Are Non-Critical Medical Devices Potential Sources of Infections in Healthcare Facilities?

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Abstract

This paper reviewed studies that investigated the contamination of non-critical medical devices (NCMDs) and their potential as routes for nosocomial infection transmission. Using MEDLINE Entrez-PubMed, relevant publications were identified using "nosocomial infections" in combination with each of the following: stethoscopes, ultrasound transducers, tourniquets, pens, scissors, white coats, thermometers, blood pressure cuffs, dermatoscopes and otoscopes. Of 258 studies identified, 51 fulfilled the study inclusion criteria and had sufficient information on microbiological assessment of the NCMDs. All the studies reported microbial contamination of NCMDs, with Staphylococcus species as the predominant contaminant. The studies reported that health workers rarely disinfect NCMDs between uses with different patients. Most studies recorded NCMD contamination rates ranging from 25% to 100%. Percentage contamination of NCMDs by methicillin-resistant Staphylococcus aureus ranged from 2.3% to 32%. To reduce the possibility of a nosocomial infection transmission through contaminated NCMDs, disinfection of NCMDs before using them on each patient must be strictly adhered to.

Introduction

Nosocomial infection or hospital-acquired infection is a major public health safety concern for patients and healthcare professionals in both developed and developing countries worldwide (Bagheri Nejad et al. 2011; WHO 2002). Nosocomial infections are defined as infections that patients acquire during the course of receiving treatment for other conditions within a healthcare setting that were not manifest or incubating at the time of admission (CDC 2012).

In recent years, nosocomial infections have reached epidemic proportions and are one of the main concerns in the healthcare arena. Consequently, global awareness has been created about the impact of nosocomial infections, and efforts are being made in various parts of the world towards reducing nosocomial infections by using a multifaceted approach focusing on high-level leadership and commitment, safe practices, clean environments and well-designed processes and systems (WHO 2005). Among the safe practice strategies is the surveillance of device-associated nosocomial infection (DA-NI), which plays a substantial role in hospital infection control and quality assurance (Edwards et al. 2009).

Unfortunately, the primary attention to DA-NI prevention is usually paid to high-risk invasive diagnostic and therapeutic healthcare tools, while the importance of non-critical healthcare tools tends to be underestimated (Uneke and Ijeoma 2011). Non-critical medical devices (NCMDs) are those that come in contact with intact skin but not mucous membranes; they are intended to make topical contact and not penetrate intact skin (CDC 2008). These NCMDs may include but are not limited to stethoscopes, ultrasound transducers, hand gloves, tourniquets, physicians' and nurses' pens, scissors, white coats, thermometers and blood pressure cuffs. Although NCMDs are among the most commonly used devices in healthcare settings, they appear to present a low risk of disease transmission when reused after reprocessed by proper disinfection. However, they are rarely disinfected between patient use by health workers, and there are numerous reports of their contamination by microbial agents (Schabrun et al. 2006; Treakle et al. 2009; Uneke et al. 2008; Uneke and Ijeoma 2010; Wolfe et al. 2009). In most healthcare facilities, sanitation of the NCMDs is neither addressed nor practiced, and the guidelines do not address issues with respect to disinfection of NCMDs between patient use (Obasi et al. 2009).

It is therefore imperative to examine the possibility of contaminated NCMDs serving as potential routes or vehicles of nosocomial infections and what implications this could have on patient safety in healthcare facilities. This is very important because the development of rational control methods for nosocomial infections may require the microbial evaluation of frequently used NCMDs due to their potential of serving as reservoirs of pathogens that can colonize patients and other persons in the hospital environment.

The objective of this paper is to systematically review scientific information and findings from studies that investigated the microbiological contamination of NCMDs. This is done with the view to highlight the importance of contaminated NCMDs as a potential route for nosocomial infection, the patient safety implications, public health policy and operational research prospects.

Methods

A MEDLINE Entrez–PubMed search was initially performed in October 2013 and performed again in May 2014 using the "Advanced" search option in PubMed, and studies reported in English that investigated the contamination of NCMDs were identified. The following are the search strategies used and the publications yielded:

stethoscopes AND nosocomial infection = 72 publications; tourniquet AND nosocomial infection = 27 publications; ultrasound transducer AND nosocomial infection = 11 publications; blood pressure cuffs AND nosocomial infection = 13 publications; thermometer AND nosocomial infection = 59 publications; white coats AND nosocomial infection = 28 publications; scissors AND nosocomial infection = 6 publications; dermatoscope AND nosocomial infection = 2 publications; otoscopes AND nosocomial infection = 2 publication; pens AND nosocomial infection = 38 publications. Using these search strategies, 258 studies were identified and considered for the review. The studies were further reviewed to exclude studies that did not fulfill the major inclusion criteria: (1) studies conducted in hospital environment; (2) studies involving health personnel who come into direct contact with patients; and (3) studies that conducted microbiological laboratory assessment of the NCMDs investigated. Consequently, 207 studies were excluded. The remaining 51 studies fulfilled the study inclusion criteria and were used.

The various reports were systematically reviewed with respect to the location, target users of the NCMDs, prevalence of microbial contamination of the NCMDs, prominent bacterial contaminant and the percentage of NCMDs contaminated by methicillin-resistant Staphylococcus aureus (MRSA). Bibliographies of all papers obtained were checked for additional relevant information, which was included in the review.

Results

The 38 selected studies provided scientific information that enabled meaningful and reasonable comparisons. The NCMDs investigated were obtained from health professionals directly in contact with patients. All of the studies reported that the health workers rarely disinfect the NCMDs between uses with different patients. High levels of bacterial contamination of NCMDs were recorded in most of the studies, with Staphylococcus species as the most prominent contaminant. A summary of the profile of the studies reviewed is provided in Table 1.

Table 1. Summary of the profile of the studies on assessment of bacterial contamination of non-critical medical devices in healthcare facilities

Type of NCMD	Number of studies included	Total number of NCMDs screened in all studies	Proportion (%) positive/contaminated NCMDs	Most prominent bacterial contaminant	Range of proportion (%) contaminated by MRSA
Stethoscopes	17	1,698	1,242 (73.1)	*Staphylococcus*	0–32
Tourniquets	7	550	196 (35.6)	*Staphylococcus*	0–25
Ultrasound transducers/probes	4	858	214 (24.9	*Staphylococcus*	0
Blood pressure cuffs	4	405	284 (70.1)	*Staphylococcus*	2–8
Thermometers	2	238	113 (47.5)	*Staphylococcus*	0
White coats	8	777	316 (40.7)	*Staphylococcus*	3.5–18
Scissors	2	235	185 (78.7)	*Staphylococcus*	0
Dermatoscopes	1	112	73 (65.2)	*Staphylococcus*	0
Otoscopes	2	95	60 (63.2)	*Staphylococcus*	0–9.5
Pens	4	222	173 (77.9)	*Staphylococcus*	0–7.3

Majority of the studies (17 publications) provided information on the potential of stethoscopes to transmit nosocomial infections (Bukharie et al. 2004; Cohen et al. 1997; Datta et al. 2013; Gopinath et al. 2011; Lecat et al. 2009; Madar et al. 2005; Marinella et al. 1997; Merlin et al. 2009; Pandey et al. 2010; Rusell et al. 2012; Sood et al. 2000; Tang et al. 2011; Uneke et al. 2008, 2010; Whittington et al. 2009; Youngster et al. 2008; Zuliani et al. 2002) (Table 2). Of these, seven studies were conducted in developed countries and 10 were done in developing countries. The number of stethoscopes screened in the various studies ranged from 40 to 300, and the prevalence of bacterial contamination ranged from 10.9% to 100% (Table 2). As high as 20%, 21% and 32% MRSA contamination was recorded in studies conducted in Slovakia, India and the USA, respectively (Table 2).

Table 2. Outcome of studies that investigated the microbial contamination of stethoscopes used by health professionals

Authors/ year of publication	Country	Target users	Number of stetho-scopes screened	Number (%) contaminated with bacteria on diaphragm	Most promi-nent bacterial contaminant	Percentage contaminated by MRSA
Cohen et al. (1997)	Israel	Physicians	55	55 (100)	*Staphylococcus*	7.3
Marinella et al. (1997)	USA	Physicians, nurses, medical students	40	40 (100)	Coagulase-negative staphylococci	0
Sood et al. (2000)	India	Health workers	106	64 (60)	*Staphylococcus*	21
Zuliani Maluf et al. (2002)	Brazil	Medical staff and students	300	261 (87)	*Staphylococcus*	NA
Bukharie et al. (2004)	Saudi Arabia	Health workers	100	30 (30)	Gram-positive bacilli	0
Madar et al. (2005)	Slovakia	Physicians, medical students	110	101 (91.8)	*Staphylococcus*	20
Youngster et al. (2008)	Israel	Physicians, medical students	43	39 (86)	*Staphylococcus*	2.3
Uneke et al. (2008)	Nigeria	Medical students	201	161 (80.1)	*Staphylococcus*	NA
Whittington et al. (2009)[21]	UK	Health workers	46	5 (10.9)	*Staphylococcus*	0
Lecat et al. (2009)	USA	Health workers	99	99 (100)	*Staphylococcus*	NA
Merlin et al. (2009)	USA	Health workers	50	16 (32)	MRSA	32
Pandey et al. (2010)	India	Health workers	80	44 (55)	*Staphylococcus*	7.3
Uneke et al. (2010)	Nigeria	Health workers	107	84 (79)	*Staphylococcus*	NA
Tang et al. (2011)	Canada	Physicians, nurses	100	70 (70)	Coagulase-negative staphylococci	0
Gopinath et al. (2011)	India	Health workers	40	11 (27.5)	Enterococci	NA
Russell et al. (2012)	USA	Health workers	141	141 (100)	*Staphylococcus*	0
Datta et al. (2013)	India	Health workers	80	21 (26.3)	*Staphylococcus*	50

NA = not assessed/not reported.

All seven studies that described the microbial contamination of tourniquets were conducted in developed countries (Ahmed et al. 2009; Brennan et al. 2009; Elhassan et al. 2012; Leitch et al. 2006; Pinto et al. 2011; Rourke et al. 2001; Thompson et al. 2011). The number of tourniquets screened ranged from 20 to 200, and prevalence of bacterial contamination ranged from 5% to 100% (Table 3). A 25% MRSA contamination was recorded in one of the studies (Leitch et al. 2006).

The four studies that investigated ultrasound transducers/probes as potential tools for nosocomial infection transmission were all conducted in developed countries (Kac et al. 2007, 2010; Patterson et al. 1996; Schabrun et al. 2006). The number of (or times) ultrasound transducers/probes screened ranged from 44 to 440, and prevalence of bacterial contamination ranged from 3.4% to 92% (Table 4). No MRSA contamination was recorded.

Table 3. Outcome of studies that investigated the microbial contamination of tourniquets used by health professionals

Authors/year of publication	Country	Target users	Number of tourniquets screened	Number (%) contaminated with bacteria	Most prominent bacterial contaminant	Percentage contaminated by MRSA
Rourke et al. (2001)	UK	Health workers	200	10 (5)	*Staphylococcus*	0
Leitch et al. (2006)	UK	Health workers	131	32 (25)	MRSA	25
Ahmed et al. (2009)	UK	Health workers	20	20 (100)	Coagulase-negative staphylococci	10
Brennan et al. (2009)	Ireland	Health workers	15	15 (100)	*Staphylococcus*	NA
Thompson et al. (2011)	UK	Health workers	34	23 (67.6)	Coagulase-negative staphylococci	NA
Pinto et al. (2011)	Australia	Health workers	100	78 (78)	MROs	14
Elhassan and Dixon (2012)	UK	Junior doctors, nursing staff	50	18 (36)	*Staphylococcus*	12

NA = not assessed/not reported.

Table 4. Outcome of studies that investigated the microbial contamination of ultrasound transducers/probes used by health professionals

Authors/year of publication	Country	Target users	Number of (or times) transducers/probes screened	Number (%) contaminated with bacteria	Most prominent bacterial contaminant	Percentage contaminated by MRSA
Patterson et al. (1996)	USA	Health workers	191	175 (92)	*Staphylococcus*	NA
Schabrun et al. (2006)	Australia	Health workers	44	12 (27.2)	*Staphylococcus*	0
Kac et al. (2007)	France	Health workers	183	12 (6.6)	*Staphylococcus*	NA
Kac et al. (2010)	France	Health workers	440	15 (3.4)	*Staphylococcus*	NA

NA = not assessed/not reported.

Table 5 shows the outcome of studies that investigated the potential of nosocomial infection transmission by blood pressure cuffs (de Gialluly et al. 2006; Uneke and Ijeoma 2010; Walker et al. 2006) and thermometers (Smith et al. 1981; Uneke and Ijeoma 2011). The number of blood pressure cuffs screened ranged from 24 to 203, and prevalence of bacterial contamination ranged from 45% to 100% (Table 4). Up to 8% MRSA contamination was recorded in one of the studies. In the study that was conducted in Nigeria (Uneke and Ijeoma 2011), 62% of the 58 thermometers screened had bacterial contamination (Table 5). MRSA contamination of the thermometers was not assessed.

Table 5. Outcome of studies that investigated the microbial contamination of blood pressure cuffs, thermometers and white coats used by health professionals

Authors/ year of publication	Country	Target users	Number of (or times) transducers/ probes screened	Number (%) contaminated with bacteria	Most prominent bacterial contaminant	Percentage contaminated by MRSA
Blood pressure cuffs						
de Gialluly et al. (2006)	France	Health workers	203	95 (45)	*Staphylococcus*	4.3
Walker et al. (2006)	UK	Health workers	24	24 (100)	*Staphylococcus*	8
Uneke and Ijeoma (2011)	Nigeria	Health workers	28	23 (82.1)	*Staphylococcus*	NA
Grewal et al. (2013)	Australia	Health workers	150	142 (94.7)	*Staphylococcus*	2
Thermometers						
Smith et al. (1981)	USA	Health workers	180	77 (43)	*Staphylococcus*	NA
Uneke and Ijeoma (2011)	Nigeria	Health workers	58	36 (62.1)	*Staphylococcus*	NA
White coats						
Wong et al. (1999)	UK	Physicians	100	25 (25)	*Staphylococcus*	NA
Treakle et al. (2009)	USA	Health workers	149	34 (23)	*Staphylococcus*	18
Priya et al. (2009)	India	Interns, graduate students, faculty members	51	39 (76.5)	Gram-positive cocci	NA
Pandey et al. (2010)	India	Physicians	130	37 (28.5)	*Staphylococcus*	7.3 (total isolates)
Uneke and Ijeoma (2010)	Nigeria	Physicians	103	94 (91.3)	*Staphylococcus*	NA
Banu et al. (2012)	India	Medical students	100	37 (28.9)	*Staphylococcus*	NA
Malini et al. (2012)	India	Medical students	30	30 (100)	*Staphylococcus*	NA
Singh et al. (2013)	Canada	Staff and students of veterinary teaching hospital	114	20 (17.5)	*MRSA*	3.5

NA = not assessed/not reported.

The potential of white coats to transmit nosocomial infection was investigated by seven of the identified studies (Banu et al. 2012; Pandey et al. 2010; Priya et al. 2009; Treakle et al. 2009; Uneke and Ijeoma 2010; Wong et al. 1991). The number of white coats screened ranged from 51 to 149, and prevalence of bacterial contamination ranged from 23% to 91.3% (Table 5). Up to 18% MRSA contamination was recorded in one of the studies.

The outcome of the studies that investigated the potential of nosocomial infection transmission by scissors, dermatoscopes and otoscopes is presented in Table 6 (Cohen et al. 1997; Embil et al. 2002; Hausermann et al. 2006; Korkmaz et al. 2013). Of the 42 otoscopes screened from physicians in Israel, 90.4% had bacterial contamination, of which 9.5% were MRSA (Cohen et al. 1997).

Table 6. Outcome of studies that investigated the microbial contamination of scissors, dermatoscopes, otoscopes and pens used by health professionals

Authors/ year of publication	Country	Target users	Number of devices screened	Number (%) contaminated with bacteria	Most prominent bacterial contaminant	Percentage contaminated by MRSA
Scissors						
Embil et al. (2002)	Canada	Health workers	232	182 (78.4)	*Staphylococcus*	NA
Nwankwo 2012	Nigeria	Health workers	3	3 (100)	*Coagulase-negative staphylococci*	NA
Dermatoscope						
Hausermann et al. (2006)	Switzerland	Health workers	112	73 (65.2)	*Staphylococcus*	NA
Otoscope						
Cohen et al. (1997)	Israel	Physicians	42	38 (90.4)	*Staphylococcus*	9.5
Korkmaz et al. (2013)	Turkey	Otolaryngologists	53	22 (41.5)	*Staphylococcus*	NA
Pens						
Bhat et al. (2009)	India	Physicians, nurses	75	26 (34.6)	*Staphylococcus epidermidis*	2.7
Sim et al. (2009)	UK	Physicians	64	64 (100)	*Staphylococcus*	NA
Wolfe et al. (2009)	USA	Respiratory therapists	20	17 (85)	*Coagulase-negative staphylococci*	0
Pandey et al. (2010)	India	Physicians	100	66 (66)	*Staphylococcus*	7.3 (total isolates)

NA = not assessed/not reported.

Four studies investigated the microbial contamination of physicians' pens (Bhat et al. 2009; Pandey et al. 2010; Sim et al. 2009; Wolfe et al. 2009) (Table 5). In one of the studies, there was a 100% contamination of the physicians' pens (Sim et al. 2009), while in another study, of the 34.6% of the pens contaminated, 2.7% had MRSA (Pandey et al. 2010).

Discussion

The high rate of microbial contamination of the so-called NCMDs demonstrated by the studies reviewed suggests that these devices might be a potential route for the transmission of nosocomial infections in health facilities. This is a serious public health issue especially in healthcare facilities in middle- and

low-income settings where effective infection control systems and standard infection control operational policies are either lacking or non-functional. The WHO Nosocomial Infection Fact Sheet (http://www.who.int/gpsc/country_work/gpsc_ccisc_fact_sheet_en.pdf) reported that most countries lack surveillance systems for healthcare-associated infections and those that do have systems often struggle with the complexity and lack of standardized criteria for diagnosing and preventing the infections. This is a common scenario in most health facilities in developing countries, and as standard infection control systems are not in place, it would not be surprising if little or no attention is given to DA-NIs.

The NCMDs reviewed in this paper are undoubtedly among the most frequently used healthcare devices by health workers when attending to patients. Because they are not usually used for invasive procedures, little attention is paid to their disinfection between patient care by health workers, as indicated by the studies reviewed. For instance, in some of the studies that investigated microbial contamination of stethoscopes, a considerable number of physicians admitted they never disinfected their stethoscopes for several months (Pandey et al. 2010; Uneke et al. 2010; Zuliani Maluf et al. 2002). There is sufficient evidence that showed that the lack of adherence to simple nosocomial infection control guidelines, including hand hygiene and disinfection of medical devices used between patient care, might enhance nosocomial infection transmission (WHO 2002). The high rate of non-compliance with hand hygiene, for instance, which is a well-established phenomenon among health workers in most healthcare facilities, may also be contributing to the DA-NI burden (Pittet 2001). This is because pathogen-contaminated hands of a health worker not only directly transmit these infectious agents to patients, but the pathogens on contaminated hands also could colonize medical devices used on patients and could further jeopardize patient safety.

The ability of the pathogens to attach and establish themselves on the components or parts of NCMDs that come into contact with patients' skin was demonstrated in some of the studies reviewed, e.g., diaphragm of stethoscopes (Cohen et al. 1997; Zuliani Maluf et al. 2002) and fabrics of blood pressure cuffs (de Gialluly et al. 2006; Walker et al. 2006). During the diagnosis of infected skin, it is possible for pathogens to be transferred to another patient during diagnosis using the same NCMDs without prior sterilization or disinfection (Obasi et al. 2009). The skin surface contacted by the NCMDs, e.g., stethoscope diaphragm, may be broken or open due to a variety of causes, including surgical incision, weeping dermatitis, infected lesion, rash, abrasion, laceration, puncture wound, needle sticks, open and infected wounds and various tubes, drains, ostomies, topical irritation, micro-cuts and skin breakdown (Patent Storm 2004).

It is of public health concern that some of the studies reviewed in this paper indicated high percentages of MRSA contamination of the NCMDs, including stethoscopes (32%) (Merlin et al 2009), tourniquets (25%) (Leitch et al 2006), blood pressure cuffs (8%) (Walker et al. 2006), white coats (18%) (Treakle et al. 2009) and otoscopes (9.5%) (Cohen et al. 1997). There is therefore the potential of transmitting such MRSA from one patient to another from these contaminated NCMDs, especially in the intensive care unit (van den Berg et al. 2000; Whittington et al. 2009). These MRSA and other antibiotic-resistant organisms are capable of initiating severe infectious epidemics in a hospital environment, and the infected patients could require contact isolation and aggressive treatment to prevent the spread of the organisms (Gupta et al. 2004; van den Berg et al. 2000). Although DA-NIs do not usually receive public attention except when there are epidemics, it is clearly unethical to wait until this has occurred before taking appropriate measures to promote patient safety. According to the WHO

Nosocomial Infection Fact Sheet (http://www.who.int/gpsc/country_work/gpsc_ccisc_fact_sheet_en.pdf), healthcare-associated infections usually receive public attention only when there are epidemics; although often hidden from public attention, the very real endemic, ongoing problem is one that no institution or country can claim to have solved, despite many efforts.

Many basic nosocomial infection prevention and control measures, such as appropriate hand hygiene, correct application of basic precautions during invasive and non-invasive procedures and sanitizing of medical devices between uses with patients, are simple and low-cost, but require staff accountability and behavioural change (WHO 2002). Most of the studies reviewed in this paper demonstrated that simply cleaning the NCMDs with disinfectants before using them with each patient considerably reduces or eliminates microbial contaminants on the devices.

Lecat et al. (2009) showed that cleaning the diaphragm of stethoscopes with an ethanol-based cleanser and isopropyl alcohol pads significantly reduced the colony-forming unit counts by 92.8% and 92.5%, respectively. In the UK, Ahmed and colleagues noted from their study on cleaning tourniquets with detergent and disinfectant wipes that there was a 99.2% reduction in contamination of the tourniquets five minutes after cleaning (Ahmed et al. 2009). Therefore, the development of rational control methods for nosocomial infections requires the consideration of frequently used medical devices such as the NCMDs. This is because the NCMDs have the potential of serving as vectors or reservoirs of pathogens that can colonize patients and other persons in the hospital environment. The need for a change in the attitudes of health workers towards sanitation of NCMDs between uses with different patients cannot be overstated because of the patient safety implications. According to Burke (2003), identification of the risk factors of nosocomial infections permits elucidation of those that are alterable from those that are not and facilitates the development of targeted interventions to reduce the risk of infection. The findings of this review therefore make a case for the classification of contaminated NCMDs as potential transmitters of nosocomial infection, and any infection control policy must take their continuous disinfection into account.

According to the WHO (2008), every patient has the right to be treated using the safest technology available in health facilities. This implies freedom from unnecessary or potential harm associated with healthcare, including that which may be caused by medical devices. WHO (2008) further noted that all healthcare professionals and institutions have obligations to provide safe and quality healthcare and to avoid unintentional harm to patients. Kohn et al. (2000), in a report on building a safer health system, advocated the need to establish processes or structures that, when applied, reduce the probability of adverse events resulting from exposure to the healthcare system across a range of diseases and procedures. This should be applied to the control of DA-NI, paying special attention to the NCMDs.

Conclusion

The studies reviewed demonstrated that NCMDs can harbour potential infectious pathogens, including antibiotic-resistant bacteria. It is pertinent to state, however, that most of the studies reviewed were unable to unequivocally demonstrate that the NCMDs actually transmitted the microbial contaminants. This is a major limitation with the studies reviewed. An exception was the study by Gupta et al. (2004), who used multiple logistic regression analysis to show that exposure to a health worker wearing artificial fingernails was associated with infection or colonization by a clone of extended-spectrum beta-lactamase-producing Klebsiella pneumoniae in a neonatal intensive care unit.

The inability of the majority of the studies reviewed to clearly demonstrate that the contaminated NCMDs were responsible for the transmission of nosocomial infections was largely due to the types of study designs used, of which the majority were cross-sectional studies. Future studies with a more complex design, such as randomized controlled designs, would be required to accomplish this. Nevertheless, all the studies did show that the NCMDs were contaminated with pathogenic bacteria and that poor NCMD cleaning/disinfection practices were significantly associated with this contamination. Based on the findings of this review, a patient safety initiative is urgently needed that can be implemented in a resource-poor setting and that must incorporate effective disinfection and handling of NCMDs as part of policy components. The following strategies have been advocated by the studies reviewed: (1) institution of policy reforms on nosocomial infection, which must include effective disinfection, handling and maintenance of NCMDs; (2) making it compulsory for NCMDs to be sanitized before using them on each patient; (3) provision of disinfectants and sanitizers at each point of patient care to encourage compliance; (4) involving both hospital management and the health worker associations in promoting compliance; (5) instituting staff education and accountability improvement mechanisms on nosocomial infection, including DA-NIs; (6) establishing an audit or feedback mechanism to monitor compliance; and (7) the use of disposable NCMDs where possible, e.g., disposable stethoscopes, tourniquets and thermometers, especially for clinical high-risk environments. Although this strategy is definitely out of reach of most resource-poor settings, under such clinical high-risk situations, healthcare workers and health facilities management should ensure strictest adherence to standard device disinfection practices. Finally, the management of healthcare facilities should ensure that competent, conscientious and safety-conscious healthcare workers are in front-line services and receive support to provide the safe delivery of healthcare.

References

Ahmed, S.M., R. Ahmad, R. Case and R.F. Spencer. 2009. "A Study of Microbial Colonization of Orthopaedic Tourniquets." *Annals of Royal College of Surgery of England* 91(2):131–34.

Bagheri Nejad, S., B. Allegranzi, S.B. Syed, B. Ellis and D. Pittet. 2011. "Health-Care-Associated Infection in Africa: A Systematic Review." *Bulletin of the World Health Organization* 89(10):757–65.

Banu, A., M. Anand and N. Nagi. 2012. "White Coats as a Vehicle for Bacterial Dissemination." *Journal of Clinical Diagnosis and Research* 6(8): 1381–84.

Bhat, G.K., L. Singhal, A. Philip and T. Jose. 2009. "Writing Pens as Fomites in Hospital." *Indian Journal of Medicine and Microbiology* 27: 84–85.

Brennan, S.A., R.J. Walls, E. Smyth, T. Al Mulla and J.M. O'Byrne. 2009. "Tourniquets and Exsanguinators: A Potential Source of Infection in the Orthopedic Operating Theater?" *Acta Orthopaedica* 80(2): 251–55.

Bukharie, H.A., H. Al-Zahrani, A.M. Rubaish and M.F. Abdulmohsen. 2004. "Bacterial Contamination of Stethoscopes." *Journal of Family and Community Medicine* 11(1): 31–33.

Burke, J.P. 2003. "Infection Control - A Problem for Patient Safety." *New England Journal of Medicine* 348: 651–56.

Centre for Disease Control and Prevention. 2008. *Guideline for Disinfection and Sterilization in Healthcare Facilities, 2008*. Retrieved October 10, 2013. <http://www.cdc.gov/hicpac/Disinfection_Sterilization/2_approach.html>

Centers for Disease Control and Prevention. 2012. *Healthcare-Associated Infections (HAIs)*. Retrieved October 10, 2013. <http://www.cdc.gov/HAI/burden.html>

Cohen, H.A., J. Amir, A. Matalon, R. Mayan, S. Beni and A. Barzilai. 1997. "Stethoscopes and Otoscopes–a Potential Vector of Infection?" *Family Practice* 14(6): 446–49.

Datta, P., N. Bansal, and H. Chander. 2013. "Hand-Held Hazards by Health-Care Workers." *Indian Journal of Medical Microbiology* 31(3): 320–21.

de Gialluly, C., V. Morange, E. de Gialluly, J. Loulergue, N. van der Mee and R. Quentin. 2006. "Blood Pressure Cuff as a Potential Vector of Pathogenic Microorganisms: A Prospective Study in a Teaching Hospital." *Infection Control and Hospital Epidemiology* 27(9): 940–43.

Edwards, J.R., K.D. Peterson, Y. Mu, S. Banerjee, K. Allen-Bridson, G. Morrel et al. 2009. "National Healthcare Safety Network (NHSN) Report: Data Summary for 2006 through 2008, Issued December 2009." *American Journal of Infection Control* 37: 783–805.

Elhassan. H.A. and T. Dixon. 2012. "MRSA Contaminated Venepuncture Tourniquets in Clinical Practice." *Postgraduate Medical Journal* 88(1038): pp. 194–97.

Embil, J.M., G.G. Zhanel, P.J. Plourde and D. Hoban. 2002. "Scissors: A Potential Source of Nosocomial Infection." *Infection Control and Hospital Epidemiology* 23(3): 147–51.

Gopinath, K.G., S. Stanley, E. Mathai and G.M. Chandy. 2011. "Pagers and Stethoscopes as Vehicles of Potential Nosocomial Pathogens in a Tertiary Care Hospital in a Developing Country." *Tropical Doctor* 41(1): 43–45.

Grewal, H., K. Varshney, L.C. Thomas, J. Kok and A. Shetty. 2013. "Blood Pressure Cuffs as a Vector for Transmission of Multi-Resistant Organisms: Colonisation Rates and Effects of disinfection." *Emergency Medicine Australasia* 25(3): 222–26.

Gupta, A., P. Della-Latta, B. Todd, P. San Gabriel, J. Haas, F. Wu et al. 2004. "Outbreak of Extended-Spectrum Beta-Lactamase-Producing Klebsiella Colonization in a Neonatal Intensive care Unit Linked to Artificial Nails." *Infection Control and Hospital Epidemiology* 25(3): 210–15.

Hausermann, P., A. Widmer and P. Itin. 2006. "Dermatoscope as Vector for Transmissible Diseases – No Apparent Risk of Nosocomial Infections in Outpatients." *Dermatology* 212(1): 27–30.

Kac, G., M. Gueneret, A. Rodi, E. Abergel, C. Grataloup, N. Denarié et al. 2007. "Evaluation of a New Disinfection Procedure for Ultrasound Probes Using Ultraviolet Light." *Journal of Hospital Infection* 65(2): 163–68.

Kac, G., I. Podglajen, A. Si-Mohamed, A. Rodi, C. Grataloup and G. Meyer. 2010. "Evaluation of Ultraviolet C for Disinfection of Endocavitary Ultrasound Transducers Persistently Contaminated Despite Probe Covers." *Infection Control and Hospital Epidemiology* 31(2): 165–70.

Kohn, L., J. Corrigan, and M. Donaldson, eds. 2000. *To Err is Human: Building a Safer Health System*. Washington, DC: Committee on Quality of Health Care in America, Institute of Medicine, National Academy Press.

Korkmaz, H., Y. Cetinkol and M. Korkmaz. 2013. "Cross-Contamination and Cross-Infection Risk of Otoscope Heads." *European Archives of Otorhinolaryngology* 270(12): 3183–86.

Lecat, P., E. Cropp, G. McCord and N.A. Haller. "Ethanol-Based Cleanser Versus Isopropyl Alcohol to Decontaminate Stethoscopes." *American Journal of Infection Control* 37(3): 241–43.

Leitch, A., I. McCormick, I. Gunn and T. Gillespie. 2006 "Reducing the Potential for Phlebotomy Tourniquets to Act as a Reservoir for Methicillin-Resistant Staphylococcus aureus." *Journal of Hospital Infection* 63(4): 428–31.

Madar, R., E. Novakova and T. Baska. 2005. "The Role of Non-Critical Health-Care Tools in the Transmission of Nosocomial Infections." *Bratislavske Lekarske Listy* 106(11): 348–50.

Malini, M., T.K. Thomas, D. Bhargava and S. Girija. 2012. "Microbiology of the White Coat in a Dental Operatory." *Indian Journal of Dental Research* 23(6): 841.

Marinella, M.A., C. Pierson and C. Chenoweth.1997. "The Stethoscope. A Potential Source of Nosocomial Infection?" *Archives of Internal Medicine* 157(7): 786–90.

Merlin, M.A., M.L. Wong, P.W. Pryor, K. Rynn, A. Marques-Baptista, R. Perritt et al. 2009. "Prevalence of Methicillin-Resistant Staphylococcus aureus on the Stethoscopes of Emergency Medical Services Providers." *Prehospital Emergency Care* 13(1): 71–74.

Nwankwo, E. 2012. "Isolation of Pathogenic Bacteria from Fomites in the Operating Rooms of a Specialist Hospital in Kano, North-Western Nigeria." *Pan African Medical Journal* 12: 90.

Obasi, C., A. Agwu, W. Akinpelu, R. Hammons, C. Clark, R. Etienne-Cummings et al. 2009. "Contamination of Equipment in Emergency Settings: an Exploratory Study with a Targeted Automated Intervention." *Annals of Surgical Innovations and Research* 3: 8.

Pandey A., A.K. Asthana, R. Tiwari, L. Kumar, A. Das and M. Madan. 2010. "Physician Accessories: Doctor, What You Carry Is Every Patient's Worry?" *Indian Journal of Pathology and Microbiology* 53(4): 711–13.

Patterson, S.L., M. Monga, J.B. Silva, K.D. Bishop and J.D. Blanco. 1996. "Microbiologic Assessment of the Transabdominal Ultrasound Transducer Head." *Southern Medical Journal* 89(5): 503–04.

Pinto, A.N., T. Phan, G. Sala, E.Y. Cheong, S. Siarakas and T. Gottlieb. 2011. "Reusable Venesection Tourniquets: A Potential Source of Hospital Transmission of Multiresistant Organisms." *Medical Journal of Australia* 195(5): 276–79.

Pittet, D. 2001. "Compliance with Hand Disinfection and its Impact on Hospital-Acquired Infections." *Journal of Hospital Infection* 48(Suppl. A): S40–46.

Priya, H., S. Acharya, M. Bhat and M. Ballal. 2009. "Microbial Contamination of the White Coats of Dental Staff in the Clinical Setting." *Journal of Dental Research, Dental Clinics, Dental Prospects* 3(4): 136–40.

Rourke, C., C. Bates and R.C. Read. 2001. "Poor Hospital Infection Control Practice in Venepuncture and use of Tourniquets." *Journal of Hospital Infection* 49(1): 59–61.

Russell, A., J. Secrest and C. Schreeder. 2012. "Stethoscopes as a Source of Hospital-Acquired Methicillin-Resistant Staphylococcus aureus." *Journal of Perianesthesia Nursing* 27(2): 82–87.

Schabrun, S., L. Chipchase and H. Rickard. 2006. "Are Therapeutic Ultrasound Units a Potential Vector for Nosocomial Infection?" *Physiology Research International* 11(2): 61–71.

Sim, D.A., N. Feasey, S. Wren, A. Breathnach and G. Thompson. 2008. "Cross-Infection Risk of Felt-Tipped Marker Pens in Cataract Surgery." *Eye (London, England)* 23(5): 1094–97.

Singh, A., M. Walker, J. Rousseau, G.J. Monteith and J.S. Weese. 2013. "Methicillin-Resistant Staphylococcal Contamination of Clothing Worn by Personnel in a Veterinary Teaching Hospital." *Veterinary Surgery* 42(6): 643–48.

Smith, L., H.N. Prince and E. Johnson. 1981. "Bacteriologic Studies on Electronic Hospital Thermometers." *Infection Control* 2(4): 315–16.

Sood, P., B. Mishra and A. Mandal. 2000. "Potential Infection Hazards of Stethoscopes." *Journal of Indian Medical Association* 98(7): 368–70.

Tang, P.H., A. Worster, J.A. Srigley, and C.L. Main. 2011. "Examination of Staphylococcal Stethoscope Contamination in the Emergency Department (Pilot) Study (EXSSCITED Pilot Study)." *Canadian Journal of Emergency Medicine* 13(4): 239–44.

Thompson, S.M., M. Middleton, M. Farook, A. Cameron-Smith, S. Bone and A. Hassan. 2011. "The Effect Of Sterile Versus Non-Sterile Tourniquets on Microbiological Colonization in Lower Limb Surgery." *Annals of Royal College of Surgery of England* 93(8): 589–90.

Treakle, A.M., K.A. Thom, J.P. Furuno, S.M. Strauss, A.D. Harris and E.N. Perencevich. 2009. "Bacterial Contamination of Health Care Workers' White Coats." *American Journal of Infection Control* 37(2): 101–05.

Uneke, C.J. and P.A. Ijeoma. 2010. "The Potential for Nosocomial Infection Transmission by White Coats Used by Physicians in Nigeria: Implications for Improved Patient-Safety Initiatives." *World Health and Population* 11(3): 44–54.

Uneke, C.J. and P.A. Ijeoma. 2011. "The Potential for Transmission of Hospital-Acquired Infections by Non-Critical Medical Devices: The Role of Thermometers and Blood Pressure Cuffs." *World Health and Population* 12(3): 5–12.

Uneke, C.J., A. Ogbonna, P.G. Oyibo and U. Ekuma. 2008. "Bacteriological Assessment of Stethoscopes Used by Medical Students in Nigeria: Implications for Nosocomial Infection Control." *World Health and Population* 10(4): 53–61.

Uneke, C.J., A. Ogbonna, P.G. Oyibo and C.M. Onu. 2010. "Bacterial Contamination of Stethoscopes Used by Health Workers: Public Health Implications." *Journal of Infections in Developing Countries* 4(7): 436–41.

van den Berg, R.W., H.L. Claahsen, M. Niessen, H.L. Muytjens, K. Liem and A. Voss. 2000. "Enterobacter cloacae Outbreak in the NICU Related to Disinfected Thermometers." *Journal of Hospital Infection* 45(1): 29-34.

Walker, N., R. Gupta and J. Cheesbrough. 2006. "Blood Pressure Cuffs: Friend or Foe?" *Journal of Hospital Infection* 63(2): 167–69.

Whittington, A.M., G. Whitlow, D. Hewson, C. Thomas and S.J. Brett. 2009. "Bacterial Contamination of Stethoscopes on the Intensive Care Unit." *Anaesthesia* 64(6): 620–24.

Wolfe, D.F., S. Sinnett, J.L. Vossler, J. Przepiora and B.G. Engbretson. 2009. "Bacterial Colonization of Respiratory Therapists' Pens in the Intensive Care Unit." *Respiratory Care* 54(4): 500–03.

Wong, D., K. Nye and P. Hollis. 1991. "Microbial Flora on Doctors' White Coats." *British Medical Journal* 303(6817): 1602–04.

World Health Organization. 2002. *Prevention of Hospital-Acquired Infections: a Practical Guide*. Geneva: World Health Organization.

World Health Organization. 2005. *World Alliance for Patient Safety – Global Patient Safety Challenge 2005–2006*. Geneva: World Health Organization.

World Health Organization. 2008. *Patient Safety in African Health Services: Issues and Solutions*. Brazzaville: World Health Organization.

Youngster, I., M. Berkovitch, E. Heyman, Z. Lazarovitch and M. Goldman. 2008. "The Stethoscope as a Vector of Infectious Diseases in the Paediatric Division." *Acta Paediatrica* 97(9): 1253–55.

Zuliani Maluf, M.E., A.F. Maldonado, M.E. Bercial and S.A. Pedroso. 2002. "Stethoscope: A Friend or an Enemy?" *Sao Paulo Medical Journal* 120(1): 13–15.