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Original Article

Impact of Footwear Practices on Reducing Bacterial Contamination in Operating Theatres: A Quasi-Experimental Study

Muhammad Farooq, Muhammad Tanvir Ahmad Qureshi*, Chaudhry Amjad Ali, Kaswar Sajjad Ansari, Kaukab Majeed, Hamid Iqbal*****

Department of Anesthesia, Quetta Institute of Medical Sciences, Combined Military Hospital, Quetta/National University of Medical Sciences (NUMS) Pakistan, *Quetta Institute of Medical Sciences, Combined Military Hospital, Quetta/National University of Medical Sciences (NUMS) Pakistan, **Department of Medicine, Quetta Institute of Medical Sciences, Combined Military Hospital, Quetta/National University of Medical Sciences (NUMS) Pakistan, ***Department of Pathology, Quetta Institute of Medical Sciences, Combined Military Hospital, Quetta/National University of Medical Sciences (NUMS) Pakistan

ABSTRACT

Objective: To measure the frequency of bacterial growth on cultures from the operating theatre before and after the application of infection control practices related to footwear.

Study Design: Quasi-experimental study

Place and Duration of Study: Anesthesiology Department, Combined Military Hospital, Quetta, Pakistan, from Jan 22 to Jan 23.

Methodology: The sample size of 198 was computed with the help of the WHO sample size calculator. The data of 99 samples was collected retrospectively (before improving practices) for five months and prospectively (after improving practices) for seven months. Randomization was done in two groups (B&A). The frequency of positive cultures was calculated before and after improvement of footwear practices and was analyzed through a chi-square test.

Results: A Total of 198 samples were taken from six operating theatres throughout the year. 34(17.7%) cultures came positive with different pathogens, which were included in the statistics. The frequency of pathogens was higher, 27(13.36%), before the improvement of practices and was lower, 7(3.5%) afterwards, with a *p*-value of 0.001.

Conclusion: This study highlights the significance of footwear practices in minimizing bacterial contamination within operating theatres. The intervention demonstrated that simple, cost-effective measures can enhance infection control.

Keywords: Bacteria, Contamination, Culture, Footwear, and Operation Theatre.

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INTRODUCTION

Nosocomial infections contribute to complications in operative procedures and increase the burden on healthcare resources. They exacerbate morbidity and mortality among hospitalized patients.[1] Urinary tract infections are the leading cause of nosocomial infections, followed closely by surgical site infections.[2] Post-operative patients are particularly vulnerable to these infections because operating rooms are exposed to various infectious agents and can harbor resistant bacteria. The operating room environment is complex and contains multiple potential sources of microbes that can contaminate the surgical site. These sources include operating room air, surfaces, antimicrobial agents, footwear, patient clothing, gowns, hands, anesthesia equipment, trolleys, monitoring devices, and stretchers used for patient transport.[3] Beyond tangible items, practices within the operating theatre also influence surgical site infection rates. The techniques employed by surgeons are especially important.[4] Despite improvements in sterilization and disinfection practices, there are still "gaps in the translation of best evidence into actual practice".[5]

The maintenance of operating room sterilization falls under the jurisdiction of anesthesiologists at the combined military hospital in Quetta. The operating theater in our setting is considered a clean area, and staff cannot enter its premises without changing into theater attire. Every effort is made to prevent patient transport routes, entry points for patients, attendants, and staff from becoming thoroughfares. Patients change into gowns before entering the theaters. Decontamination of equipment, cleaning of surfaces, and fumigation of operating theaters are performed weekly. Samples are collected from surfaces of all six elective surgery theaters each month and sent to the pathology department for cultures.

Correspondence: Dr Muhammad Farooq, Department of Anesthesia, QIMS Combined Military Hospital, Quetta Pakistan
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The Combined Military Hospital Quetta is affiliated with Quetta Institute of Medical Sciences. Medical students from all five years regularly visit the operating theater for their clinical rotations and lectures. More than a hundred house officers also visit the operating theater for learning and practical experience. It was observed that standing operating procedures for footwear were not properly followed by recently graduated junior doctors and house officers. The observation was communicated to them, and practices were improved starting from June 2022. There is conflicting evidence regarding the use of protective footwear in the operating room. According to a study by Gupta *et al*., there was no significant difference in outcomes when over-shoes were worn in operating theaters, and bacterial counts were similar whether or not over-shoes were used.[6] However, the study by Amirfeyz *et al*., recommends that dedicated shoes for the operating theater should be used to prevent bacterial contamination.[7]

The rationale of our study is to investigate the sterilization of the operating theatre before and after implementing a simple measure to improve practices related to footwear. We will examine the prevalence of different microbes identified through positive cultures before and after the modification of our procedures. Our study will assist in monitoring the sterilization process of the operating theatre and guide us in taking steps to prevent nosocomial infections.

METHODOLOGY

The Quasi-experimental study was conducted in Operation Theatre of Combined Military Hospital, Quetta, Pakistan, from Jan 22 to Jan 23. Ethical approval was obtained (ERC#CMH QTA-IERB/11/2023). Data was collected both retrospectively (before improving practices) and prospectively (after improving practices). The WHO sample size calculator was used to determine the sample size, with a significance level of 5%, a power of 80%, an anticipated contamination rate of 6.6% before changing footwear practices, and 2.69% after[9]. The calculated sample size was 180.

Inclusion Criteria: Samples for cultures taken from the floors of six elective specialty theaters that are Gynecology & Obstetrics, Orthopedic /Neurosurgery, Thoracic & Laparoscopic Surgery, Urology & ENT Theater, Pediatric Surgery & Dental Surgery, General Surgery & Vascular Surgery.

Exclusion Criteria: Samples for cultures taken from sites other than floor such as, operating theatre instruments, operating table and anesthesia machines.

A total of 198 samples in our study were collected over a duration of one year. 99 cultures were taken before the improvement of footwear practices (Group-B) and 99 cultures were taken after the improvement of practices (Group-A). The distribution of operating theatres is presented in Table-I. The samples were taken from floor of all elective surgery operation theatres after cleaning thoroughly with washing powder and water. The operating theatre was fumigated with Nocolyse (Surface Cleaner, OXY.Pharma) and closed over a time period of twelve hours. The sampling was done early in the morning before start of elective cases. Doctors were instructed to use dedicated shoes, and 30 pairs of new shoes were purchased by the hospital and were kept in operating theater for use by the duty doctors.

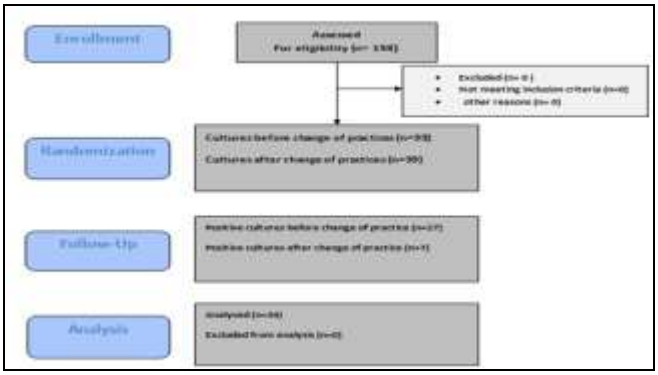

Figure: Consort Flow Diagram

A representative from the pathology department came, and he collected a sample after wearing a sterile gown, gloves, shoe covers, and a mask. Sampling was done from the floor. The samples from all operating theaters were sent to the laboratory for cultures every month. The medium for culture was blood agar and MacConkey agar. The swabs were inoculated in agar and incubated over a period of twenty-four hours at thirty-seven degrees Celsius. An aerobic environment was provided for bacteria to cultivate and form colonies. The count of colonies was kept, and isolates were recognized. The culture report was generated by pathology department of the hospital and collected by a representative of anesthesia department. The positive blood culture was marked, and the nature of pathogen was also noted.

The data was analyzed using frequency of positive culture, which was computed before and after the improvement of footwear practices. The chi-square analysis was utilized to calculate the *p*-value, and a *p*-value<0.05 was considered to be statistically significant.

Table-I: Distribution of Operation Theatres

Operation Theaters (OT)	Specialty
OT-1	Gynecology & Obstetrics
OT-2	Orthopedic /Neurosurgery
OT-3	Thoracic & Laparoscopic Surgery
OT-4	Urology & ENT Theater
OT-5	Pediatric Surgery & Dental Surgery
OT-6	General Surgery & Vascular Surgery

RESULTS

A total of 198 samples were taken from six operating theatres throughout the year. 34(17.7%) cultures came positive. The frequency of positive cultures was higher, 27(13.36%), before improvement of practices and was lower, 7(3.5%) afterwards, with a *p*-value <0.05.

Among the positive cultures with n=34, the most frequent causative organisms were Enterococci and Klebsiella pneumoniae. Enterococci were found in 9(33.3%) positive cultures before application of footwear practices, and Klebsiella pneumoniae was found to be present in 9 (33.%3) positive cultures before improvement in practices. MRCoNS was found positive in 2(7.4%) cultures, and Streptococcus was positive in 7(25.1%) cultures before improvement of footwear practices. The statistics after adherence strictly to the standing operating procedures of operating theatre footwear were significantly reduced, with frequency of Enterococcus being 3(42.85%), Klebsiella Pneumoniae being 2(28.57%), and MRCoNS being 1(14.28%). The Streptococcus Pneumoniae was found positive in 1(14.28%) culture reports as presented in Table-I and *p*-value of <0.05.

The positive cultures of different operation theatres are presented in Table-II. The gynecology and obstetrics theatre (OT-1) had positive culture 3(11.11%) times in months of January 1(3.7%) times in month of April and 1(3.7%) times in month of May. The orthopedic /neurosurgery operation theatre (OT-2) was found to have positive culture in two consecutive months of February and March. There were 6 positive culture reports of Thoracic/ Laparoscopic Surgery theatre (OT-3). There were 9 positive cultures of Urology/ENT Theater(OT-4) in five months, one positive culture of pediatric& dental OT (OT-5) and 4 positive cultures of general surgery/ vascular surgery operation theatre (OT-6) before improvement of practices. After the strict compliance of operation theatre footwear, the frequency of positive cultures reduced to seven. There was no positive culture of Gynecology And Obstetrics theater (OT-1), Orthopedic and Neurosurgery operation theatre (OT-2), Pediatric& Dental OT (OT-5) and General surgery/Vascular surgery operation(, OT-6). There was one positive culture of Thoracic & Laparoscopic surgery theatre (OT-3), one positive culture for Urology/ENT Theater (OT-4) as displayed in Table-III.

Table-II: Frequency & Type of Different Pathogens found in Blood Cultures Before (Group-B) & after (Group-A) Improvement Of Footwear Practices (n=34)

Type of Pathogens	Group-B Frequency (%) n=27	Group-A Frequency (%) n=7	*p*-value
Enterococcus	9(33.3)	3(42.9)	0.003
Klebsiella Pneumoniae	9(33.3)	2(28.6)	
MRCoNS	2(7.4)	1(14.3)	
Streptococcus Pneumoniea	7(25.1)	1(14.3)	

Table-III: The Frequency of Positive Cultures Before Improvement of Footwear Practices in Different Months & Operating Theatres (Group-B) (n=27)

	Frequency (%)				
	January	February	March	April	May
OT-1	3(42.9)	0(0)	1(3.7)	0(0)	1(3.7)
OT-2	1(14.3)	1(3.7)	1(3.7)	0(0)	0(0)
OT-3	2(28.6)	0(0)	0(0)	2(7.4)	2(7.4)
OT-4	2(7.4)	3(11.11)	0(0)	2(7.4)	2(7.4)
OT-5	0(0)	0(0)	1(3.7)	0(0)	0(0)
OT-6	2(7.4)	1(3.7)	0(0)	1(3.7)	0(0)
Total	10(33.33)	5(18.51)	3(11.11)	5(18.51)	5(18.51)

Table-IV: The Frequency of Positive Cultures after Improvement of Footwear Practices in Different Months and Operation Theatres (Group-A) (n=7)

	Frequency (%)						
	June	July	August	September	October	November	December
OT-1	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
OT-2	0(0)	0(0)	0(0)	0(0)	1(20)	0(0)	0(0)
OT-3	0(0)	0(0)	1(20)	0(0)	1(2(0)	0(0)	0(0)
OT-4	1(20)	0(0)	1(20)	0(0)	0(0)	0(0)	0(0)
OT-5	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
OT-6	0(0)	2(28.57)	0(0)	0(0)	0(0)	0(0)	0(0)
Total	1(14.2)	2(28.57)	2(28.57)	0(0)	2(28.57)	0(0)	0(0)

DISCUSSION

The study revealed a statistically significant reduction in bacterial contamination of operating theatre floors following the implementation of improved footwear practices. Sustained compliance with footwear guidelines was found to be essential in maintaining sterilization standards. These results underscore that wider adoption of such practices can play a pivotal role in enhancing patient safety and optimizing surgical outcomes. Improvement of a single practice showed a lot of improvement with an 18% percent reduction in frequency of positive cultures. The contamination of the operating theatre is the greatest risk factor for superficial surgical site infection.

Frederick *et al*., highlighted the importance of contaminated footwear in breaching the sterility of operating theatre.[8] They compared the bacterial contamination between the restricted shoes used in the confines of the theatre and the street shoes. They studied the bacterial growth from samples taken before the arrival of staff in the operating room in the morning to mid-morning. The results of this study also emphasized that the use of clean footwear reduced bacterial contamination of the operating room floor. Another study by Ansari *et al*., studied risk factors influencing the sterility of surgical theaters. They understated the role of over-shoes in reducing the bacterial counts of the operating theater.9 However, this study observed that the new doctors deviated from standard operating procedures and showed significant resistance to following the guidelines when they were asked to change their shoes. The administration was advised to maintain a stock of designated footwear within the operating theatre for physicians who did not provide their own. Despite this provision, medical students and house officers continued to demonstrate poor adherence to the established standard operating procedures.

Zheng *et al*., also highlighted their observations that over-shoes didn't contribute to reducing bacterial contamination in the operating theatre. They studied a day care operating theatre that was traversed by patients and their attendants. They also allowed a small number of parents to enter with the pediatric patients. The rest of the staff in their study used dedicated footwear and did not cross the barrier at the entrance of the operating theatre in street shoes. So, it is quite possible that because of the small number of people allowed to wear street shoes, the results did not show much difference, leading them to consider overshoes unnecessary.[10]

Ali *et al*., studied the sterilization of Intensive Care Units (ICUs) that experience higher infection rates due to the severity of illness and frequent use of invasive devices. Use of personal protective equipment reduces the risk of acquiring an infection. This study has been conducted to determine the role of using shoe covers by medical staff and visitors on infection rates, mortality, and length of stay in ICU. But the authors also determined that the use of shoe covers in critical care area does not help prevent infections of common ICU pathogens and length of stay in ICU patients; nor has it decreased the mortality.[11]

Rashid et at.[12] presented the results of their systematic review on evidence regarding the contribution of footwear in the dynamics of nosocomial infections. They studied evidence of pathogens on shoe soles and their link to bacterial contamination. They presented that thirteen studies supported the fact that shoes were contaminated with pathogens. There was a 15% increase in contamination of shoes after the ward rounds. Almost eighty-eight percent of street shoes were found to be contaminated with at least two microbes. Surgical shoes were also found harboring dangerous bacterial species. The list of organisms included Staphylococcus (MRCoNS). Listeria monocytogenes, Enterococcus, Clostridium difficile, E. coli, Campylobacter jejuni, and Salmonella. All of these were observational studies, but our study design was quasi-experimental. Based on their study, a study by Nwankwo *et al*., also suggested that decontamination of shoe soles for the prevention of cross-contamination. However, effective decontamination of street shoes is not feasible; therefore, dedicated footwear for exclusive use within the operating theatre was provided, and all operating theatre personnel were required to wear them. The use of shoe covers was not permitted, as the donning process was anticipated to increase the risk of hand contamination, potentially leading to the spread of pathogens to other surfaces.

Blood from surgical procedures and patient secretions may also serve as potential sources of bacterial contamination. To address this possible source of bias, two precautionary measures were implemented as studied by Burnett *et al*. Firstly, visibly soiled footwear was decontaminated by manual brushing and rinsing with tap water, followed

by drying with a paper towel and disinfection using a sanitizer containing 70% alcohol, after which the footwear was dried again. Second, in cases where footwear was not visibly soiled, such as for anesthetists and anesthesia assistants, decontamination and disinfection were performed every third day.[14]

The study of Tateiwa *et al.,* studied the influence of surgical scrubs and footwear on the contamination of the operating theatre. They used a particle counter and studied the air quality using a detector utilizing a photodiode.[15] They counted particles as small as size of an epithelial cell. With the use of this sophisticated gadgetry, they concluded that unsterilized clothing and shoes cause surgical site infection by airborne contamination. Based on their research, they recommended using a sterilized scrub and one footwear system. Unlike their study, the focus of this study was on footwear practice. The use of sterilized scrubs is not possible in resource-limited setups. Also, Bonnet *et al*., explained that the method of sterilization also affects the contamination level. Keeping in view, the author of the study used the conventional method of sampling and culture used in our setup for the detection of bacterial contamination, which is reasonably reliable and cost-effective as compared to the particle detector.[16] Moreover, these biosensors have limitations of misrecognition and non-target analytes.[17]

The operating room table represents the most critical site of contamination within the operating theatre, posing a heightened risk for surgical site infections, and has been reported as the surface harboring the highest concentration of pathogens.[18] A potential mechanism for the transfer of bacteria from footwear to the operating room table is the donning of shoe covers. Strict adherence to hand hygiene practices is equally essential to limit further dissemination of contamination. Reported compliance with hand hygiene exceeds 80% among operating theatre and intensive care unit personnel.[19]

Regular surveillance of operating theatres for bacterial contamination is essential. Implementation of a dedicated footwear system within the operating theatre is recommended to minimize environmental contamination and reduce the risk of surgical site infections.

LIMITATIONS OF STUDY

In this study, the authors restricted their focus to assessing bacterial contamination of the operating theatre floor attributable to footwear. Nevertheless, it must be acknowledged that several other sources, such as airborne particles, surgical instruments, surgical staff movement, and inadequate cleaning protocols, can also contribute to floor contamination. A comprehensive evaluation of these additional factors would provide a more holistic understanding of contamination dynamics within the operative environment.

CONCLUSION

The improvement of footwear practices resulted in a substantial decrease in bacterial contamination of operating theatre floors. Strengthening compliance with footwear guidelines can further sustain these improvements. Broader implementation of such practices is recommended to improve patient safety and surgical outcomes.

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Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

MF & MTAQ: Study design, drafting the manuscript, data interpretation, critical review, approval of the final version to be published.

CAA & KSA: Data acquisition, data analysis, approval of the final version to be published.

KM & HI: Critical review, concept, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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