coliforms	24	18	14
<i>Bacillus</i> spp.	25	4	4
<i>Diphtheroid</i> spp.	1	1	2
<i>Neisseria</i> spp.	1	0	0
<i>Micrococcus</i> spp.	1	0	0

result of infection can be disastrous. The presence of foreign material, such as implants, results in a 6-fold reduction in the quantity of inoculates required to initiate infection, such that only a few bacterium may result in sepsis.¹⁸ Implant material also increases the risk of sepsis from bacteria of low pathogenicity which are not otherwise associated with wound infection.^{4,19}

The major cause of deep postoperative wound sepsis is contamination from airborne colony forming units (CFUs), as well as contaminated equipment or gloves placed in the wound²⁰ and direct inoculation from skin adjacent to the incision. The majority of airborne contamination originates from skin squames from patients⁸ and the surgical team¹⁰ with the concentration of CFUs in the operating theatre shown to be proportional to the activity and numbers of people present.

Since Charnley's work in the 1960s, evidence has amassed to support the use of laminar flow, occlusive drapes, disposable surgical gowns and prophylactic antibiotics. These measures have helped reduce infection rates to as low as 0.6% versus 1.5% in traditionally ventilated theatres.² However, there remains little evidence supporting the use of dedicated theatre shoes.

Floor bacteria have been shown to account for up to 15% of airborne CFUs with walking contributing to their redispersal from floor to air.¹⁴ Disinfection of hospital ward floors demonstrated only temporary benefit with rapid recolonisation²¹ highlighting the need to prevent recontamination from air, shoes and other objects. However, current thought is that the infection risk from floor bacteria is small and there is little benefit from rigorous enforcement of transfer areas and changing trolleys when taking patients to theatre.²²

The use of overshoes has been contentious with some studies demonstrating no difference in theatre-floor contamination with their use when compared to outdoor shoes²³ and other studies showing a benefit.²⁴ Nagai *et al.*²⁵ demonstrated increasing rates of bacterial contamination with proximity to areas where footwear is changed and concerns have been raised regarding the transfer of floor bacteria to hands with overshoe use.²²

Our results demonstrate that dedicated theatre shoes are less contaminated than outdoor shoes. The study also demonstrates that even without regular shoe cleaning, contamination levels appear to be controlled and, indeed, decrease during the course of the day. It is likely that bacterial colonies then multiply overnight, hence the difference found between the morning and afternoon samples although this difference failed to achieve statistical significance.

It is likely that this reduction may result from exposure to floor detergents during the course of the day. In our institution, the general corridors and areas outside the operating rooms are cleaned by domestic staff every evening. The operating theatres are cleaned at the conclusion of the day's list by the theatre staff. The area around the operating table, within the

laminar flow is cleaned after every case. In all cases, D1 Plus (Johnson Diversey) 30 ml in 5-l of warm water is used.

Of note is the decreased level of contamination by coagulase-negative staphylococcal species in particular, as these have been shown to represent the commonest pathogen in infections complicating lower limb arthroplasty at our^{16,17} and other²⁶ institutions. The presence of coagulase-negative staphylococci on theatre shoes and within postoperative wounds suggests a possible common pathway. Coagulase-negative staphylococci, *Micrococcus* spp. and coliforms have been isolated from water droplets spilt by surgeons after meticulous surgical scrubbing.²⁷ The same study further demonstrated that Gram-positive bacteria within these droplets can penetrate paper packaging to contaminate sterile gloves within.

We also isolated coliform, *Bacilli*, *Diphtheroid*, *Neisseria* and *Micrococci* species from theatre shoes. All of these have been demonstrated to result in lower limb arthroplasty infection.^{5,4,26}

There are a number of deficiencies in our study. We cannot comment on the level of shoe contamination at the time operative procedures were being performed. Our study also provides no information on the degree of wound contamination originating from theatre shoes, an area that remains to be investigated.

Conclusions

This study supports the use of dedicated theatre shoes by surgical staff involved in implant surgery, given the attendant risks of postoperative infection. Our study demonstrated the presence of pathogenic bacteria on theatre shoes.

Bacteria on theatre shoes contribute to a proportion of airborne CFUs within theatre and will contribute to hand contamination of theatre staff when being put on at the beginning of duty. Whilst this contribution is likely to be small, it is intuitive that heavy contamination should be avoided and our results suggest a potential common pathway from floor to wound via either airborne CFUs or contact from shoe to hand with subsequent droplet contamination of gloves after scrubbing.

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