Bacterial contamination of protective lead garments in an operating room setting

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Abstract

Background: Protective lead garments (PLG) worn in the operating room are a potential source for bacterial colonisation and thus may increase the risk of intraoperative infection. The clinical significance of such bacterial contamination has yet been established. Although disinfection protocols have been employed, their effectiveness is also unknown.

Objective: We sought to describe and compare the bacterial profile of PLGs with a focus on common pathogens involved in surgical site infections (SSI) and prosthetic joint infections (PJI).

Methods: We studied body aprons and neck-thyroid protective shields. We sampled 20 body aprons and 21 neck PLGs, swabbing the inside and outside of the PLGs. Swabs were cultured on different media and the results were assessed and compared.

Results: Of PLGs, 87.8% were contaminated. The neck-thyroid shield PLGs was generally more contaminated than body apron PLGs and exhibited significantly higher loads of *Staphylococcus epidermidis* ($P = 0.048$). Other pathogen cultured were *Micrococcus* spp., *Acinetobacter lwoffii* (*A. lwoffii*), *Bacillus* species (*Bacillus* spp.), *Moraxella osloensis* (*M. osloensis*) and *Pseudomonas stutzeri* (*P. stutzeri*). No other common pathogens associated with SSI or PJI were detected.

Conclusions: PLGs are heavily contaminated despite regular cleaning protocols. Neck PLGs are highly contaminated with potentially infectious agents. As neck PLGs are often directly exposed above the surgical sterile gown and the surgical field, measures should be undertaken to reduce their exposure and bacterial load, perhaps by suggesting users consider avoiding the use of intraoperative fluoroscopy when possible or alternatively supporting the use of body exhaust suits when PLGs are needed.

Keywords

Protective lead garments, PLG, aprons, thyroid shield, bacterial contamination

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Introduction

Protective lead garments (PLG) are used to protect hospital personnel and patients against ionising radiation during intraoperative fluoroscopy. PLGs are used in many orthopaedic trauma procedures but are not limited to this subspecialty and are also commonly used in many other invasive orthopaedic and non-orthopaedic procedures. Previous studies have suggested PLGs to be a potential reservoir of bacteria (Boyle and Strudwick, 2010; Feierabend and Siegel, 2015; Jaber, 2017; La Fauci et al., 2016).

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Infection of implants caused by bacterial adhesion, which produces biofilms, makes bone and joint infections notoriously hard to treat. Surgical site infections (SSI) and prosthetic joint infections (PJI) are therefore complications with devastating consequences for most patients (Tande and Patel, 2014). The most common causative organisms of SSI and PJI are *Staphylococcus aureus* (*S. aureus*), coagulase-negative staphylococci (*CoNS*) such as *Staphylococcus epidermidis* (*S. epidermidis*) and gram-negative rods such as *Escherichia coli* (*E. coli*) (Mangram et al., 1999).

A major source for intraoperative wound contamination is airborne bacteria found in the operating room (OR). Many preventive measures such as protective surgical attire, room structure and airflow have been developed to reduce contamination risk. The incidence of surgical site contamination corresponds to the number of bacterial colony-forming units (CFU) circulating in the air (Chauveaux, 2015). Research has shown regular cleaning of PLGs is successful in reducing the harboured CFU load (Boyle and Strudwick, 2010; Feierabend and Siegel, 2015; Grogan et al., 2011); however, this is not consistently nor uniformly done in all hospitals (Honigsberg et al., 2017; Jaber, 2017; La Fauci et al., 2016). Furthermore, while PLGs worn on the body (vests, skirts and aprons; Body PLG) are usually covered by sterile surgical gowns serving as barriers, PLGs that are worn on the surgeon's neck (thyroid shields and collars; Neck PLG) are often uncovered by the surgical gown and are exposed above the surgical field, unless body exhaust suits are used. Neck PLGs were shown to be contaminated with possibly harmful bacteria, although the clinical significance has yet to be established (Feierabend and Siegel, 2015; La Fauci et al., 2016). Nevertheless, airflow beneath body garments has long been assumed to be capable of carrying pathogens to the surgical field (Howorth, 1985). PLGs are also often shared by hospital personnel and patients in sequential procedures thus theoretically increasing their risk of being a transmission vector for pathogens.

The aim of the present study was to assess and compare the bacterial profile on body aprons and neck-thyroid shield PLGs worn in the OR, with particular interest in pathogens known to be common culprits in SSI and PJI.

Materials and methods

Specimen collection and sampling procedures

This observational study was conducted on all PLGs in our institution's OR floors during a single day. PLGs that were used outside the OR were excluded. PLGs in our medical institution include a body apron (Full Wrap Classic Aprons, INFAB Corporation, Camarillo, CA, USA) and a thyroid neck shield (Thyroid Collar, INFAB Corporation, Camarillo, CA, USA). All PLGs are typically used numerous times a week and are shared by many different personnel and

students in the 13 ORs available at our institution. PLGs are stored on a designated hanger that can be moved around between ORs as necessary. PLGs in our institution are cleaned on a weekly basis by the OR personnel. Cleaning is done using warm water and a detergent according to the manufacturer's instructions. We chose to conduct this study the day before cleaning to allow for the detection of maximal pathogenic loads.

Included PLGs were numbered and then swabbed in specific locations. We used Transystem™ sterile transport swabs (COPAN Diagnostics Inc., Murrieta, CA, USA). These sterile swabs were moistened with sterile saline to improve their sample collection capability. The sampling process was determined according to proximity to the surgeon's skin, edges of the surgical gown and the surgical field as well as commonly grasped areas when handling PLGs. Therefore, we sampled aprons using two swabs per garment. One, methodically swabbing from the outside: the collar, armpits and frontal chest midline areas. Another swab was applied to the inside part of the apron, in a similar fashion. Thyroid shields were sampled from the upper and lower collar areas on both the inside and the outside, similarly using two different swabs. To ensure quality of data collection, each side was swabbed by two different investigators in a sterile manner using sterile surgical gloves. The swabs were numbered respectively to the sampled PLGs and sent to the microbiology laboratory, where they were cultured.

Terms and measures

Culture was performed in conventional methods according to the *Manual of Clinical Microbiology* (Versalovic et al., 2011). Swabs were streaked directly onto the agar plate. We used blood agar, chocolate agar, MacConkey agar and brain heart infusion (BHI) broth. VITEK®2 Automated System (bioMérieux) was used for species identification. The detection of at least one CFU/swab was deemed as a positive bacterial growth. Once detected, the laboratory proceeded to determine the species and number of CFU/swab. *CoNS* other than *S. epidermidis* were grouped together as 'Other *CoNS*' (Becker et al., 2014). If there was growth on more than one agar, counting of colonies was performed on blood agar only in order to avoid counting colonies twice. All results were recorded in Microsoft Excel (2013) spreadsheets.

Statistical analysis

Absolute prevalence, means and standard deviation (SD) of the CFU/swab of each bacterium were calculated together with their cumulative CFU loads assuming normal distribution (Callewaert et al., 2014). To evaluate the differences in prevalence of bacteria between Neck and Body PLGs as well as between their inside and outside areas we calculated

Table 1. Contamination of garments.

PLG samples (n = 82)	Contamination	CFU load	CFU
Body PLG			
Inside (n = 20)	15 (75.00)	256 (0–60)	11.63 ± 19.47 (3.00–20.27)
Outside (n = 20)	14 (70.00)	114 (0–40)	5.43 ± 9.46 (1.12–9.73)
Neck PLG			
Inside (n = 21)	19 (90.47)	509 (0–100)	5.00 ± 25.34 (8.82–28.88)
Outside (n = 21)	16 (76.19)	266 (0–100)	11.57 ± 22.00 (2.05–21.08)

Values are given as n (%), sum (range) or mean ± SD (95% CI).

CI, confidence interval; CFU, colony-forming unit; sum, total sum of all CFU detected; PLG, protective lead garment; SD, standard deviation.

and compared 95% confidence intervals (CI). To test the differences in the CFU loads of common SSI and PJI pathogens on PLGs, we performed paired and independent t-tests as appropriate. Statistical significance was determined with a *P* value of < 0.05. Data analysis was performed using IBM SPSS V19 Statistics software.

Results

Contamination of PLGs

Twenty Body PLGs and 21 Neck PLGs have been included in this study and, overall, 82 samples were collected and are described in Table 1. Of PLGs, 87.80% were found to be contaminated. The Neck PLGs were more heavily contaminated with a total CFU load of 775; however, the prevalence of their contamination and mean CFU load were not significantly different from Body PLGs (*P* = 0.184). The inside areas of PLGs were generally more contaminated, though this observation was not statistically significant for both the Neck and Body PLGs (*P* = 0.410 and *P* = 0.723, respectively).

Bacterial profile

The most common bacteria cultured were *CoNS* (70.67%), of which 39.47% were *S. epidermidis*; it had the highest CFU load with a total of 405 CFU consisting 35.40% of all CFU. *Micrococcus* spp. was the next most common isolate (14.67% of samples) with a CFU load of 228 CFU. *Acinetobacter lwoffii* (*A. lwoffii*) has also demonstrated a particularly high CFU load of 142. Other notable growth included *Bacillus* species (*Bacillus* spp.), *Moraxella osloensis* (*M. osloensis*) and *Pseudomonas stutzeri* (*P. stutzeri*).

Two Body PLGs were found to be contaminated with more than one organism. One PLG was contaminated both on the inside and on the outside while the second PLG grew multiple organisms only on the inside.

Six Neck PLGs grew multi-organism colonies. Two of the PLGs were contaminated with multiple species both on the inside and on the outside. Three neck pieces had multiple species that grew from their inside and one neck piece was contaminated with multi-organism colonies only on the outside. The use of BHI broth did not add value to the results and growth was similar to that on the plates.

The microbial profile is described in more detail in Table 2 and illustrated in Figures 1 and 2.

Delineation of common SSI and PJI pathogens

S. epidermidis contaminated 20% of all PLGs; however, growth of *S. aureus* or *E. coli* was not detected. Its mean CFU load was 40.53 ± 40.84. Neck PLGs were significantly more contaminated with *S. epidermidis* than Body PLGs (*P* = 0.048) with a total load of 364 CFU compared with 41 CFU. The inside of Neck PLGs harboured a significantly greater bacterial load compared with the outside area (*P* = 0.039). There was no statistical difference in contamination levels of *S. epidermidis* between the inside and outside of Body PLGs.

Discussion

The present study confirms that PLGs are a potential reservoir for bacterial colonies in the OR. Furthermore, the results show that *S. epidermidis*, which is a common culprit of SSI and PJI, is the most common contaminant. This study also demonstrated Neck PLGs to significantly harbour more *S. epidermidis* CFUs, a finding which may suggest greater risk for SSI and PJI with the use of Neck PLGs.

Our main findings are consistent with those of other researchers. High prevalence of *CoNS* contamination was found on PLGs in other centres, ascertaining this is a global problem (Boyle and Strudwick, 2010; Feierabend and Siegel, 2015; Jaber, 2017; La Fauci et al., 2016). Greater

Table 2. Microbial profile.

Isolates	Positive cultures	CFU (relative load)*
Any isolates (n = 82)	75 (91.46)	1145 (100.00)
<i>Specific isolates</i>		
Other CoNS†	38 (50.67)	335 (29.29)
<i>S. epidermidis</i>	15 (20.00)	405 (35.40)
<i>Micrococcus</i>	11 (14.67)	228 (19.90)
<i>A. lwoffii</i>	4 (5.33)	142 (12.36)
<i>Bacillus</i> spp.	4 (5.33)	14 (1.22)
<i>M. osloensis</i>	2 (2.67)	9 (0.79)
<i>P. stutzeri</i>	1 (1.33)	12 (1.05)

Values are given as n (%).

*Relative CFU load of the total number of CFU.

†*S. hominis*, *S. haemolyticus*, *S. saprophyticus* and *S. warneri*.

bacterial contamination of Neck PLGs compared to Body PLGs has been described, although this study was performed in an institution with an incomplete and inconsistent cleaning protocol for PLGs (La Fauci et al., 2016). The significant presence of *S. epidermidis* in proximity to the surgeon's skin is unsurprising as *S. epidermidis* belongs to the natural skin flora, particularly in moist areas (Becker et al., 2014). Our findings show that Neck PLGs are more heavily contaminated than Body PLGs by potentially harmful bacteria despite regular hospital cleaning protocols. These results are in contrast with the low levels of contamination detected in a previous study performed in an institution where similar regular cleaning protocols were employed (Grogan et al., 2011).

Although we did not detect growths of other common SSI pathogens such as *S. aureus* or *E. coli*, it seems colonies

of *Micrococcus*, *Bacillus* spp. and other pathogens, not previously reported to grow on PLGs such as *Acinetobacter*, are prevalent.

Micrococcus is the second greatest isolate we detected (Table 2). Like *CoNS*, although distinct, it is common on human skin, which similarly explains the high levels present. *Micrococcus* is considered less virulent than *S. epidermidis* although it had been implicated in soft tissue and biomaterial infections in immunodeficient patients (Magee et al., 1990; Smith et al., 1999).

Growth of *Bacillus* spp. is found mainly on Neck PLGs (Figure 2). These are spore-forming bacteria found mainly in soil and the intestinal tract; however, they have also been reported to contaminate plaster of Paris used for casts (Drobniewski, 1993). This could explain their presence on PLGs in the OR after orthopaedic procedures, when splinting or casting is performed. Their spore-forming capability allows them to resist some disinfectants and, like *S. epidermidis*, they are also capable of forming biofilms on biomaterials. They have been described in soft-tissue infections after traumatic injuries as well as in PJI (Bottone, 2010; Veyseyre et al., 2015).

A. lwoffii grows a high CFU load relative to its prevalence (Figure 1). It is one of the most common species of *Acinetobacter* and is often recognised as normal flora of the skin, oropharynx and perineum of healthy individuals (Ku et al., 2000). *Acinetobacter* species consist of several members which are multidrug-resistant nosocomial pathogens (Manchanda et al., 2010). *A. baumannii* is a commonly reported opportunistic pathogen that can cause a potential life-threatening infection. Less commonly, *A. lwoffii* is capable of causing bacteraemia, usually after insertion of a catheter (Ku et al., 2000). It has recently been described as a common orthopaedic SSI pathogen in some medical facilities (Al-Mulhim et al., 2014; Maksimović et al., 2008). These were assumed to be

Figure 1. Illustration of the sample sites and methods. This pattern was used for both the internal and external parts of the garments.

Figure 2. Prevalence and bacterial load of cultured isolates reported in the percentage of total positive cultures and total number of colony-forming units, respectively.

infections acquired during stays in the intensive care unit after surgeries and not directly related to the OR. The present study may indicate otherwise.

It appears PLGs may pose an important risk for intraoperative wound contamination. PLGs carry high levels of bacterial contamination despite regular cleaning. These results are not unexpected, as weekly cleaning of lead aprons and thyroid shields will not mitigate for the sweat and skin commensals that will accumulate over that period from multiple users. The heavy CFU burden of *S. epidermidis* we detected on Neck PLGs is concerning for two reasons: one is because the risk of infection is proportional to CFU levels; and the other is because Neck PLGs are often exposed above the surgical field (i.e. not completely covered by the sterile surgical gown). This study emphasises the importance of regular cleaning of PLGs and perhaps the use of other sterile barriers to cover Neck PLGs, such as the commonly used body exhaust suits. However, the role of body exhaust suits or surgical helmet systems in preventing SSI has yet to be established (Shohat and Parvizi, 2017; Young et al., 2016). Furthermore, we believe our findings should urge surgeons to assume responsibility in cleaning their Neck PLGs before beginning operations despite regular hospital cleaning protocols. Just as hand washing is part of the preoperative routine, perhaps so should be the cleaning of Neck PLGs before each surgery. This can apparently be achieved simply with a disinfecting wipe or a detergent and hot water (Boyle and Strudwick, 2010; Feierabend and Siegel, 2015).

The main limitation of the present study is that it does not account for adherence of hospital personnel to the regular cleaning protocols set in our institution. The results can thus be explained if the protocols are not followed completely and equally for both Neck and Body PLGs. In addition, we only examined PLGs, but it is more than likely that other equipment in the OR area is expected to accumulate viable colonies of micro-organisms as well. However,

PLGs are in a unique position in the OR, being worn by several surgeons throughout the day in very close proximity to the surgical field.

The clinical relevance of the bacterial contamination levels and distribution we found is limited by lack of correlation between airborne bacterial counts and risk of SSI as well as some evidence that body exhaust suits may not be effective in reducing air contamination (Chauveaux, 2015). Furthermore, we currently have no data to associate the detected bacteria with SSI and PJI in our institution. Therefore, the presence of the detected micro-organisms does not necessarily correlate with perioperative infection; however, in order to mitigate the risk of perioperative infection, it is sensible to advise cleaning of the garments on a more frequent basis and between users. This study also did not examine the correlation between frequency, duration or time since last use and the number of colonies. All the above should be the focus of future studies.

In summary, the present study shows that despite regular cleaning protocols, PLGs in the OR are a reservoir of harmful bacteria. More specifically, Neck PLGs are significantly more heavily contaminated with *S. epidermidis* than Body PLGs. Thus, the exposure of Neck PLGs above the surgical field potentially increases the risk for SSI, and therefore may support the use of body exhaust suits. Since hospital cleaning protocols may be inconsistent or inadequate, surgeons should assume responsibility in cleaning their Neck PLGs before surgery until an alternative appropriate solution is found. Further research should look to reinforce the clinical relevance of pathogens inhabiting PLGs and develop sterile barriers for Neck PLGs.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Figure 3. Prevalence of bacteria on different sampled areas.

	Other CONS	S. Epidermis	Micrococcus	A. lwoffii	Bacillus spp.	M. Osloensis	P. stutzeri	No growth	Total
Body Inside	9 (40.90%)	1 (4.54%)	5 (22.72%)	1 (4.54%)	0	1 (4.54%)	0	5 (22.72%)	22
Body Outside	9 (42.85%)	4 (19.04%)	0	1 (4.76%)	1 (4.76%)	0	0	6 (28.57%)	21
Neck Inside	9 (34.61%)	6 (23.07%)	4 (15.38%)	1 (3.84%)	2 (7.69%)	1 (3.84%)	1 (3.84%)	2 (7.69%)	26
Neck Outside	10 (50%)	3 (15%)	2 (10%)	0	1 (5%)	0	0	4 (20%)	20

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