

Can diagnostic ultrasound scanners be a potential vector of opportunistic bacterial infection?

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Abstract

Ultrasound examinations are recognised as being safe. The greatest epidemiological threat during the performance of examination is the transfer of pathogenic and opportunistic microorganisms between patients and from personnel to patients. Colonization of the skin with opportunistic bacteria of immunocompromised and high risk patients may lead to infection following an ultrasound scan. **Aim:** To identify and evaluate the strains of bacteria occurring on ultrasound equipment subjected to unexpected control performed by a local infectious diseases control team. We assumed that transducers, gel holders and gel bottles can be contaminated with normal human skin microflora. The remaining tested parts of the ultrasound equipment could possibly be contaminated with normal human skin microflora and other pathogens. **Material and methods:** The swabs were taken from ultrasound scanners located in various hospital settings, from out-patient based radiology scanning rooms to operating theatre, and cultured. **Results:** Among all isolated 23% strains were classified as environmental microflora; 8% as strains related to patient's skin contamination; and 13 % strains constituted pathogenic Gram-negative rods. The remaining strains were classified as opportunistic flora 38%. High prevalence of opportunistic bacteria cultured in our study lead to the modification of the ultrasound cleaning procedures in both institutions and recommendation of the use of antibacterial wipes to clean all parts of ultrasound equipment in contact with patients' skin and examiners. **Conclusions:** Contamination not only affects parts of diagnostic equipment placed in direct contact with the patient, but also, those surfaces that only medical personnel have had contact with.

Keywords: ultrasonography, cross infection, bacterial contamination

Introduction

A variety of imaging techniques are used in the diagnostic process or for monitoring the treatment process, and their use is becoming more common, with significant annual increases of the number of imaging examinations performed worldwide [1]. Personnel and patients are aware of the risks associated with exposure

to the ionising radiation at the time of X-ray, computed tomography, vascular studies as well as possible interference of the magnetic field with heart pacing devices and metallic body implants in patients subjected to magnetic resonance imaging. However, ultrasound examination is regarded as non-invasive, and the patients assume no additional risk while undergoing it is involved [2]. The greatest epidemiological threat during the performance of the ultrasound examination is the transfer of pathogenic microorganisms between patients and from personnel to patients that may lead to infection with alert pathogens as well as infection with opportunistic bacteria.

The aim of this study was to identify and evaluate the strains of bacteria occurring on ultrasound equipment subjected to decontamination procedures recom-

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mended by manufacturers. We developed the hypothesis that contamination not only affects parts of the diagnostic equipment placed in direct contact with the patient, but also those surfaces that only medical personnel have had contact with.

Materials and methods

The prospective study was performed in two hospitals in June 2014: The Jan Kochanowski University Hospital in Kielce referred to as centre A and 1st Department of Clinical Radiology Medical University of Warsaw referred to as Centre B. The following ultrasound scanners were submitted to control: in Centre A – Esaote Mylab Class C and Esaote Mylab Seven at main ultrasound room and Esaote Mylab Twice at surgical department operating theatre; in Centre B – two Logiq 9 GE at main ultrasound room, ATL3000 Philips at transplantology department ultrasound room, Logiq 5 GE at intensive care unit and Xario Toshiba at surgical department operating theatre. In both hospitals the ultrasound machines in outpatient settings – in radiology department, transplantology department were sampled at the end of ultrasound session. The machines in operating theatre and at intensive care unit were sampled before use. Sterile swabs that have been moistened with sterile water were used for material collection. Samples were taken from the following elements of ultrasound scanners: convex transducer – the scanhead scanning surface and 60 – 80 cm connecting cable length proximal to from the transducer, keyboard, touch screen/controls, gel containing bottle, and gel bottle holder. The scanners were located at Radiology Department, the operating theatre of the General Surgery Department, the transplantation clinic and the intensive care department in two Hospitals.

Swabs were taken in both centres. A total number of 39 swabs were taken: site 1 – convex transducer – scanning surface and cable – 8 swabs, site 2 – keyboard – 8 swabs, site 3 – touch screen and controls – 8 swabs, site 4 – gel bottle – outer surface and area around opening – 7 swabs, site 5 – gel bottle holder – 8 swabs. One sampling site was omitted in Centre B, that is the ultrasound scanner in the operating theatre, because sterile, disposable ultrasound gel was used there, not gel stored in the bot-

ties. The swabs were put into the transfer medium and sent to the microbiology laboratory within the hour. All samples were taken by a competent sampling officer who had been trained to carry out this procedure.

Swab alone is not highly sensitive for detecting the bacteria present on tested surfaces. To increase the sensitivity of the test, the samples were seeded on a Schaedler liquid base [3] incubated under laboratory conditions for 48 hours, and after growth was observed, they were inoculated seeded on blood agar, McConkey medium and chromogenic media to isolate MRSA, ESBL and VRE strains (bioMeriux, Poland). Strains were identified on the basis of cell and colony morphology [4] and additional tests. In addition, tests intended to identify epidemiological markers were carried out.

Results

A total of 39 swabs were taken from 8 ultrasound machines in two centres in June 2014. Fifteen swabs were taken in centre A and 24 swabs in centre B. All swabs were cultured. In centre A Gram-positive bacteria grew on 15 swabs and Gram-negative bacteria grew on 2 swabs. In centre B 9 swabs showed growth of Gram-positive bacteria and 3 Gram-negative (table I). No growth was observed in 12 swabs taken in centre B. In both centres Gram-negative bacteria were isolated only from swabs collected from equipment belonging to Radiology Department 2 in centre A and 3 in centre B. The isolated rods belonged to the *Pantoea* and *Pseudomonas* (*P. stutzeri*) or *Achromobacter* spp. The cultured strains were not ESBL (Extended spectrum beta lactamase). No carbapenem non-susceptibility was observed. While Meticillin-Resistant Coagulase-Negative Staphylococci belonging to genera: *Staphylococcus haemolyticus* and *S. hominis* were isolated from 11/15 swabs in Centre A, no such staphylococci were isolated in Centre B. Meticillin-susceptible *S. aureus* was isolated only in Centre A. No isolates of meticillin-resistant *S. aureus* were isolated in either centre. Similarly, no glycopeptide-resistant enterococci were isolated.

Spores forming rods *Bacillus* spp. were isolated in both centres with roughly equal frequencies: 3/15 swabs in A and 7/24 swabs in B (table II).

Table I. Comparison of positive swab cultures of ultrasound scanners in radiology departments and in other departments.

Centre	Bacteria	In Radiology Department	In other Departments
A	Gram-positive	10/10	5/5
	Gram-negative	2/10	0/5
B	Gram-positive	7/10	2/14
	Gram-negative	3/10	0/14

The results are expressed as the number of positive swab culture/total number of samples

Table II. Strains of isolated bacteria in both Centres

Sampling site	Bacteria	Centre A Radiology Dept. scanner No 1	Centre A Radiology Dept. scanner No 2	Centre A Surgery Dept. Operating theatre scanner	Centre B Radiology Dept. scanner No 1	Centre B Radiology Dept. scanner No 2	Centre B Transplantology Dept. scanner	Centre B Surgery Dept. Operating theatre scanner	Centre B ICU scanner
1. Convex transducer – scanning surface and cable	Gram positive	S. haemolyticus MR	S. hominis MR	Bacillus spp. – three phenotypes	Bacillus spp.	MSCNS	No growth	No growth	No growth
	Gram negative	No growth	No growth	No growth	No growth	No growth	No growth	No growth	No growth
2. Keyboard	Gram positive	S. aureus MS S. haemolyticus MR Corynebacterium spp.	S. haemolyticus MR S. epidermidis MS	S. hominis MR	Enterococcus spp.	Bacillus spp.	No growth	No growth	No growth
	Gram negative	No growth	No growth	No growth	rods ESBL (-)	rods ESBL (-)	No growth	No growth	No growth
3. Touch screen and controls	Gram positive	S. haemolyticus MR E. faecium	S. haemolyticus MR E. hirae	S. aureus MS	No growth	No growth	MSCNS, Bacillus spp.	No growth	No growth
	Gram negative	Rods ESBL (-)	Rods ESBL (-)	No growth	No growth	No growth	No growth	No growth	No growth
4. Gel bottle – outer walls, area around the mouth	Gram positive	S. hominis MR	Corynebacterium striatum	S. hominis MR E. faecalis, Corynebacterium spp.	No growth	MSCNS, Bacillus spp.	No growth	NC	No growth
	Gram negative	No growth	No growth	No growth	Rods ESBL (-)	No growth	No growth	NC	No growth
5. Gel bottle holder	Gram positive	S. hominis MR	Kocuria kristinae	S. haemolyticus MR S. hominis MR	Bacillus spp.	Bacillus spp.	No growth	No growth	Bacillus spp.
	Gram negative	No growth	No growth	No growth	No growth	No growth	No growth	No growth	No growth

MR – methicillin resistant, MS – methicillin susceptible, MRCNS – Methicillin-Resistant Coagulase-Negative Staphylococcus, ESBL: Extended Spectrum Beta Lactamase, NC – not cultured (no swab was taken, disposable sterile US gel is used in operating theatre settings in site B)

Isolated bacteria were classified as environmental flora – *Bacillus* spp. rods – isolated from 9 (23%) swabs, strains related to patient's contamination – *Kocuria kristinae* and *Corynebacterium* – isolated from 3 (8%) swabs, pathogenic Gram-negative rods not producing either ESBL or KPC were isolated from 5 (13%) swabs. The remaining strains were classified as opportunistic flora: methicillin-resistant *S. hominis*, methicillin-resistant *S. haemolyticus*, methicillin-susceptible *S. aureus*, *E. faecalis*, *E. faecium*, *E. Hirae* and were isolated from 15 (38%) swabs.

The following differences were also observed between centres: bacteria were isolated from 100% of swabs in Centre A, and from 42% in Centre B, of which 80% were taken from equipment in the Radiology Department. Bacteria were cultured from 5 out of 8 swabs taken from ultrasound transducers – 3 cultures contained opportunistic strains. In centre B out of 14 swabs taken from scanners located in the Transplantology Department, Operating Theatre and Intensive Care Unit – ICU bacterial growth was obtained in only 2 samples. Bacterial isolates belonged to environmental microflora.

Discussions

There are different types of ultrasound scans: external, internal, and endoscopic. Procedures may vary from noninvasive (ex. transabdominal ultrasound, transthoracic echocardiography, small parts and musculoskeletal examinations, Doppler vascular assessment), through procedures with direct contact with mucous membranes (ex. transesophageal echocardiography, transvaginal ultrasonography), and invasive procedures (ex. endovascular ultrasonography). Sonographers differ in habits and skill during ultrasound scan. The “critical instruments” penetrating the skin or mucous membranes require sterilization. Semicritical instruments that come into contact with mucous membranes (e.g. fiber-optic endoscopes require high-level disinfection). Noncritical devices come into contact with intact skin but not mucous membranes. External probes that only come into contact with clean, intact skin are considered noncritical devices and require cleaning after every use [5]. These devices should be cleaned by low-level disinfection techniques [6].

Ultrasound machines and transducers may act as both a source and a vector of nosocomial infection. Several studies have confirmed the transmission of bacteria and viruses from a patient's skin to ultrasound equipment, the most significant organisms including *Staphylococcus aureus* (including methicillin-resistant strains, i.e. MRSA), *Pseudomonas*, *Acinetobacter* species, *Candida albicans*, hepatitis B and C viruses, human immunodeficiency vi-

rus (HIV) and herpes simplex virus, human papilloma virus [7,8].

There are several possible routes of pathogen transmission during ultrasound examinations. In order to ensure good conduction of the ultrasound wave from the transducer to the examined tissues and back again, the skin is covered with a thin layer of gel. The gel is then distributed over the skin of the patient by moving the transducer back and forth. Ultrasound examination is dynamic: it requires numerous changes in position by both the patient and the examiner. During this process, the cable often comes into contact with the patient skin, and the clothing of the examiner with the gel-covered surface of the skin. After placing the transducer in the holder after use, the possibility of its contamination remains. Most of the radiologist and radiographers are right handed and hold the transducer in right hand. The free hand – usually the left, is used to take measurements, introduce text comments on the obtained images, enable/disable Doppler imaging, to adjust the imaging parameters – requiring from a few to several movements – by changing the control knob, pressing buttons, selecting fields on the touch screen and using the keyboard controls. In the case of the equipment housing and its controls being dirtied, pathogens can be rapidly transferred to virtually all usable parts of the equipment.

In many centres, the procedures for preparing the ultrasound equipment for operation and then leaving it for the following user may become less restrictive moving from the operating theatre and towards the Radiology Department. It is recommended to clean the transducers and the cable after completing each examination with alcohol-free disinfectant. Ethyl and propyl alcohol are effective decontaminants with success rates as high as 100 % [9] however, may damage the transducer, therefore Koibuchi et al [10] has suggested wiping the probes with a plain paper towel after every ultrasound examination, although to a degree that is not comparable with that obtained by using an alcohol-soaked paper towel. The other suggestion is wiping the probe with an alcohol-soaked paper towel before examination for patients with immunosuppression disease or after the examination of a patient with a skin infection, and at the end of each working day, additionally, the probe should be wiped with an alcohol-soaked paper towel [11].

According to AIUM (the American Institute of Ultrasound in Medicine) guidelines transducers should be cleaned after each examination with soap and water or quaternary ammonium (a low-level disinfectant) sprays or wipes. The probes must be disconnected from the ultrasound scanner for anything more than wiping or spray cleaning. After removal of the probe cover (when applica-

ble), running water should be used to remove any residual gel or debris from the probe, then with a moist gauze pad or other soft cloth and a small amount of mild nonabrasive liquid soap (household dish-washing liquid is ideal) thoroughly cleanse the probe. Usage of a small brush, especially for crevices and areas of angulation, depending on the design of the particular probe should be considered. Finally the probe should be rinsed thoroughly with running water, and dried with a soft cloth or paper towel [5].

The issues concerning the preparation of ultrasound equipment to work in conditions where pathogen transmission might be possible, are the most rigorously defined in the operating theatre settings. Usually, sterile disposable covers are used for the transducer and the cable, and a sterile plastic cover is placed over the control panel of the equipment. During the examination, sterile ultrasound gel or water or alcoholic solutions are poured directly onto the skin of the patient. These steps do not cause damage to the active surface of the transducer, because it is secured by a protective plastic sleeve. If patients or out-patients admitted to the Radiology Department display skin changes which appear to be infected, it is recommended to spread a thin layer of sterile gel on the skin, and then cover with a thin layer of cling film foil, which effectively prevents contamination of the transducer, or the transducer can be placed in a glove filled with a small amount of gel. Swabs taken from the ultrasound equipment used in the operating theatre in the present study did not demonstrate any bacterial contamination.

Sykes et al [12] report a study where swabs were taken from 5 pieces of ultrasound equipment over the course of three months, seeding samples from the keyboard, gel holder, keyboard and gel itself. On 64.5% of samples environmental organisms were cultured, 7.7% potential pathogens, and no bacterial growth was obtained from remaining 27.8 % of samples. Just as in the present study, greater contamination was found to occur in pieces of equipment used for routine examinations as opposed to scanners used in sites requiring higher standards of disinfection, such as operating theatres.

Taking into account the need for decontamination procedures after each ultrasound examination, the results of Ejtehadi et al [13] are particularly interesting. The author notes that merely removing the gel from the transducer using a non sterile paper towel is an effective way to decontaminate equipment, and this also applies to transducers coming into contact with infected skin surfaces and open wounds. Only after the end of the working day were the transducers subjected to decontamination with a chlorhexidine solution.

In our study ultrasound equipment was used for external scans only. The bacterial isolates from swabs taken

from the ultrasound probes constitute normal bacterial flora of the skin, and do not pose any threat in case of possible transmission. It is important to note the presence of Gram-negative bacilli on swabs taken from the touch screens of two ultrasound units. The presence of Gram-negative bacteria may be associated with excessive humidity in the room where the ultrasound equipment is used, faulty ventilation or failure to comply with the appropriate decontamination procedures. In most cases, the touch panel of the equipment is operated with the left hand without the possibility to transfer pathogens from the skin of the person performing examination to transducer. When transmission of pathogens occurs the results of the cultures of swabs taken from touch panel and transducer should be similar.

Contamination by alert pathogens is unacceptable and could be due to the result of incomplete disinfection procedures or the lack of adherence to them. No alert pathogens were isolated during the course of the present study.

According to the recommendations of one of the producers of the tested ultrasound devices [14], safe and correct operation of the system requires not only the transducer to be cleaned regularly, but the following parts also need to be subjected to weekly cleaning and maintenance: LCD display, equipment housing, touch panel and control panel.

In view of the results obtained in the present study, bacterial growth of swabs taken from the touch screen and control panel, suggests the disinfection protocol recommended by the manufacturer for the equipment housing, touch screen and display monitor appears to be insufficient to maintain the desired level of decontamination. Information regarding cleaning substances is inconsistent and recommends the use of cleaning agents, disinfectant substances and "domestic disinfectants". Analysing the bacterial growth of swabs obtained in centre B there is significant difference in the frequency of positive cultures. Eight out of 10 swabs taken in Radiology Department were positive in contrast to swabs taken from scanners located in the Transplantology Department, Operating Theatre and Intensive Care Unit (ICU) where bacterial growth was obtained in 2 out of 14. Bacteria belonging to environmental microflora were isolated. In centre A all swabs were positive for bacterial growth. Cleaning procedures in both centres were revised and a new checklist for ultrasound room preparation was implemented. These include replacing weak detergent containing wipes with antibacterial disposable wipes for cleaning the surfaces of the ultrasound equipment in constant contact with examiner hands as well as gel bottle.

In the literature there are papers on a variety of bacterial microflora isolated from ultrasound equipment. Our study was conducted as a part of audit activity assuming that personnel adheres to local guidelines on ultrasound equipment decontamination. Diversity of microorganisms is related to the epidemiological situation, as well as the carrier status of the person performing the scan and quite probably, that of the patient. Our isolates generally belong to the normal human microflora and strains typically occurring in the environment. Our results confirm those described by authors from other centres, including university hospitals [9,12,13,13]. However, in our opinion, special attention should be given to the fact that spore-producing microorganisms were present on a number of surfaces of the ultrasound scanner. There were some limitations of our study – only aerobic cultures were performed thus we were unable to assess the presence of clostridia, for example *Clostridium difficile*.

In the literature attention is paid to the critical and semicritical elements (for example: the probe) during the performance of ultrasound examination. We have focused on the problem of the possible transmission of strains associated with non-critical sites namely high frequency touch surfaces of ultrasound devices. Transmission of microorganisms, including multidrug resistant strains, that could lead to colonization of the patient, according to our preliminary observation is related to the differences in the scanning technique by individual doctors. Sonographers differ in habits and skill during ultrasound scan. Furthermore, the presence of an assistant during examination may influence the number of surfaces touched. This issue is not likely taken into account in the standard procedures for the decontamination of equipment recommended by the manufacturers and therefore, the persons responsible for the performance of the decontamination procedure such as technicians, nurses, or in some centers, even doctors (in Poland) will not be aware of these. This issue needs further studies.

Conclusions

Contamination not only affects parts of diagnostic equipment placed in direct contact with the patient, but also, as shown in the study, those surfaces that only medical personnel have had contact with. The isolated strains belong to the human normal and environmental microflora as well as opportunistic strains. No alert pathogens were isolated in our study. It is strongly recommended to implement the proper decontamination procedure for ultrasound scanners including, cleaning not only transducers but also the equipment housing the touch panels and control panels with antimicrobial wipes to reduce

possible risk of infection transmission. This study may lead to the limitation of infections resulting from the use of ultrasound scanners.

Conflict of interest: none

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