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Editorial

Learning from Semmelweis: engaging in sensible infection control

Healthcare-acquired infection is considered an adverse event and anaesthetic practitioners share a professional responsibility to ensure that high standards of infection control are maintained. However, there are

significant challenges to this undertaking, because as humans we most effectively act upon what we are able to perceive by sight, touch or smell, and in the absence of such stimuli, we rely on external cues to prompt a response. As a result, the battle against healthcare-acquired infection is destined to remain challenging and at times, controversial.

The daily working pattern of most anaesthetists takes them from operating theatre to ward and office and back again. In this issue of *Anaesthesia*, these working patterns are explored with respect to infection control [1]. Hee and colleagues report the results of their study, which found that visits to the ward and office did not significantly increase bacterial contamination of scrub suits [1]. Their study was designed to identify the impact of wearing operating theatre scrub suits outside the theatre environment by measuring the microbial colonisation of garments. In so doing, the authors attempt to answer pertinent infection control questions, the answers to which may challenge further our attitudes to infection control.

While the role of medical dress in the transmission of infection remains poorly established, there are no shortages of studies that contradict the work of Hee and colleagues. Thus Burden et al. [2] demonstrated pathogenic colonisation of hospital uniforms by up to 50% within a single hospital shift. Bearman and colleagues [3] took such findings one step further and by means of a novel intervention using antimicrobial-impregnated scrub suits, successfully reduced the contamination of such garments with methicillin-resistant *Staphylococcus aureus* (MRSA), when compared with standard scrub suits. Although the impact of scrub suits as vectors for transmission of pathogens is not well defined in clinical studies, consideration of the wider infection control and prevention debate provides us the opportunity to consider how infection control practice and clinical anaesthesia might better co-exist. In 1847, the Hungarian physician Ignaz Semmelweis reduced the incidence of puerperal fever and maternal mortality in childbirth by demonstrating the importance of handwashing during delivery [4]. Failure to accept the hypothesis that puerpural sepsis was a disease spread between patients on the hands of physicians can, in part, be laid at the feet of Semmelweis himself. While his data suggested that the pathogen was passed from physician to mother, his argument was fragmented and poorly presented, failing ultimately to influence colleagues and change practice.

Semmelweis challenged the popular perception of disease, but failed to deliver a coherent message. Compounding what would become an ineffectual infection prevention and control message was in part its delivery but more importantly, it was delivered to an audience not then ready to accept it. Ironically, in 1865 Semmelweis was admitted to an asylum, where he was to die of septicaemia in the same year. More than 150 years after Semmelweis, doctors are still challenged by new evidence, much of it methodologically sound, some of it less so, and some poor in design and assertion. Anaesthetists assimilate, synthesise and utilise these studies to varying degrees, some practising blind to this evidence, others selecting evidence wisely, while others, like the physicians of old, fail to accept any new evidence at all.

If an anaesthetist fails to take adequate infection control measures when placing a central venous catheter, what must we assume? Ignorance of the evidence, disbelief of that evidence, or the belief that his/her personal experience was more important? In 1847, the hubris of Semmelweis's peer group, mortified at the suggestion that a gentleman-physician should need to wash his hands, would result in no improvement in the puerperal sepsis mortality rates for many years.

However, for those engaged in clinical practice, making evidence-based decisions remains challenging. Does the work of Hee and colleagues give us the green light to wander freely within the hospital, safe in the knowledge that we carry no harmful pathogens? Should hospital Trusts invest in antimicrobial-secreting theatre scrub suits in an attempt to reduce the impact of harmful bacteria, as suggested by Bearman et al.'s results? Or should free access of movements between theatre and hospital wards be restricted, based on limited evidence of harm?

Healthcare-acquired infection rates appear to be falling and this trend may be related to the adoption of more user-friendly systems that represent a carefully fashioned interface between those who produce and those who are required to

follow guidelines [5, 6]. Such examples include the successful control of MRSA in many European countries over the last ten years, through a variety of measures including root cause analysis, improved hand hygiene monitoring and feedback, screening, publicly available performance tables, patient isolation and government fines. However, as some infection rates decline, other infection rates increase [7]. In some countries, control of multi-resistant gram-negative infection has been lost, probably as the result of poor compliance with infection control measures and a lack of antimicrobial stewardship [8]. In some centres, the lack of effective antimicrobials in critical care is having a serious impact on patient outcomes. There is a risk that such pathogens as *Klebsiella pneumoniae* and New Delhi metallo-β-lactamase (NDM) carbapenemase producers will spread in numbers and increase in virulence if the environment is favourable [9, 10]. While the effect of a theatre dress code on rates of wound infection is difficult to prove, poor adherence is symptomatic of a broader disregard for the possibility of involvement in the spread of pathogens between patients and the environment. A tightly run theatre suite with an enforced dress and access protocol is more likely to engender scrupulous infection control and low rates of infection.

In response, healthcare organisations have invested heavily in developing clinical guidelines based on both the available evidence and expert opinion to bring clarity, mitigate against poor clinical decision-making, and ensure a consistent and co-ordinated institutional response. Guidelines become policies and varying grades of evidence become conflated and blurred with 'expert opinion', and ultimately can impact in a negative way on our daily clinical practice. If poorly developed, such guidelines attract criticism and ultimately cynicism from those charged with ensuring high-quality care. The perception is that such guidance evolves in a 'vacuum' and is often insensitive to the interactions between those engaged in healthcare and their complex working environments [11]. Poorly constructed guidelines on infection control and prevention, therefore, might – like other guidelines – be seen as stand-alone edicts, unrelated to daily activities and unwieldy to many anaesthetists: we might have time to deliver a high-quality anaesthetic or alternatively concentrate on adherence to an infection control policy, but not both! It has been suggested that the credibility of clinical guidance has been lost and what remains is an unwieldy attempt to corral activity based on limited evidence.

Operating theatre dress code is usually subject to local policy guidelines and may vary widely between institutions in the absence of good supporting evidence or national/international consensus, despite efforts of professional bodies to offer guidance [12]. Developing credible guidance requires an understanding of the barriers that exist in the workplace, and the proper engagement with staff to bring about responsive guidance that offers both the opportunity and the motivation to change practice [13].

Recapturing credibility and the inevitable ground lost may lie in the science of ergonomics and a behavioural approach. Bridging the gap between people and policies may offer a more readily accepted solution. The World Health Organization (WHO) surgical checklist [14] and a critical care central venous catheter 'care bundle' [15] are examples of well-crafted interventions, in the form of simple checklists, that have influenced and shaped workplace activity. Such simple checklists, which have a strong supporting evidence-base, when incorporated into everyday practices have demonstrated improved patient outcomes. When applied intelligently, such methods reduce variance in clinical practice and promote a move towards system-based care, avoiding an over-reliance on the action of individuals. In 2006, Pronovost and colleagues reported on the impact of a simple checklist intervention of infection control measures that ultimately reduced catheter-related bloodstream infections in patients within intensive care units by up to 66% across the US state of Michigan. In that study, researchers demonstrated the need for change, supported staff to achieve it and actively engaged in clinical leadership, to make this checklist intervention the norm of practice. Key to its success was the active engagement by the researchers in delivering a 'living, breathing' change, woven into the fabric of daily intensive care activities. This large-scale quality improvement project had

important consequences for public health, and the methodology was readily adopted by other nations, including the UK [16].

When there is failure to embrace a checklist philosophy, however, the process may be as doomed as the unread clinical guideline from which it was borne. In a recent observational study assessing the impact of the introduction of the WHO surgical checklist in 101 hospitals across Ontario, Canada, failure to demonstrate mortality or other benefit cautions against 'top-down' policy implementation [17]. In an accompanying editorial [18], Leape argues that participating hospitals saw no outcome benefit in the intervention, as they had failed to participate in the process of change. Clinical practice, it was argued, is not a technical issue associated with a checklist, but rather a problem of human behaviour and interaction.

Today, in the fight against healthcare-acquired infection, all healthcare workers acknowledge that we must put the patient's well-being first. The challenge for the future will be to do the right thing well, time and time again. Importantly, we must avoid cynicism, which might be seen as a personal defence against engaging with the new infection challenges that lie ahead. Today, the so-called 'Semmelweis effect' is a metaphor for the reflex-like tendency to reject new evidence or new knowledge because it contradicts established norms or beliefs. If healthcare policy makers are to learn from the 'Semmelweis experience', they must work hard to promote clinical evidence in better ways and prioritise systems of staff engagement through novel and meaningful workplace interventions.

Competing interests

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Original Article

Bacterial contamination of surgical scrub suits worn outside the operating theatre: a randomised crossover study*

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Summary

In this study, we aimed to evaluate the bacterial contamination of surgical scrub suits worn outside the operating theatre. We randomised 16 anaesthetists on separate occasions into one of 3 groups: restricted to the operating theatre only; theatre and surgical wards; and theatre and departmental office. For each group, sample fabric pieces attached to the chest, waist and hip areas of each suit were removed at 150 min intervals between 08:30 and 16:00 on the day of study, and sent for microbiological assessment. Mean bacterial counts increased significantly over the course of the working day ($p = 0.036$), and were lower in the chest compared to the hip ($p = 0.007$) and waist areas ($p = 0.016$). The mean (SD) bacterial counts, expressed as colony-forming units per cm^2 at 16:00 on the day of study, were 25.2 (43.5) for those restricted to theatre and 18.5 (25.9) and 17.9 (31.0) for those allowed out to visit the ward and office, respectively ($p = 0.370$). We conclude that visits to ward and office did not significantly increase bacterial contamination of scrub suits.

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Introduction

Human skin is colonised with bacteria that are continuously shed from our skin and dispersed into the air [1–5]. Dispersal of these microorganisms into the operating theatre environment poses a source of microbial contamination [2, 3, 6, 7] and surgical wound infection [7, 8]. Surgical scrub suits worn by staff in the operating theatre help environmental control by containing shed skin squames and microbes [2, 3, 9].

Although some institutions allow the use of scrub suits outside the operating theatre [4, 10], many restrict the use of surgical scrubs to within the theatre and recommend changing into street clothes [2] or the use of gowns to cover the scrub suits if staff work outside the theatre [4, 10]. This recommendation may not

be met by anaesthetists with work duties demanding frequent movement in and out of the theatre.

At the moment, there is still a lack of scientific evidence to show that wearing of surgical scrub suits in theatre after wearing them outside the operating suite results in wound infection [1, 10, 11]. Studies of this nature are few, small in size or not well designed [12, 13]. The protective role of cover gowns against bacterial contamination of surgical attire is still inconclusive. Mailhot et al. [13] supported cover gown use, whereas others reported that it had little or no effect on scrub suit contamination [2, 9, 14] or infection rates [10].

Frequent movement of anaesthetists in and out of the operating theatre is necessary as they perform administrative, teaching and clinical duties as a part of a day's work. Clinical duties encompass pre-operative and postoperative review, airway management and attending to emergency calls. They may visit many areas of the hospital, including general wards, the Emergency Department, the Intensive Care Unit, the departmental office and more remote areas too. There is a concern that cross-contamination will occur from these areas into the operating theatre via the surgical scrubs [2]. In the practice of paediatric anaesthesia particularly, direct physical contact between anaesthetists and young children occurs frequently during the induction of anaesthesia and recovery. Hence, cross-contamination from surgical attire to patients by direct transfer is a potential problem.

In recent years, increased awareness of the impact of anaesthetists on the intra-operative environment and on healthcare associated infections [15–17] has led to greater recognition of the role that anaesthetists can play in the prevention of disease transmission in the operating theatre [17]. With increasing requirements for anaesthetists to leave the operating theatre for other work duties, it is timely to re-evaluate the practice of wearing surgical scrubs outside the theatre.

Other than surgical scrubs, other potential sources of cross-contamination by anaesthetists are the wearing of stethoscopes and identity lanyards round one's neck. These objects may come into direct contact with patients, our hands and the external environment and could act as carriers for pathogens, thus representing a potential source of contamination in the operating theatre.

In this study, we hypothesised that there would be no difference in the level of bacterial contamination of surgical scrub suits whether they are worn solely in the operating theatre, or both in and out of the theatre. The primary aim of this study was to compare the level of bacterial contamination of surgical attire when worn in the operating theatre and when outside the theatre, on the wards and in the office. Our secondary aim was to evaluate the impact of time, sites of sampling and the wearing of the stethoscopes and lanyards on bacterial contamination of scrub suits.

Methods

This was a prospective crossover study performed over 6 days in 2012 at the children's operating theatre in KK Women's and Children's Hospital, Singapore. Approval from Singhealth Institutional review board was obtained, with no requirement for patient or provider consent. Study participation was voluntary for all anaesthetists in the study.

Our institution's policy mandates the use of cover gowns over surgical scrub suits when they are worn outside the operating theatre. For the purpose of this study, the requirement was waived for participants. All other policies and procedures relating to infection control in the operating theatre, and other aspects of attire discipline within theatre were strictly adhered to.

A full suit used in our institution consists of a V necklined, short-sleeved shirt and a pair of trousers. The shirt has two pockets on the front – on either side – and is worn over the trousers.

Participants' scrub suit sizes were identified so that designated scrub suits could be prepared for them during the study period. All participants were right handed.

Sampling fabric squares (each measuring 1.5 cm by 1.5 cm) were cut from a surgical scrub of the same material. A Velcro piece was attached to all sampling fabric pieces and corresponding Velcro pieces were sewn onto surgical scrubs at all sampling sites.

Each scrub suit was prepared with three sampling sites:

1 Chest area at the vertex of the V neckline of the shirt.
2 Waist area of the shirt on the upper part of the right sided waist pocket.

3 Hip area at the lateral aspect of the thigh on the left side of the trousers, corresponding to the hip pocket.

Six squares were attached onto each site to allow for any unexpected losses.

The suits, together with the attached fabrics, were autoclaved in our hospital facility and individually wrapped in sterile packs. Each pack was then labelled for each participant.

Sixteen anaesthetists from the department of paediatric anaesthesia volunteered for the study. They were enrolled as their duties included routine clinical and administrative duties outside the operating theatre. All participants were briefed about the procedures but not about the objective of the research. They were assured that all data obtained would be de-identified and that the results would be presented as cohort data. A sample size of 16 was selected as that was the maximum possible number of participants without causing disruption to the theatre operations.

In order to minimise disruption to both training of anaesthetists and the running of theatres, and to capture a variety of surgical procedures, the study was conducted over 6 days. A crossover study design was used and each participant acted as his/her own control in the study. Participants were randomly assigned on separate occasions into one of 3 groups as described below, having not been previously assigned to that group.

In the operating theatre group, participants were restricted to clinical work within the operating theatre. In the operating theatre + ward group, participants were allocated to clinical work in the operating theatre and scheduled visits to the surgical wards for pre-operative and postoperative reviews. Medical wards, high dependency wards and the intensive care unit, where microbial flora are thought to be potentially more abundant, were excluded from the wards allowed. In the operating theatre + office group, participants were allocated to clinical work in theatre, with scheduled visits to the office for administrative duties involving desk work on computers. In the operating theatre + ward and operating theatre + office groups, three scheduled visits of 20–30-min duration outside the theatre were carried out by participants between 09:00 and 11:00, 11:30 and 13:30, and 14:00 and 16:00.

Clean surgical scrubs in sterile packs were collected by participants from the operating theatre reception area every morning at 08:00 before they proceeded to change in the operating theatre changing area in the usual manner.

The periods when lanyards and stethoscopes were worn by participants were noted and recorded by designated observers. In both the operating theatre + ward and operating theatre + office groups, the duration and venue of their scheduled visits was logged by one of the authors. Participants were tracked by one of the authors during the study period, to ensure that they stayed within their allocated groups. Shoe covers but not cover gowns were used by participants during their scheduled visits outside the theatre.

The fabric squares were removed at regular intervals of 150 min starting at 08:30, within a time window of 15 min, before the scheduled time points of 08:30, 11:00, 13:30 and 16:00, using sterile techniques. The sampling of specimens took place in a designated holding area.

One square was removed from each of the three sites at each sampling time. For sampling from the waist and hip region, the squares were sequentially removed in a fixed right to left direction (in the participants' orientation). For the chest, the sampling was done in a clockwise manner. Samples were then placed into sterile specimen containers and transported to the microbiology laboratory. All specimen containers were coded such that the microbiology team was blinded to the group allocations.

Each sampled fabric square was vortex-mixed with 3 ml of phosphate buffered saline with 0.5% Tween 80. Three hundred microlitres of the solution were spread onto blood agar plates. These were incubated in a 5% CO_2 atmosphere at 35 °C for 48 h. After 48 h, the number of bacterial colonies was counted and recorded as colony-forming units (CFU).

The outcome measure, bacterial colony count, was the number of bacterial CFU.cm^{-2} in each of the 1.5 × 1.5 cm fabric squares from all 3 groups and 3 sites (chest, waist, hip) and at different times. The data were analysed using SPSS statistical software, version 18.0 (Chicago, IL, USA).

Paired observations of bacterial colony count between two groups, sampling time points or sampling

sites were compared using the Wilcoxon signed rank sum test. To allow for the repeated measurements for each participant, a linear mixed model was used to model bacterial colony count with the tested groups, sampling sites and sampling times as independent variables and bacterial colony count as dependent variable. A value of $p \leq 0.05$ was considered statistically significant.

Results

All 16 participants completed the study, with 36 fabric specimens from each participant, yielding a total of 576 fabric specimens, all of which were included in the analysis.

Five (31%) of the participants were men and 11 (69%) women. They visited four different surgical wards. For the duration of the study, anaesthetists allocated to the operating theatre + ward group and the operating theatre + office group spent 14–21% of their working hours in the office or on the ward, which is comparable to the actual nature of the work at our hospital. A total of 93 surgical procedures were performed in the theatre, including all surgical disciplines. There were no cases that required reverse barrier protective isolation or 'dirty' cases that required the use of dedicated personal protection equipment in the operating list to which the participants were scheduled. On no occasion did a scrub suit become visibly soiled.

The bacterial colony count of the 576 specimens ranged from 0 to 199.1 CFU.cm^{-2} (mean 16.4, SD 32.1, median 4.0). Mean (SD) bacterial colony count at 08:30 h was 7.1 (12.9) CFU.cm^{-2} in the operating theatre group, 11.8 (31.2) CFU.cm^{-2} in the operating theatre + ward group and 13.4 (35.1) CFU.cm^{-2} in the operating theatre + office group. At 16:00 h, the mean (SD) bacterial colony count was higher than 08:30 h: 25.2 (43.5); 18.5 (25.9); and 17.9 (31.0) CFU.cm^{-2} in the operating theatre, operating theatre + ward and operating theatre + office groups, respectively. The difference in bacterial colony count between the groups at 16:00 h was not statistically significant ($p = 0.370$). Further results based on univariate tests showed that the difference in the mean bacterial colony count was not statistically significant between the 3 groups at any of the 3 sites (chest, waist, hip) at the 4 sampling time points (results not shown). After adjustment for sampling time points and sites in the mixed model, the difference in mean bacterial colony count (of all 4 time points and 3 sites) between groups was not statistically significant, with a maximum (95% CI) difference of −1.8 (−9.1 to 5.4) CFU.cm^{-2} between the operating theatre + ward group and the operating theatre + office group ($p = 0.616$) (Table 1).

The scatter plots of the bacterial colony count with fitted curves (Fig. 1) suggested that overall the bacterial colony count increased over time in all groups, though fluctuation was observed between time points. This is consistent with Fig. 2, where the mean bacterial count increased over time in both operating theatre and operating theatre + ward groups but not in the operating theatre + office group. The increase in mean bacterial colony count over time was more evident in the hip and waist specimens, especially in the operating theatre group, compared to the chest sample in all three groups (Fig. 3). Consequently, the mean bacterial colony count was much higher in hip and waist specimens than in chest samples at time points other than at 08:30.

A higher mean bacterial colony count was observed in the operating theatre group compared to operating theatre + ward and operating theatre + office groups at several time points, especially at the chest and waist sampling areas, although the difference did not reach statistical significance.

Table 1 Pairwise comparisons of bacterial CFU.cm^{-2} between study groups. Values are mean (95% CI).

Group A	Group B	Colony count (A)	Colony count (B)	Difference in colony count Group A–B	p value
Operating theatre	Operating theatre + ward	16.8 (9.8, 23.8)	15.3 (8.3, 22.3)	1.6 (−5.7, 8.8)	0.669
Operating theatre	Operating theatre + office	16.8 (9.8, 23.8)	17.1 (10.1, 24.1)	−0.3 (−7.5, 7.0)	0.942
Operating theatre + ward	Operating theatre + office	15.3 (8.3, 22.3)	17.1 (10.1, 24.1)	−1.8 (−9.1, 5.4)	0.616

CFU, colony-forming unit.

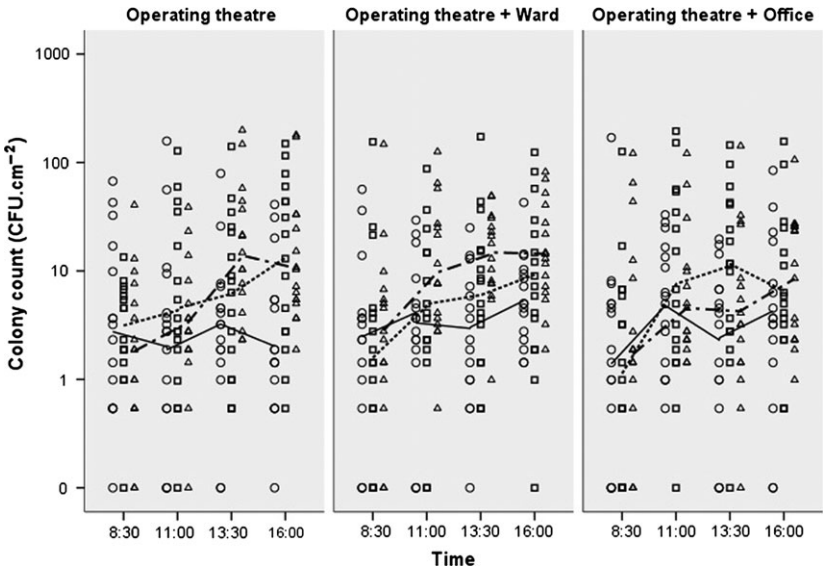

Figure 1 Scatter plot of bacterial colony count with fitted line from different fabric sites in different groups. Operating theatre only (○), operating theatre + ward (□), operating theatre + office (△). Fitted line for chest (—), hip (···), waist (----).

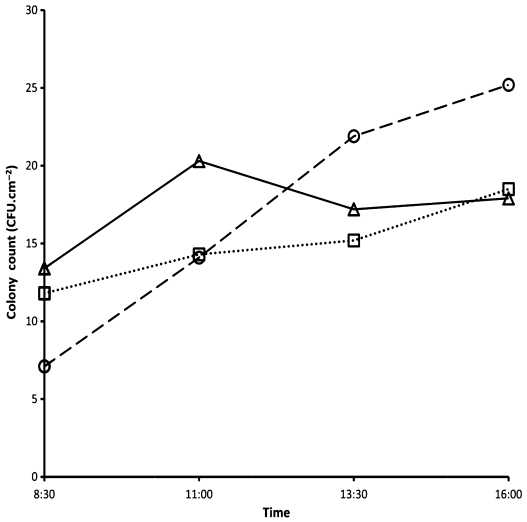

Figure 2 Plot of mean colony-forming units over time between the groups. Operating theatre only (○), operating theatre + ward (□), operating theatre + office (△).

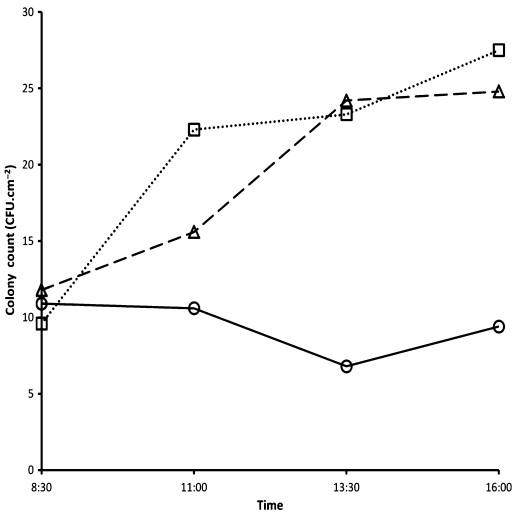

Figure 3 Plot of mean colony-forming unit over time between the sites. Chest (○), hip (□), waist (△).

The above observations were confirmed by the results of the linear mixed model analysis. The mean bacterial colony count was higher at 11:00, 13:30 and 16:00 h at 08:30 ($p = 0.080$, 0.033, and 0.005, respectively). The pair-wise comparisons between time points suggested that the increase in bacterial count was faster in the first few hours and then slowed down (Table 2). The mean (95% CI) difference in bacterial colony count on fabrics from the chest area was smaller by 10 (−17.3 to −2.8) CFU.cm^{-2} than at the hip area ($p = 0.007$) and 9 (−16.2 to −1.7) CFU.cm^{-2} at the waist area ($p = 0.016$) (Table 3). However, there was no significant difference between hip and waist areas ($p = 0.776$, 95% CI −6.2 to 8.3).

Table 2 Pairwise comparisons of bacterial CFU.cm^{-2} between time points. Values are mean (95% CI).

Time A	Time B	Colony count at time A	Colony count at time B	Increase in colony count from time A–B	p value
08:30	11:00	10.8 (4.1,17.4)	16.2 (9.1, 23.3)	5.4 (−0.7, 11.5)	0.080
08:30	13:30	10.8 (4.1, 17.4)	18.1 (11.1,25.1)	7.3 (0.6, 14.0)	0.033
08:30	16:00	10.8 (4.1,17.4)	20.5 (13.6, 27.5)	9.8 (3.0, 16.6)	0.005
11:00	13:30	16.2 (9.1, 23.3)	18.1 (11.1, 25.1)	1.9 (−4.5, 8.3)	0.561
11:00	16:00	16.2 (9.1, 23.3)	20.5 (13.6, 27.5)	4.3 (−2.7, 11.4)	0.226
13:30	16:00	18.1 (11.1,25.1)	20.5 (13.6, 27.5)	2.5 (−3.8, 8.7)	0.440

CFU, colony-forming unit.

Table 3 Pairwise comparisons of CFU.cm^{-2} between fabric sampling sites. Values are mean (95% CI).

Fabric site A	Fabric site B	Colony count at Fabric site A	Colony count at Fabric site B	Difference in colony count	p value
Chest	Hip	10.1 (3.1, 17.1)	20.1 (13.1, 27.1)	−10.0 (−17.3, −2.8)	0.007
Chest	Waist	10.1 (3.1, 17.1)	19.0 (12, 26)	−9.0 (−16.2, −1.7)	0.016
Hip	Waist	20.1 (13.2, 27.1)	19.0 (12, 26)	1.0 (−6.2, 8.3)	0.776

CFU; colony-forming unit.

Of the 192 chest samples, 95 chest samples were taken from surgical scrub suits where no lanyard or stethoscope were worn and 97 chest samples were taken from surgical scrub suits where lanyard or stethoscope were worn. In the subgroup analysis of the association between bacterial colony count and the wearing of stethoscope and lanyard, a linear mixed model was used with bacterial colony count as the dependent variable and groups, time of fabric sampling and wearing of stethoscopes as the independent variables. Results from the model indicated that none of the factors, including workplace ($p = 0.561$), time ($p = 0.657$) and wearing of stethoscope ($p = 0.123$), had a statistically significant association with bacterial colony count in the chest samples, although numerically the mean (SD) bacterial colony count was larger when stethoscope or lanyards were worn, at 10.9 (23.1) CFU.cm^{-2} than for not wearing them, at 7.9 (18.2) CFU.cm^{-2}.

Discussion

In this study, we found no significant difference between three groups of anaesthetists, working within or outside the operating theatre, in bacterial colony counts in samples taken from scrub suits. Bacterial colony counts in hip and waist samples were statistically higher than in chest samples. The mean bacterial count increased significantly over time and was lower in the chest compared to hip and waist areas. The colony counts in the chest samples were also higher for those who wore stethoscopes and lanyards compared to those who did not, but the difference observed was not statistically significant. We did not perform a sample size calculation before the study. It is not known what level of bacterial contamination is considered clinically significant. However, a post hoc power analysis showed that with a sample size of 16 participants, the study was powered at 85% to detect an effect size of 0.80 and at 75% to detect an effect size of 0.70 between the groups.

This study is the first to investigate groups of anaesthetists working both inside and outside the operating theatre without the use of cover gowns outside. The results of our study have clinical implications for those anaesthetists who need to attend often to duties outside the operating theatre during the course of a day's work. This is especially relevant with the expanding role of anaesthetists in administration and teaching, and patient review and assessment outside the theatre. Mandated scrub suit changes with each passage in and out of the theatre can impede workflow unnecessarily, and relevant policy should be re-examined as to whether it will lead to a better patient outcome or not. Previously, both the microbial flora of the patient [3, 8] and the

operating room personnel [3, 8, 18] were implicated in surgical wound infection or contamination acquired in the operating theatre. Existing evidence from recent studies does not conclusively support the clothing of healthcare workers as a vehicle for transmission of infection [19]. However, we have found a recent case report identifying the scrub suit worn by a nurse anaesthetist as the source of wound infection in three patients [20], suggesting that scrub suit contamination may be a potential risk factor for contamination for the operating theatre environment.

Nevertheless, the fact that there we found significant differences neither in bacterial contamination between the three groups, nor in the increase in bacterial contamination of scrub suits with time across all groups in all sampling sites, suggests that cross-contamination from external environments is not a major factor in surgical scrub contamination. Rather, it is the continuous shedding and dispersal of skin microorganism of the wearer throughout the day that plays a major role in the increasing contamination of one's clothing or scrub suit with time; this phenomenon has also been observed by others [12, 21, 22].

The trend towards numerically (but statistically insignificant) greater contamination in the operating theatre group compared to the operating theatre + ward group at the chest and waist region is unclear and deserves further study. We postulate that the greater contamination on the chest in the operating theatre only group may be due to greater patient contact during clinical work in the group such as during patient transfers (as the practice of carrying children brings paediatric anaesthetists into close and direct contact with them before, during and after anaesthesia).

We were especially interested in bacterial contamination in the hip region as several reports [7, 23, 24] had documented greater bacterial air dispersal from the lower body compared to the upper body. Besides being the area where most movement occurs – and hence more friction and greater microflora shedding – it is also the area that most often into direct contact with external surfaces such as seats in operating rooms, pantry and restrooms.

The impact of wearing 'chest accessories' such as stethoscopes and lanyards on the scrub suit contamination in the chest region was not statistically significant as expected, but the lack of statistical significance does not equal to lack of clinical relevance. Further study is warranted to assess the potential impact of wearing stethoscopes and lanyards on bacterial contamination.

Sivanandan et al. also studied bacterial contamination in scrub suits in 20 doctors (orthopaedic surgeons and anaesthetists) working both inside and outside the operating suite (ward and clinic) [12]. Their results were largely in agreement with ours in that the level of contamination of scrub suits was similar when worn inside or outside the operating theatre, and contamination in both groups increased with time. However, they also observed a statistically significantly greater contamination 2 h after baseline in the group who worked outside the theatre. The demographic characteristics of his study subjects were different from our study, including as they did both surgeons and anaesthetists. Surgeons spent most time in operating theatre scrubbed up, whereas anaesthetists were usually unscrubbed unless they were performing aseptic procedures. There was also great variety in work areas and tasks performed outside the operating theatre. The characteristics of patients in clinic areas and ward areas also differ. Sivanandan et al. did not comment about the nature of work involved and the time spent in each of the workplaces by their participants outside the operating theatre. We do not know the type of wards (surgical, high dependency or intensive care) that their subjects worked in, nor the subjects' gender. In their study, a Petri dish was used for bacterial sampling, and the sampling site was the back of the scrub suit top. With repeated sampling from the same site, we feel that counts were also less likely to reflect an actual accumulative raw count with time. We believe that we avoided many of the methodological pitfalls in our study. Despite the differences in methodology, both studies demonstrated that time is the more relevant factor in contamination of scrub suits.

Woodhead et al. suggested that surgical scrub suits only needed to be 'socially clean' [10]. We do not know the level of contamination of surgical scrub that is considered typical, clinically significant or 'socially clean'. It is known that the normal skin flora is colonised with bacteria, the count of microorganisms

ranging from 100 to 106 CFU.cm^{-2} depending on the site [25, 26]. Hence in our study, we compared differences rather than measuring the absolute level of bacterial contamination.

It has been recommended that surgical attire should be changed daily, or at the end of a shift, or when it becomes wet or contaminated [2, 9]. Our work suggests that it may be prudent to have at least one change of surgical scrub suits during the day, even if the scrub suits are not visibly soiled, and even if one has not left the operating theatre. Our results support a mid-day change, especially of the trousers. This seems especially important in clinical practice where direct contact with patients is frequent, to prevent potential direct transfer of microbes. Of interest is the relatively high basal level of bacterial contamination at the start of the day, despite autoclaving of the scrub suits before use. Cross-contamination by contact with hands, surfaces in the changing room or from the wearer's bioflora arising from shedding of one's scalp squames and microbes during wearing of the scrub suit shirt may possibly explain this observation. Loftus et al. [16] reported that in their study, contaminated hands of anaesthesia providers were a significant source of patient environment and intravenous giving set contamination in the operating theatre. In fact, total bacterial counts on the hands of medical personnel have been found to range from 3.9×10^4 to 4.6×10^6 [25]. We did not examine the microbial flora from patients and participating anaesthetists to evaluate the route or source of contamination, as that was not the aim of our study. Hand hygiene measures before donning surgical scrubs may be useful in reducing contamination. In this respect, these findings are important because they provide basis for change in practice and provide background for further study.

Gender, sampling sites and personal hygiene are known to affect bacterial contamination. Men are known to disperse significantly more normal skin microorganisms, and notably more *Staphylococcus aureus,* than women [10, 19]. There is also a gender difference in bacterial counts between various sites on the body [19]. Participants in our study were mostly women. We chose a cross-over design so that the above confounding covariates were greatly reduced. The scrub suits in this study were autoclaved and stored in restricted storage area before use to control the baseline bacterial contamination and eliminate bias arising from storage conditions and cross-contamination from non-participants handling the scrubs in the changing rooms.

Our study design has its own flaws and limitations. Bias might have occurred due to order or carry-over effects that we were unaware of. However, the tested variable in this study was the fabric samples, with the participants acting as carriers. Therefore, we feel that the relevance of carry-over or order effect may not be so significant. During the study period, all participants carried out normal activities, such as having meals and tea breaks, besides clinical work. All participants kept to their study groups; participants of different groups did however come into contact with each other in the common areas of the operating theatre such as in the rest room and the pantry. However, there were also occasions where participants allocated to different study groups were working together in the same operating theatre suite. Transfer of microbes between participants of different groups might have occurred at these points, and could have affected our results. Participants' behaviour in the study may also be different from their usual behaviour, which might have influenced the bacterial counts. Although participating anaesthetists were not told the purpose of the study, it is possible for them to have guessed our intention and altered their behaviour in some way with respect to the sampling fabrics. However, the behaviour of participating anaesthetists in the operating theatre was monitored by the investigating team, and they did not observe any participant deliberately touching the sampling fabrics. Further, although staff in the hospital in general achieve very high performance in hand hygiene compliance, we did not collect hand hygiene data on the individual participants in the study, raising the possibility that this might have affected our results. It is also important to note that even the participants who were permitted to leave the operating theatre stayed in the relatively 'clean' areas of the department office and surgical wards. A final limitation to interpreting the results of this study is the large variability in bacterial colony count in fabric specimens collected at the four time points during a day from one site on a surgical scrub suit. This leads

to a substantial decrease in the precision of estimates and interpretability of results. Since it is almost certain that bacterial colony counts increase with time, at least at the hip and waist areas, and time effect was not of primary interest in this study, a further study may be done where only one sufficiently large piece of fabric is collected from each site at the end of a working day, to avoid issue of large sampling variability in bacterial count at the same site. Future research could also examine whether bacterial contamination varies by type of surgical procedure or patient, and between different wards or areas within the hospital (e.g. medical vs. surgical wards, or the Emergency Department).

We conclude that the wearing of surgical scrubs for brief visits out of the operating theatre to surgical wards, and to the nearby anaesthetic departmental office, did not result in a significant increase in bacterial count on scrub suits. The duration of wearing the same suit, and the sites on the scrub suits, are important factors contributing to bacterial contamination. We recommend that anaesthetists clean their hands before donning a new scrub suit, and also suggest a mid-day change of suit to reduce bacterial counts later in the day.

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Competing interests

No external funding and no competing interests declared.

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