

## Microorganism identification and environmental cleaning effectiveness in radiology settings: cross-sectional and experimental studies

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### Abstract

**Introduction:** Despite the large number of patients passing through and some invasive procedures, radiology may still be considered unlikely to transmit pathogens. However, radiation protection aprons touched by radiology professionals and shared between patients could be prone to contamination. Our goals were to (1) assess qualitatively and quantitatively the microorganisms present on the radiation protection aprons with a cross-sectional study, and (2) determine the effectiveness of routine cleaning with an experimental design.

**Methods:** For objective 1, 108 samples were collected on radiation protection aprons of two radiology settings: the diagnostic radiology (DR) setting, with a cleaning procedure in place, and the emergency setting without. Total cultivable bacteria, staphylococci, enterobacteria and fungi were quantified. For purpose 2, the number of total bacteria and staphylococci were compared between before and after cleaning the aprons.

**Results:** The median number of total bacteria were respectively 0.97 and 1.56 cfu/cm<sup>2</sup> in the DR and emergency settings, whereas the median number of Staphylococcus were 0.04 and 0.15 cfu/cm<sup>2</sup> in these settings (Objective 1). Thus, the number of microorganisms were

lower in the setting with the cleaning procedure, although significantly only for staphylococci ( $p = 0.025$ ). Enterobacteria, fungi and *Staphylococcus aureus* were not detected in any sample. In the second part of the study, the median number of total bacteria dropped from 0.80 to 0.17 cfu/cm<sup>2</sup> between before and after cleaning ( $p = 0.0017$ ) and for *Staphylococcus* it decreased from 0.84 to 0.15 cfu/cm<sup>2</sup> ( $p = 0.13$ ).

**Conclusion:** A number of microorganisms have been found, although the absence of enterobacteria, fungi and *S. aureus* is reassuring as they can cause serious healthcare-associated infections. Our study showed that the cleaning of radiation protection aprons can significantly reduce the microbial load and should be encouraged.

## Introduction

In recent decades, owing to the technological developments and population ageing the number of radiological examinations has increased globally. Consequently, many patients transit in radiology. Outpatients and hospitalized patients mingle, as well as cancer or immunocompromised patients and patients admitted to the emergency unit, who are at increased risk of infection (World Health Organization [WHO], 2011). Due to the diversity of patients who go through it, radiology is considered a hub, which can favor cross-transmission of infectious microorganisms (Zhang & Burbridge, 2011).

Added to this are invasive procedures such as CT-guided biopsies (Lopes Floro, Munckhof, & Coucher, 2018) or more commonly the injection of contrast media through a catheter (Saade, Bourne, Wilkinson, & Brennan, 2011). A systematic literature review highlighted the major risk of blood infection when using a catheter (WHO, 2011). For example, the hepatitis C virus was transmitted between patients after performing scanners with contrast media injection (Bibbolino, Pittalis, Schininà, Busi Rizzi, & Puro, 2009). The transfer was confirmed by the genetic resemblance between the viruses of the initially infected patient and those of the newly infected people. The transmission occurred when handling the intravenous line because of a defect in hand hygiene of healthcare workers between patients (Bibbolino et al., 2009).

Healthcare-associated infections (HCAI) are deemed a global challenge as they affect 3.5 to 12% of patients in developed countries (WHO, 2011) and up to 19% in developing ones (Allegranzi et al., 2011). Annually, these infections are responsible for 99 000 deaths in the USA and 37 000 in Europe (WHO, 2011), but also lead to longer hospital stay and impair patients' quality of life. The repercussions are thus important for the safety of the patients and the healthcare professionals (Storr et al., 2017). The impacts on the health systems are massive with annual costs in the USA and Europe of at least US\$ 30 billion (Scott, 2009) and € 7 billion respectively (WHO, 2011).

In high-income countries, the main HCAI affect the urinary tract, the surgical sites, the bloodstream, and the lower respiratory tract (WHO, 2011), and are caused by leading

pathogens such as *Staphylococcus aureus*, enterobacteriaceae, *Pseudomonas* spp., *Candida* spp, and *Acinetobacter* spp (WHO, 2011). Due to the increased spread of antimicrobial resistance in hospital setting, these infections can be difficult to eliminate. Furthermore, virulence and resistance to antimicrobial agents are enhanced by the aggregation of biofilm-forming bacteria on medical devices, such as catheters, prostheses, and cardiac pacemakers (Hall-Stoodley & Stoodley, 2009).

Accordingly, a number of recommendations encouraging thorough cleaning and disinfection of surfaces, hands and reusable instruments and equipment have been published (National Health and Medical Research Council [NHMRC], 2010; Storr et al., 2017; Boqvist & Rudi, 2018). Studies have shown a reduction in the risk of pathogen transmission when the cleaning effort is increased, particularly in rooms where the prior occupant was infected or colonized by the target pathogens (Anderson et al., 2017; Datta, Platt, Yokoe, & Huang, 2011).

Cleanliness of reusable medical equipment is paramount when in direct contact with the patient. This is particularly the case for radiation protection devices used in radiology, such as radiation protection aprons (Johnston, Comello, Vealé, & Killion, 2010; Weber, Monnin, Elandoy, & Ding, 2015). Such equipment could be reservoirs of microorganisms, especially with proven lifespan of infectious organisms on inert substrates up to several weeks (Nyhsen et al., 2017; Otter, Yezli, Salkeld, & French, 2013).

In spite of the contamination threat related to the use of shared clinical equipment and the transit of patients from various health facilities or services, few studies on the surveillance of environmental contamination and cleaning efficiency were conducted in radiology departments and none in Switzerland. In addition, to our knowledge only two studies considered radiation shielding aprons that, however, are in direct contact with patients (Boyle & Strudwick, 2010; Feierabend & Siegel, 2015). Nevertheless, the authors did not quantify the *Staphylococcus* load on the aprons.

Our study, consisting of two phases, was intended to firstly identify and quantify the microorganisms -among which are staphylococci- on the radiation protection aprons of a teaching hospital. In this cross-sectional study, two settings were compared: one with an institutionalized cleaning protocol, the diagnostic radiology (DR) setting, and the other without, the emergency setting. Secondly, the effectiveness of routine cleaning procedure was assessed through an experimental study. The widely used agar plate method (ISO 14698-1, 2003) was utilized for both studies. It offers the advantage of enumerating only viable microorganisms -thus constituting a potential source of cross-infection- over the adenosine triphosphate (ATP) method that detects without discrimination both living and dead organisms of any kind (Childress et al., 2017).

## Methods

### **Quantitative and qualitative assessment of the microorganisms: a cross-sectional study**

The study was conducted in the DR and emergency settings of one of the five university hospitals of the country. Whereas in the DR setting a routine cleaning procedure of the radiation protection equipment exists, this is not the case in the emergency one.

The microorganism load was assessed on all the radiation protection aprons (19) of the radiology department. These aprons come from five rooms of the DR setting and three rooms of the emergency setting. The aprons are non-antibacterial and composed of a large central protective part and sometimes two straps to keep it around the patient. Samples were collected on the apron per se and on one strap, if the apron was equipped with straps. This was the case for eight aprons.

Four types of microorganisms were sought: total cultivable bacteria, Staphylococcus, enterobacteriaceae and fungi. Accordingly, four types of sampling based on different standard methodologies were performed to assess their presence and number. For Staphylococcus swabbing technique was used, whereas the collections of total bacteria, enterobacteriaceae and fungi were achieved by application of contact plates of 55 mm in diameter, following the recommendations of ISO 14698-1 (2003). Thus, the presence and number of total bacteria was estimated with plate count agar medium (Oxoid). MacConkey agar (Oxoid) was used for enterobacteriaceae and Sabouraud Agar (Oxoid) for fungi. In the case of Staphylococcus, sterile and moistened swabs (bioMérieux) were stroked over a sampling area defined by a stencil of 125 cm<sup>2</sup>. Swabs were then stroked over a SAID agar (S. aureus chromid ID<sup>®</sup>, bioMérieux). To account for the inhomogeneous distribution of microorganisms on the garment and more accurately reflect the overall microbial load, the collections of each of the four samples types were made at different places for each apron.

Incubation of the four types of plates was performed at 37°C for 48h. Then the colony-forming units (CFU) were counted. In order to determine whether staphylococci were Staphylococcus aureus, Staphaurex<sup>TM</sup> Plus Latex Agglutination Test (Thermo Scientific<sup>TM</sup>) were used. A total of 108 samples were collected and counted.

### **Before and after cleaning sampling: an experimental study**

This part of the study focused on the effectiveness of routine cleaning. As no cleaning protocol exists in the emergency setting, solely the aprons from the DR setting were considered in this part. Consequently, the 13 aprons from the five rooms of this hospital setting were sampled for the pre- and post-cleaning study. The number of aprons per room might slightly differ from that in the first phase of this study, since, although the aprons are assigned to a room, they are sometimes transported to another room to meet clinical practice needs, but always within the same setting (DR vs. emergency).

Sampling for the pre- and post-cleaning study consisted of seeking total bacteria and Staphylococcus. The presence of enterobacteriaceae and fungi was not assessed, given the results obtained for these microorganisms in the first phase of this study (see results part). The collection, incubation, counting and determination of the strains were carried out as for the "Quantitative and qualitative assessment of the microorganisms" section. The only difference being that sampling was performed once, then the aprons were cleaned, and sampling was repeated within 10 minutes. The location of sampling after cleaning was different from that before cleaning. This prevents strains from being removed by sampling in addition to those eliminated by cleaning. Cleaning was always done by the same radiographer, using disinfectant wipes (Cleanplanet Steriwipes®), following the habits of the service. He was asked to clean the aprons as usual.

### **Statistical analysis**

Because the numbers of microorganisms were not normally distributed, their median values were reported.

Owing to the different cleaning practice between the two settings, the numbers of microorganisms (total cultivable bacteria and Staphylococcus) observed on the DR and emergency aprons were compared with unilateral Wilcoxon Mann-Whitney tests. To test whether the numbers of microorganisms differ between before and after cleaning, unilateral paired Wilcoxon Mann-Whitney tests were realized. Statistical analysis was performed using R software (R Core Team, 2017).

## **Results**

### **Quantitative and qualitative assessment of the microorganisms: a cross-sectional study**

The microorganisms detected on the radiation protection aprons and their numbers are presented in Table 1. For each DR room, the median number of total bacteria varied from 0.29 (room 4) to 3.08 cfu/cm<sup>2</sup> (room 6). Some staphylococci were present on some plates of agar medium, with median values from 0.01 (room 4) to 1.11 cfu/cm<sup>2</sup> (room 6). The lowest median values of total bacteria and Staphylococcus were observed in the same DR room. Similarly, the highest median values of total bacteria and Staphylococcus were detected in the same room, but in an emergency room. The number of Staphylococcus (medians for emergency: 0.15 cfu/cm<sup>2</sup> vs DR: 0.04 cfu/cm<sup>2</sup>;  $p = 0.025$ ) and total bacteria (medians for emergency: 1.56 cfu/cm<sup>2</sup> vs DR: 0.97 cfu/cm<sup>2</sup>;  $p = 0.22$ ) were higher in the emergency compared to the DR setting; although the difference is significant only for Staphylococcus. None of the Staphylococcus was a Staphylococcus aureus.

Table 1. Sampling design and number of colony forming units (CFU) for total bacteria, fungus, enterobacteriaceae and *Staphylococcus*.

Setting	Room No.	Apron No.	Total bacteria	Fungus	Enterobacteriaceae	<i>Staphylococcus</i>	
Diagnostic radiology	1	1	8.82	0.00	0.00	0.05	
		2*	2.95	0.00	0.00	0.14	
		3*	1.64	0.00	0.00	0.01	
		4*	0.51	0.00	0.00	0.00	
		<b>Median</b>	<b>2.29</b>	<b>0.00</b>	<b>0.00</b>	<b>0.03</b>	
	2	5	6.06	0.00	0.00	0.00	
		6	0.69	0.00	0.00	1.64	
		7*	0.04	0.00	0.00	0.04	
		8*	0.97	0.00	0.00	0.02	
		<b>Median</b>	<b>0.83</b>	<b>0.00</b>	<b>0.00</b>	<b>0.03</b>	
	3	9*	0.84	0.00	0.00	0.07	
	4	10*	0.29	0.00	0.00	0.01	
	5	11	0.97	0.00	0.00	0.15	
	Emergency	6	21	5.83	0.00	0.00	1.59
			22*	0.34	0.00	0.00	0.62
<b>Median</b>			<b>3.08</b>	<b>0.00</b>	<b>0.00</b>	<b>1.11</b>	
7		23	1.60	0.00	0.00	0.16	
		24*	1.52	0.00	0.00	0.14	
		<b>Median</b>	<b>1.56</b>	<b>0.00</b>	<b>0.00</b>	<b>0.15</b>	
8		25	1.49	0.00	0.00	0.08	
		26	3.68	0.00	0.00	0.06	
		<b>Median</b>	<b>2.59</b>	<b>0.00</b>	<b>0.00</b>	<b>0.07</b>	
		<b>Median for diagnostic radiology</b>	<b>0.97</b>	<b>0.00</b>	<b>0.00</b>	<b>0.04</b>	
<b>Median for emergencies</b>	<b>1.56</b>	<b>0.00</b>	<b>0.00</b>	<b>0.15</b>			

\*Apron without straps

### Before and after cleaning sampling: an experimental study

The changes in the number of microorganisms between before and after cleaning are given in Table 2. Before cleaning, the median values of total bacteria in the different DR rooms ranged from 0.52 (room 3) to 1.48 cfu/cm<sup>2</sup> (room 1), and after cleaning, they ranged from 0 (room 3) to 1.83 cfu/cm<sup>2</sup> (room 5). The results show a reduction to up to 100% of the number of microorganisms after cleaning the lead aprons. The number of total bacteria was

lower after cleaning compared to before for each apron, except two (No. 4 and 11). The median values of total bacteria per apron significantly decreased between pre and post-cleaning (total medians for pre-cleaning: 0.80 cfu/cm<sup>2</sup> vs post-cleaning: 0.17 cfu/cm<sup>2</sup>;  $p = 0.0017$ ). No bacteria were observed, after cleaning, on three aprons originating from the same radiology room. The rooms where the aprons are the least contaminated after cleaning are those where the median number of total bacteria was lowest pre-cleaning.

Before cleaning Staphylococcus was found in all aprons except for one (No. 9). After cleaning, no Staphylococcus was detected on this apron, as well as on three others (No. 7, 10 and 13). The median number of Staphylococcus per room ranged from 0.34 (room 3) to 1.12 cfu/cm<sup>2</sup> (room 1) pre-cleaning. Post-cleaning, it ranged from 0 (room 3) to 1.75 cfu/cm<sup>2</sup> (room 2). As for total bacteria, cleaning decreased the number of Staphylococcus on each apron, except for three aprons (No. 6, 12 and 14). However, the reduced number of Staphylococcus on garments after cleaning, compared to before, was not significant (medians for pre-cleaning: 0.84 cfu/cm<sup>2</sup> vs post-cleaning: 0.15 cfu/cm<sup>2</sup>;  $p = 0.13$ ). None of the Staphylococcus was Staphylococcus aureus.

Table 2. Sampling design and number of colony forming units (CFU) for total bacteria and *Staphylococcus* pre- and post-cleaning.

Room No.	Apron No.	Total bacteria pre-cleaning	Total bacteria post-cleaning	Variation (%)	<i>Staphylococcus</i> pre-cleaning	<i>Staphylococcus</i> post-cleaning	Variation (%)
1	1	1,37	0,17	-87,69	0,65	0,15	-77,42
	2*	1,60	0,29	-81,58	1,09	0,17	-84,62
	3*	1,68	0,46	-72,50	1,35	0,34	-75,00
	4*	0,51	0,72	41,67	1,14	0,21	-81,48
	<b>Median</b>	<b>1,48</b>	<b>0,38</b>	<b>-74,47</b>	<b>1,12</b>	<b>0,19</b>	<b>-83,02</b>
2	5	0,67	0,11	-84,38	0,84	0,11	-87,50
	6	1,43	0,57	-60,29	0,88	3,39	283,33
	<b>Median</b>	<b>1,05</b>	<b>0,34</b>	<b>-68,00</b>	<b>0,86</b>	<b>1,75</b>	<b>102,44</b>
3	9*	0,63	0,00	-100,00	0,00	0,00	nf
	10*	1,26	0,00	-100,00	0,88	0,00	-100,00
	12	0,40	0,19	-52,63	0,21	3,77	1690,00
	13	0,27	0,00	-100,00	0,46	0,00	-100,00
	<b>Median</b>	<b>0,52</b>	<b>0,00</b>	<b>-100,00</b>	<b>0,34</b>	<b>0,00</b>	<b>-100,00</b>
4	7*	0,80	0,04	-94,74	1,18	0,00	-100,00
	14	0,40	0,15	-63,16	0,06	0,11	66,67
	<b>Median</b>	<b>0,60</b>	<b>0,09</b>	<b>-84,21</b>	<b>0,62</b>	<b>0,05</b>	<b>-91,53</b>
5	11	1,45	1,83	26,09	0,46	0,17	-63,64
<b>Total median</b>		<b>0,80</b>	<b>0,17</b>	<b>-78,95</b>	<b>0,84</b>	<b>0,15</b>	<b>-82,50</b>

\*Apron without straps; nf: not feasible

## Discussion

The fight against nosocomial diseases should constitute a constant effort given the implications on patients and healthcare costs. In this study, we pointed out the occurrence of microorganisms on radiation protection aprons and the effectiveness of cleaning in reducing the frequency of microorganisms.

The plates assessing the presence of total bacteria were all positive in the cross-sectional study characterizing and quantifying the microorganisms. They were also positive before cleaning in the experimental study. These results reinforce those reported in the only two other articles on patient-worn aprons, with 100% of contamination in England (Boyle & Strudwick, 2010) and 81% in the USA (Feierabend & Siegel, 2015). However, with maximum values as high as 10 or 16 CFU/cm<sup>2</sup> the shield contamination levels in the UK exceed the values of ours.

A majority of our aprons had staphylococci but no strain belonging to the species *S. aureus*. This is in contrast with a previous study where between 13 and 42% of lead shielding worn by health professionals were contaminated with *S. aureus* (La fauci, Riso, Facciola, Merlina, & Squeri 2016). As in our study, the authors did not find any fungi; on the other hand, some of their aprons were contaminated by enterobacteria -organisms that are part of the commensal flora of our intestines- that we did not detect. The absence of *S. aureus*, fungi and enterobacteria in our samples suggests a good level of hygiene, which is reassuring because these microorganisms are responsible for serious infections.

Antibacterial radiation protection aprons are launched on the market and appear in radiology departments. If our aprons exhibited this property, fewer microorganisms may have been detected. Note, however, that the antibacterial activity often concerns only one side of the shielding. In addition, few studies have tested the effectiveness of antibacterial surfaces in healthcare settings to reduce microbial contamination and HCAI. These studies show that the efficacy is not total, and the duration of the effect is not clearly established (see Muller et al., 2016 for a systematic review). Finally, the health and environmental security of the bactericidal agents often remain to be demonstrated and some of them can increase antimicrobial resistance (Adlhart et al., 2018; Hasan, Crawford, & Ivanova, 2013). Cleaning of shared equipment between patients is essential to reduce cross-transmission and strain frequencies (Storr et al., 2017). This effect is noted in our study with significantly fewer total bacteria on radiation shielding aprons after cleaning compared to before. The median value of staphylococci was also lower post-cleaning (0.15 cfu/cm<sup>2</sup>) compared to pre-cleaning (0.84 cfu/cm<sup>2</sup>), although not statistically significantly. Furthermore, significantly more staphylococci were quantified on the aprons of the emergency versus DR settings. If the difference was not significant for total bacteria, the median value for the emergency service was nevertheless higher (1.56 vs 0.97 cfu/cm<sup>2</sup>). These results may be explained by the absence of guidelines for aprons cleaning in the emergency setting whereas such guidelines exist in the DR setting. In addition, it is known that working in the



emergency room (Pittet et al., 2004) is a risk factor for non-adherence to hand hygiene, as is high workload (Nyirenda, ten Ham-Baloyi, Williams, & Venter, 2018; WHO, 2009). On five aprons, more microorganisms were quantified after cleaning compared to before. However, for each of these five aprons, the increase was solely noted for one type of microorganisms, either total bacteria or Staphylococci. For the other type, cleaning decreased the incidence of microorganisms. An explanation is that samplings at these two moments were performed at different locations on the same shield and that the microbial distribution on a single shield may not be homogeneous. Because of that, caution in interpreting results of this kind is necessary. Nevertheless, this research approach is of great interest in visualizing environmental contamination at a given moment, and in the identification of potential reservoirs (Karageorgopoulos & Falagas, 2008; NHMRC, 2010). Radiographers play a key role in maintaining a clean environment. An increase in cleaning frequency has been shown to promote control of outbreaks (Denton et al., 2004). Yet cleaning practices are often deficient (Nyhsen, Humphreys, Nicolau, Mostbeck, & Claudon, 2016; Nyirenda et al., 2018). As reported in the literature, an explanation is the insufficient knowledge about microbiological risks (Abdelrahman et al., 2017; Nyirenda et al., 2018). Accordingly, recommendations highlight the importance of training professionals in the hands, equipment and environment cleaning, and at the infection risk (Nyhsen et al., 2017; Zhang & Burbridge, 2011). Levin et al. (2009) showed that an educational intervention significantly increased adherence to hygiene measures (such as hand washing and the use of gloves) and decreased the number of microorganisms found on x-ray machine. However, five months after this intervention period, the infection control was not sustained. Apart from education, other strategies have been proposed to improve compliance to infection control measure, including availability of cleaning products or practice auditing and feedbacks (Bibbolino et al., 2009; Zhang & Burbridge, 2011). In this context, our study highlighted the importance of regular cleaning in reducing the number of microorganisms. It enhanced the awareness of professionals (managers and clinicians) in this teaching hospital to the existence of potential human pathogens on commonly used equipment, the associated risks and the significance of regular equipment disinfection.

## **Conclusion**

The use of a standardized testing protocol showed the microbial contamination of the aprons, even if no MRSA or Enterobacteriaceae was found. The equipment cleanliness is therefore essential for the health of both patients, who may be fragile or immunocompromised, and professionals of the whole hospital. By showing the effectiveness of disinfection in reducing the number of microorganisms, this study provided a positive reinforcement to radiographers to sustain a high level of compliance with hygiene recommendations.

## References

- Abdelrahman, M. A., Alhasan, M., Alewaidat, H., Rawashdeh, M. A., Al Mousa, D. S., & Almhdawi, K. A. (2017). Knowledge of nosocomial infection control practices among radiographers in Jordan. *Radiography*, 23(4), 298-304. <https://doi.org/10.1016/j.radi.2017.07.005>
- Adlhart, C., Verran, J., Azevedo, N. F., Olmez, H., Keinänen-Toivola, M. M., Gouveia, I., ... Crijns, F. (2018). Surface modifications for antimicrobial effects in the healthcare setting: A critical overview. *Journal of Hospital Infection*, 99(3), 239-249. <https://doi.org/10.1016/j.jhin.2018.01.018>
- Allegranzi, B., Nejad, S. B., Combescure, C., Graafmans, W., Attar, H., Donaldson, L., & Pittet, D. (2011). Burden of endemic health-care-associated infection in developing countries: Systematic review and meta-analysis. *The Lancet*, 377(9761), 228-241. [https://doi.org/10.1016/S0140-6736\(10\)61458-4](https://doi.org/10.1016/S0140-6736(10)61458-4)
- Anderson, D. J., Chen, L. F., Weber, D. J., Moehring, R. W., Lewis, S. S., Triplett, P. F., ... Sexton, D. J. (2017). Enhanced terminal room disinfection and acquisition and infection caused by multidrug-resistant organisms and *Clostridium difficile* (the Benefits of Enhanced Terminal Room Disinfection study): A cluster-randomised, multicentre, crossover study. *The Lancet*, 389(10071), 805-814. [https://doi.org/10.1016/S0140-6736\(16\)31588-4](https://doi.org/10.1016/S0140-6736(16)31588-4)
- Bibbolino, C., Pittalis, S., Schininà, V., Busi Rizzi, E., & Puro, V. (2009). Hygiene precautions and the transmission of infections in radiology. *La Radiologia Medica*, 114(1), 111-120. <https://doi.org/10.1007/s11547-009-0363-0>
- Boqvist, K. P., & Rudi, N. H. (2018). Er hygiene-protokollene i radiologiske avdelinger optimale for å hindre MRSA-smitte? *Radiography Open*, 4(1), 13. <https://doi.org/10.7577/radopen.3112>
- Boyle, H., & Strudwick, R. M. (2010). "Do lead rubber aprons pose an infection risk?" *Radiography*, 16(4), 297-303. <https://doi.org/10.1016/j.radi.2010.03.002>
- Childress, J., Burch, D., Kucharski, C., Young, C., Kazerooni, E. A., & Davenport, M. S. (2017). Bacterial Contamination of CT Equipment. *Academic Radiology*, 24(8), 923-929. <https://doi.org/10.1016/j.acra.2017.01.022>
- Datta, R., Platt, R., Yokoe, D. S., & Huang, S. S. (2011). Environmental Cleaning Intervention and Risk of Acquiring Multidrug-Resistant Organisms From Prior Room Occupants. *Archives of Internal Medicine*, 171(6). [doi:10.1001/archinternmed.2011.64](https://doi.org/10.1001/archinternmed.2011.64)
- Denton, M., Wilcox, M. H., Parnell, P., Green, D., Keer, V., Hawkey, P. M., ... Murphy, P. (2004). Role of environmental cleaning in controlling an outbreak of *Acinetobacter baumannii* on a neurosurgical intensive care unit. *Journal of Hospital Infection*, 56(2), 106-110. <https://doi.org/10.1016/j.jhin.2003.10.017>
- Feierabend, S., & Siegel, G. (2015). Potential Infection Risk From Thyroid Radiation Protection: *Journal of Orthopaedic Trauma*, 29(1), 18-20. <https://doi.org/10.1097/BOT.0000000000000161>
- Hall-Stoodley, L., & Stoodley, P. (2009). Evolving concepts in biofilm infections. *Cellular Microbiology*, 11(7), 1034-1043. <https://doi.org/10.1111/j.1462-5822.2009.01323.x>

- Hasan, J., Crawford, R. J., & Ivanova, E. P. (2013). Antibacterial surfaces: The quest for a new generation of biomaterials. *Trends in Biotechnology*, 31(5), 295-304.  
<https://doi.org/10.1016/j.tibtech.2013.01.017>
- ISO 14698-1. Cleanrooms and associated controlled environments – Biocontamination control. Part 1: General principles and methods. Geneva. 2003
- Johnston, J., Comello, R. J., Vealé, B. L., & Killion, J. (2010). Radiation Exposure Dose Trends and Radiation Dose Reduction Strategies in Medical Imaging. *Journal of Medical Imaging and Radiation Sciences*, 41(3), 137-144. <https://doi.org/10.1016/j.jmir.2010.06.003>
- Karageorgopoulos, D.E., Falagas, M.E. Current control and treatment of multidrug-resistant *Acinetobacter baumannii* infections. *The Lancet Infectious Diseases*, 8(12), 751–762.  
[https://doi.org/10.1016/S1473-3099\(08\)70279-2](https://doi.org/10.1016/S1473-3099(08)70279-2)
- La Fauci, V., Riso, R., Facciola, A., Merlina, V., & Squeri, R. (2016). Surveillance of microbiological contamination and correct use of protective lead garments. *Annali di igiene : medicina preventiva e di comunità*, 23, 1-7. doi:[10.7416/ai.2016.2116](https://doi.org/10.7416/ai.2016.2116)
- Levin, P. D., Shatz, O., Svir, S., Moriah, D., Or-Barbash, A., Sprung, C. L., ... Block, C. (2009). Contamination of Portable Radiograph Equipment With Resistant Bacteria in the ICU. *Chest*, 136(2), 426-432. <https://doi.org/10.1378/chest.09-0049>
- Lopes Floro, K., Munckhof, W., Coucher, J. (2018). Retrospective review of CT-guided intervertebral disc biopsies performed at a tertiary referral centre for suspected osteodiscitis. *Journal of Medical Imaging and Radiation Sciences*, 62,307-312. <https://doi.org/10.1111/1754-9485.12686>
- Muller, M. P., MacDougall, C., Lim, M., Armstrong, I., Bialachowski, A., Callery, S., ... Vearncombe, M. (2016). Antimicrobial surfaces to prevent healthcare-associated infections: A systematic review. *Journal of Hospital Infection*, 92(1), 7-13. <https://doi.org/10.1016/j.jhin.2015.09.008>
- National Health and Medical Research Council. Australian Guidelines for the Prevention and Control of Infection in Healthcare. Commonwealth of Australia. 2010. Available at: <https://nhmrc.gov.au/about-us/publications/australian-guidelines-prevention-and-control-infection-healthcare-2010> Date accessed: June 25, 2019
- Nyhsen, C. M., Humphreys, H., Koerner, R. J., Grenier, N., Brady, A., Sidhu, P., ... Claudon, M. (2017). Infection prevention and control in ultrasound—Best practice recommendations from the European Society of Radiology Ultrasound Working Group. *Insights into Imaging*, 8(6), 523-535. <https://doi.org/10.1007/s13244-017-0580-3>
- Nyhsen, C. M., Humphreys, H., Nicolau, C., Mostbeck, G., & Claudon, M. (2016). Infection prevention and ultrasound probe decontamination practices in Europe : A survey of the European Society of Radiology. *Insights into Imaging*, 7(6), 841-847.  
<https://doi.org/10.1007/s13244-016-0528-z>

- Nyirenda, D., ten Ham-Baloyi, W., Williams, R., & Venter, D. (2018). Knowledge and practices of radiographers regarding infection control in radiology departments in Malawi. *Radiography*, 24(3), e56-e60. <https://doi.org/10.1016/j.radi.2018.01.002>
- Otter, J. A., Yezli, S., Salkeld, J. A. G., & French, G. L. (2013). Evidence that contaminated surfaces contribute to the transmission of hospital pathogens and an overview of strategies to address contaminated surfaces in hospital settings. *American Journal of Infection Control*, 41(5), S6-S11. <https://doi.org/10.1016/j.ajic.2012.12.004>
- Pittet, D., Simon, A., Hugonnet, S., Pessoa-Silva, C. L., Sauvan, V., & Perneger, T. V. (2004). Hand Hygiene among Physicians : Performance, Beliefs, and Perceptions. *Annals of Internal Medicine*, 141(1), 1. <https://doi.org/10.7326/0003-4819-141-1-200407060-00008>
- R Core Team. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. 2017. Available at: <https://www.R-project.org> Date accessed: May 9, 2019
- Saade, C., Bourne, R., Wilkinson, M., & Brennan, P. (2011). Contrast Medium Administration and Parameters Affecting Bolus Geometry in Multidetector Computed Tomography Angiography : An Overview. *Journal of Medical Imaging and Radiation Sciences*, 42(3), 113-117. <https://doi.org/10.1016/j.jmir.2011.05.002>
- Scott, R.D. The direct medical costs of healthcare-associated infections in U.S. hospitals and the benefits of prevention. Atlanta (GE): Center for Disease Control and Prevention. 2009. Available at: [https://www.cdc.gov/HAI/pdfs/hai/Scott\\_CostPaper.pdf](https://www.cdc.gov/HAI/pdfs/hai/Scott_CostPaper.pdf) Date accessed: August 20, 2019
- Storr, J., Twyman, A., Zingg, W., Damani, N., Kilpatrick, C., ... the WHO Guidelines Development Group (2017). Core components for effective infection prevention and control programmes : New WHO evidence-based recommendations. *Antimicrobial Resistance & Infection Control*, 6(1), 1-18. <https://doi.org/10.1186/s13756-016-0149-9>
- Weber, N., Monnin, P., Elandoy, C., & Ding, S. (2015). A model-based approach of scatter dose contributions and efficiency of apron shielding for radiation protection in CT. *Physica Medica*, 31(8), 889-896. <https://doi.org/10.1016/j.ejmp.2015.06.007>
- WHO. Guidelines on Hand Hygiene in Health Care. First Global Patient Safety Challenge Clean Care is Safer Care. 2009. Available at: <https://www.who.int/gpsc/5may/tools/9789241597906/en/> Date accessed: June 25, 2019
- WHO. Report on the Burden of Endemic Health Care-Associated Infection Worldwide. World Health Organization. 2011 [cited 2019 Feb 12] Available from: <http://www.who.int/iris/handle/10665/80135>
- Zhang, E., & Burbridge, B. (2011). Methicillin-Resistant Staphylococcus Aureus : Implications for the Radiology Department. *American Journal of Roentgenology*, 197(5), 1155-1159. <https://doi.org/10.2214/AJR.11.6584>