Bacterial contamination of ultrasound probes in different radiological institutions before and after specific hygiene training: do we have a general hygienical problem?

Eur Radiol (2017) 27:4181–4187
DOI 10.1007/s00330-017-4812-1

ULTRASOUND

Bacterial contamination of ultrasound probes in different radiological institutions before and after specific hygiene training: do we have a general hygienical problem?

Thomas Sartoretti[1,2] · **Elisabeth Sartoretti**[1,2] · **Candid Bucher**[3] · **Aleksis Doert**[2] · **Christoph Binkert**[2] · **Klaus Hergan**[4] · **Matthias Meissnitzer**[4] · **Johannes Froehlich**[5] · **Orpheus Kolokythas**[2,6] · **Simon Matoori**[5] · **Christina Orasch**[7] · **Sebastian Kos**[5] · **Sabine Sartoretti-Schefer**[2] · **Andreas Gutzeit**[1,4,5]

Received: 3 October 2016 / Revised: 3 March 2017 / Accepted: 13 March 2017 / Published online: 3 April 2017

Abstract
Objectives Aim was to investigate hygienic conditions of ultrasound probes before and after hygiene training in radiology institutions in comparison to bacterial contamination in public places.
Methods In three radiology departments, bacterial contamination was evaluated using baseline agar plates for cultures taken from 36 ultrasound probes. Afterwards teams were trained by a hygiene service centre and 36 ultrasound probes were routinely disinfected with regular disinfecting wipes and then evaluated. In comparison, bacterial contamination in public places (bus poles, $n = 11$; toilet seats, $n = 10$) were analysed. Plates were routinely incubated and the number of colony forming units (CFU) analysed.
Results Cultures taken from the probes showed a median of 53 CFU before and 0 CFU after training ($p < 0.001$). Cultures taken from public places showed a median of 4 CFU from toilets and 28 from bus poles and had lower bacterial load in comparison to ultrasound probes before training ($p = 0.055$, toilets; $p = 0.772$, bus poles), without statistical significance.
Conclusions Bacterial contamination of ultrasound probes prior to hygiene training proved to be high and showed higher bacterial load than toilets seats or bus poles. Radiologists should be aware that the lack of hygiene in the field of ultrasound diagnostics puts patients at risk of healthcare-associated infections.
Key points
- *Hospital-associated infections are a problem for patient care.*
- *Hygiene training of staff prevents bacterial contamination of ultrasound probes.*
- *Disinfection of ultrasound probes is an easy method to protect patients.*

Keywords Ultrasound probes · Bacterial contamination · Disinfection · Healthcare-associated infections · Colony forming units

✉ Andreas Gutzeit
andreas.gutzeit@hirslanden.ch

1 Department of Chemistry and Applied Biosciences, Institute of Pharmaceutical Sciences, ETH Zurich, Vladimir-Prelog-Weg 1-5/10, 8093 Zurich, Switzerland

2 Institute of Radiology, Kantonsspital Winterthur, Brauerstrasse 15, 8401 Winterthur, Switzerland

3 Bioexam AG, Labor für Lebensmittel, Heilmittel und Hygiene, Maihofstrasse 95a, P.O. Box 6858, 6000 Lucerne 6, Switzerland

4 Department of Radiology, Paracelsus Medical University Salzburg, Salzburg, Austria

5 Institute of Radiology and Nuclear Medicine, Hirslanden Klinik St. Anna, St. Anna-Strasse 32, 6006 Lucerne, Switzerland

6 Department of Radiology, University Washington, 1959 NE Pacific St., Seattle, WA 98190, USA

7 Department of Infectious Diseases and Hospital Epidemiology, Hirslanden Klinik St. Anna, St. Anna-Strasse 32, 6006 Lucerne, Switzerland

Introduction

There is a constantly high risk in vulnerable or healthy patients of suffering from healthcare-associated infections (HAIs), especially in hospitals and medical departments [1]. The estimated number of HAIs in hospitals is approximately 1.7 per million patients. The death rate in the USA as a result of HAIs was 98,987 patients per year [2]. The overall direct cost of

HAIs ranges from 28 to 45 billion US$ per year, which has a tremendous influence on the economic aspects of healthcare systems worldwide [3]. To our knowledge, there are no investigations of HAIs exclusive to Europe.

The main aim of every hospital or medical department and of the medical staff should be to guarantee the best healthcare services which includes minimizing HAI in patients during routine medical examinations, interventions or normal medical procedures by establishing and implementing standardized hygiene protocols. In our experience, medical staff are frequently unaware of how important standard hand hygiene or the hygiene of the medical device is in the prevention of iatrogenic bacterial transfer to the patients [4].

The surfaces of technical equipment in medical institutions are well-known sources of bacterial contamination by normal skin flora and also by multiresistant pathogens [5]. If the medical devices are used in different patients without proper decontamination in between each usage, bacteria can be transmitted from one patient to another or from one patient to the doctor, leading to possible hospital-acquired cross infections.

Ultrasound probes are used daily for multiple patients with a variety of medical diseases and conditions ranging from benign to critical. There are only a few publications which have investigated this kind of bacterial contamination on the surfaces of medical devices and ultrasound probes [6, 7].

To our knowledge, there is no publication which has systematically investigated the bacterial contamination of ultrasound probes in different radiology departments before and after specific hygiene training. Thus, the aim of the study was to investigate the bacterial load on ultrasound probes before and after hygiene training of medical staff. To qualify the contamination rate more realistically, we also compared the bacterial contamination of ultrasound probes with public places like public toilet seats or bus poles. Ultimately, we aim to demonstrate the importance of prevention strategies in radiology departments when performing ultrasound examinations in order to reduce the transmission of potential nosocomial pathogens by applying minimal hygiene standards.

Material and methods

The bacteriological investigations were conducted in the period between 6 January 2016 and 31 July 2016. General authorization was granted for the study by the local ethics commission in Basel/Switzerland.

Examination of ultrasound probes before specific team hygiene training

To evaluate bacterial contamination of ultrasound probes, we investigated randomized ultrasound probes in three different radiology institutions in Europe (institutes 1–3). Institute 1 had about 190 workplaces, institute 2 about 120 workplaces and institute 3 about 40 workplaces in the department of radiology. In each medical facility, 12 samples of the probes' surfaces were evaluated (overall 36 probes before training in all three departments). All probes were generally used for the examination of the whole body in adults and children and for image-guided interventions in the daily routine. In general the institutes used a regular ultrasound gel (Skintact®, Diagramma AG, Dietikon, Switzerland). After ultrasound the different teams in different hospitals only used dry towels to clean the probes. No disinfection wipes were used. The staff were not previously informed of the exact day of the tests.

Measurement of bacterial load

The scanning surfaces of the different curved and linear ultrasound probes before and after training were pressed cautiously onto the surface of the sterile agar plates (TSA TLHTh Contact plate, VWR Chemicals, Leuven, Belgium) for 10 s while wearing latex gloves and surgical masks (Fig. 1). The agar plates were carefully stored away and labelled for correct identification.

The incubation of the agar plates was started in a specialized laboratory within 6 h of taking the samples. Incubation lasted for 3 days at 30 °C. Afterwards, two examiners counted the number of colony forming units (CFU) per plate independently. Differentiation of the bacterial species was performed by a trained professional.

The numbers of CFU in the three different radiology institutions as well as in the public locations (buses and restrooms) were evaluated and compared (described below). The effect of training and disinfection was monitored.

Hygiene training of staff

In the days following the first examination, the staff were trained by the hygiene team in a 30-min training session concerning the correct surface disinfection. This involved the use of a commercially available alcohol-free disinfection

Fig. 1 Technique used to evaluate the bacterial cultures derived from the ultrasound probe. The ultrasound probe is rolled over the agar plate in a rolling movement and subsequently examined bacteriologically

wipe suitable for use on ultrasound probes (Septiwipe®, Medical Services Group, UK). The wipes are based on quaternary ammonium compounds consisting of 0.25 g didecyldimethylammonium chloride and 0.5 g benzyl-C12–16-alkyldimethyl chloride. All three hospitals used the same wipes. Disinfection of an ultrasound probe took an average of 10 s total time. The ultrasound probe was wiped with regular movements. Cleaning was always begun with the ultrasound probe and then the hygiene tissue was moved in the direction of the cable (Fig. 2). Up until now the implemented training has not been written down in a standardised hygiene policy because different hospitals were included and we cannot give instructions to foreign hospitals.

Examination of ultrasound probes after hygiene training of medical staff

After the radiology team had been trained and after implementing a regular surface disinfection process the imprint collection of 12 individual ultrasound probes was repeated similar to the baseline evaluation. This examination was made 1 month after the first evaluation. The same three radiology departments were included (overall, 36 probes after training).

Examination of public places

In order to validate the ultrasound probe bacterial contamination before and after training with other locations, a total of 11 samples were taken from the toilet seats in hospital restrooms accessible to the general public.

In addition, bacterial imprints of bus poles of a public bus in the City of Lucerne/(bus number 14; in service) were examined (Fig. 3).

Statistics

The analyses were conducted using System R ® (version 3.2.0). In the paired sample comparison (before–after comparison, dependent samples) a normal *Q*–*Q* plot was used to decide whether the differences between the samples followed a normal distribution. If this was the case, a parametric test (*t* test) was applied, otherwise a non-parametric test (either exact Wilcoxon signed rank test or sign test) was used. The distributions of the differences were checked whether they were symmetric (median – mean ≈ 0 and $-1.0 < \text{skewness} < 1.0$). The exact Wilcoxon signed rank test was used when distributions were symmetric. If distributions were not symmetric, the sign test was used.

In the unpaired sample comparison (independent samples) there was also a normal *Q*–*Q* plot used to decide whether the differences between the samples followed a normal distribution. If this was the case, a parametric test (*t* test) was applied, otherwise a non-parametric test (Mann–Whitney *U* test) was used. The level of significance was set at $\alpha = 0.05$.

Fig. 2 Rapid disinfection procedure which always starts with the cleaning of the curved surface of the probe and subsequently includes the cable

Fig. 3 Samples were taken from the bus pole on the agar plate to evaluate the number of colony forming units (CFU)

Results

The following results were analysed as an overall group. To maintain the anonymity of the individual hospitals, no analyses were made known at the hospital level, but only analysed as an overall cohort. For training purposes, the specific results of every hospital were internally communicated very clearly.

Comparison of bacterial contamination of ultrasound probes before and after hygiene training of medical staff

Initially, a median of 53 CFU per plate (range 0–800) was counted for the various ultrasound probes. This contamination rate dropped to a median of zero after the hygiene training ($p < 0.0001$) with very few contaminated probes remaining. Apparently, it could be shown that there was a clear effect on reducing bacterial contamination after the hygiene training of the staff (Table 1, Fig. 4).

Table 1 Bacterial contamination and number of CFU before and after the hygiene training of the staff ($n = 36$)

Time	*n*	Min	Q1	Median	Mean	Q3	Max	SD	IQR
Bacterial contamination of ultrasound probes before hygiene training	36	0.00	3.75	53.00	104.72	124.25	800.00	160.02	120.50
Bacterial contamination of ultrasound probes after hygiene training	36	0.00	0.00	0.00	12.14	1.25	300.00	51.06	1.25
Difference in bacterial contamination	36	−750.00	116.00	−37.50	−92.58	−2.75	3.00	148.48	118.75

IQR interquartile range (Q1–Q3)

Bacterial contamination of public toilets

A median of 4 CFU per plate resulted for the seats of public toilets situated in the hospitals. This result seems much better than the one of the ultrasound probes (median of 53 CFU without hygiene training of the staff), despite not achieving statistical significance. ($p = 0.055$) (Table 2, Fig. 5).

Comparison of bacterial contamination of ultrasound probes with bus poles in public buses

In comparison to ultrasound probes without hygiene training of the staff, bacterial contamination was higher (53 CFU) in comparison to bus poles in public buses (28 CFU) ($p = 0.772$) (Table 3, Fig. 5).

Following analysis of the number of CFU, identification of bacteria species on the ultrasound probes was done *before* hygiene training. No highly virulent bacteria like *Enterobacteriaceae*, *Enterococcus*, *Staphylococcus aureus* or nonfermenters were found; however, in seven cases less pathogenic Gram-negative microorganisms were found: *Acinetobacter lwoffii* ($n = 3$), *Brevundimonas diminuta* ($n = 1$) and *Paracoccus yeei* ($n = 3$).

The remaining bacteria mainly consisted of usual skin commensals like coagulase-negative staphylococci, micrococci, *Bacillus* spp. and corynebacteria. We did not perform antibiotic resistance testings.

No potentially pathogenic bacteria whatsoever were found on the ultrasound probes after hygiene training. We did not identify the bacteria found in buses and on the toilet seats.

Discussion

In this study, we showed that bacterial contamination of routinely used ultrasound probes in teams without specific

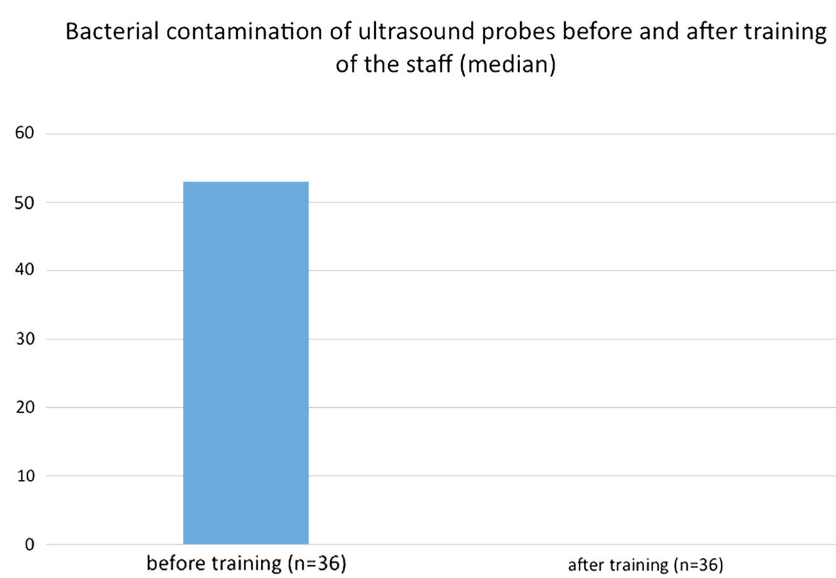

Fig. 4 Significant reduction of colony forming units (CFU) originating from ultrasound probes before and after systematic training of the radiology staff

Table 2 CFU on ultrasound probes before cleaning ($n = 36$) and on toilet seats ($n = 10$)

Time	*n*	Min	Q1	Median	Mean	Q3	Max	SD	IQR
Bacterial contamination of ultrasound probes	36	0.00	3.75	53.00	104.72	124.25	800.00	160.02	120.50
Bacterial contamination of public toilet seats	10	0.00	1.50	4.00	95.00	6.50	914.00	287.79	5.00

Ultrasound probes showed a median of 53 CFU, whereas public toilet seats showed a median of 4 CFU ($p = 0.055$)

hygiene training was high. There was a median of 53 CFU derived from the probes before training. After systematic training of the teams and systematic cleaning procedures the median colony count derived from the probes was 0 CFU ($p < 0.001$), which showed that quick and easy hygiene procedures were very effective.

Bacterial contamination of public toilet seats yielded a median of 4 CFU and were hence considerably cleaner than the ultrasound probes before training of the team ($p = 0.055$). With a median of 28 CFU, the bus poles in public buses tended to be cleaner than the ultrasound probes before team training, without significance ($p = 0.772$).

No highly virulent bacteria were found; nevertheless, seven less pathogenic bacteria were identified.

It should be emphasized that hospitals are bound to guaranteeing a hygienic environment. For this reason, it is disturbing that the publically accessible areas such as toilets and buses showed lower bacteriological contamination than the ultrasound probes, which came daily into contact with sick and immunocompromised patients.

Ultrasound examinations are used routinely for the examination of patients with a variety of diseases and conditions both in the emergency setting as well as in routine examinations. The ultrasound probes covered with layers of ultrasound gel have direct contact with the skin of the patients and the doctors. In a few studies, it could be shown that bacterial contamination after ultrasound examinations could be a potential source of nosocomial infections [6–9].

A diverse microbial flora lives on the skin of humans from birth until death. The number of bacteria on an individual's skin remains relatively constant with specific bacterial genera in different skin regions [10–12]. In immunocompromised individuals, bacteria can cause severe diseases either by not suppressing other pathogens or by directly causing infections. For this reason, it is alarming that such a high bacterial load was found on ultrasound probes before training, especially considering the potential for more virulent and/or multiresistant bacteria which could result in epidemics or serious HAI. The fact that such bacteria in this study were not found is probably a combination of coincidence and an epidemiologic setting with a low prevalence of multiresistant microorganisms in the hospitals examined.

Recent publications have shown that contamination of the ultrasound transducers by pathogens like *Staphylococcus aureus* (methicillin-resistant or methicillin-sensitive) and *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *E. coli*, *Acinetobacter* as well as *Candida albicans* has been reported within a range from 2% to 17.5% of cases [6–8, 13].

Recently, Hayashi et al. reported that bacterial transmission of contaminated ultrasound probes has been suspected in different settings, i.e. in an outbreak of *K. pneumoniae* infection in pregnant women [13].

Over the last few years an increasing number of nosocomial infections overall as well as infections caused by multiresistant strains have been observed in hospitals. The reason for this development lies, on the one hand, in often

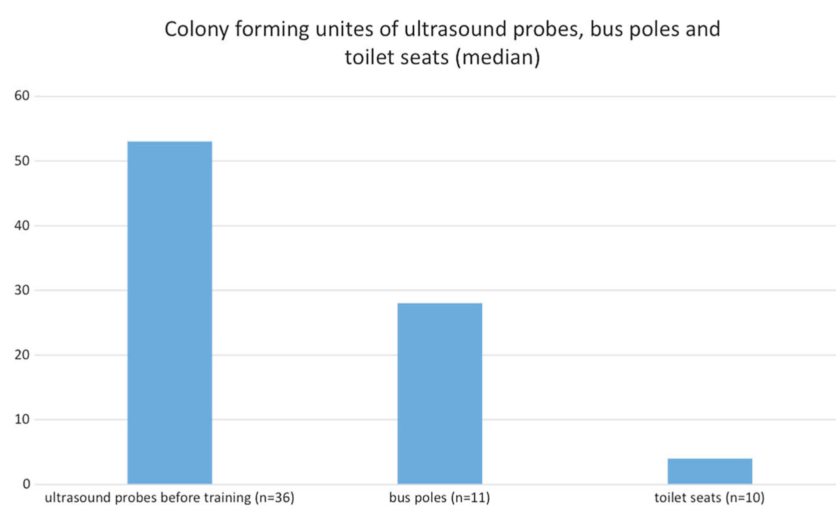

Fig. 5 Difference in colony forming units (CFU) in a comparison between ultrasound probes before training and toilet seats/bus poles

Table 3 CFU on ultrasound probes before cleaning ($n = 36$) and in public buses ($n = 11$)

Time	*n*	Min	Q1	Median	Mean	Q3	Max	SD	IQR
Bacterial contamination of ultrasound probes	36	0.00	3.75	53.00	104.72	124.25	800.00	160.02	120.50
Public bus	11	9.00	11.5	28.0	83.73	46.00	600.00	173.54	34.50

Ultrasound probes showed a median of 53 CFU, whereas public buses showed a median of 28 CFU ($p = 0.772$)

unreflected application of antibiotic therapy, but also in improper hygienic conditions in healthcare settings [14]. In the USA, every day one in 25 patients acquires an infection during hospitalisation. It must be pointed out that a majority of healthcare-associated infections are preventable [15]. This causes not only an increase of infection-associated morbidity and mortality but also places a big financial burden on the health system.

For this reason, hygiene training and regular standardized cleaning/disinfection strategies should be mandatory for all medical devices, especially those in direct contact with the patient. Healthcare providers and especially radiologists/sonographers need to know about microbiological transmission pathways, the wide range of preventive strategies and their effectiveness aiming at the highest hygiene standards possible so as to prevent HAI [16].

It should be emphasized that routine decontamination procedures and disinfection of the individual ultrasound probes only take a few seconds. Therefore, in our opinion, there is actually no reason that such a simple disinfection procedure should not be performed every time after using an ultrasound probe before using it on the next patient. Obviously the germicidal wipes used in our routine cleaning protocol were per se effective for the bacterial contamination of the ultrasound probes after the proper cleaning procedure for it reduced the bacterial colonisation very effectively [17]. We did not find mandatory international guidelines for normal ultrasound probes, which are normally used in a general radiology department. There are only recommendations that ultrasound probes which are used for endocavitary (vagina, rectum, etc.) examinations should be used with sterile condoms [18]. This is not necessary for normal radiology probes. Our results prove that normal disinfection, which is described above, is very effective for a normal radiology workflow to guarantee proper hygiene.

Although all hospitals yielded a high baseline contamination rate, some aspects need to be considered further bearing in mind the following limitations:

1. The number of included hospitals was rather limited. Therefore, on the basis on the data, we cannot generalize and speak of a general hygiene problem as other hospitals may have stricter hygiene regulations.
2. The choice of reference values from public toilets in hospitals or from bus poles was made spontaneously. These controls, at least in the hospitals, often undergo specific cleaning programs and monitoring in part, possibly explaining the better hygiene environment. Moreover, it is possible that the restrooms in other hospitals yield differing results. We chose this approach on purpose to make the teams more aware of the importance and plausibility of hygiene in general.
3. To maintain anonymity, the data are presented as a whole not differentiating between the single hospitals.

Conclusion

The bacterial contamination rate of ultrasound probes proved to be high with a median of 53 CFU. After hygiene training of the medical staff, the bacterial load was clearly reduced. The bacterial cultures derived from public toilets and bus poles showed that these locations were considerably less contaminated in comparison to ultrasound probes of untrained teams.

The bacterial contamination was caused by an inadequate routine decontamination and disinfection procedure after usage. A strict disinfection policy is mandatory in order to avoid bacterial transmission from one patient to another.

Acknowledgements We would like to thank Daniela Jegher from St. Anna Clinic in Lucerne (Switzerland), who led and organized hygiene training of the radiology team in an outstanding manner. We would also like to thank Andrea Pfeifer from the statistical service centre University Zürich for evaluating biomathemathical data.

Compliance with ethical standards

Guarantor The scientific guarantor of this publication is Andreas Gutzeit.

Conflict of interest The authors of this manuscript declare no relationships with any companies whose products or services may be related to the subject matter of the article.

Funding The authors state that this work has not received any funding.

Statistics and biometry Andrea Pfeifer kindly provided statistical advice for this manuscript.

Ethical approval Approval from the institutional animal care committee was not required because no animals were included.

Methodology
• prospective
• randomised controlled trial
• multicentre study

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