Contamination of pulse oximeter probes before and after decontamination in two intensive care units

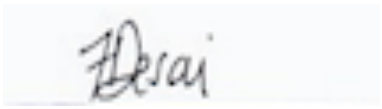
Farriel Desai

A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg in partial fulfilment of the requirements for the degree of Master of Medicine in the branch of Anaesthesiology.

Johannesburg, 2020

Declaration

I, Farriel Desai declare that this research report is my own unaided work. It is being submitted for the Degree of Master of Medicine in the branch of Anaesthesiology at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



25 May 2020

Dedication

I dedicate this piece of work to my father, Faizel Omar Desai and my mother, Salma Desai for their belief in me and unending support. My pillars of strength I rest on.

To my loving husband, Hassan Suleman, for his emotional support and continuous encouragement. My solace.

To my daughter, Hannah Suleman, for making everything an incentive always.

Abstract

Background

The internal surfaces of pulse oximeter probes may be overlooked as “hot spots” for pathogenic microorganisms in an intensive care unit (ICU), thereby contributing to the high incidence of hospital acquired infections.

Aim

The aim of this study was to determine the growth and identification of microorganisms on pulse oximeter probes in the multidisciplinary ICU (MICU) at Charlotte Maxeke Johannesburg Academic Hospital and the burns ICU (BICU) at Chris Hani Baragwanath Academic Hospital before and after decontamination.

Methods

This was a cross-sectional, descriptive, comparative and contextual study, using purposive sampling. Data was collected from the internal surfaces of 34 pulse oximeter probes in a MICU and BICU. Each pulse oximeter probe was swabbed before and after decontamination. The endemic microorganism profile for the two ICUs was obtained from a laboratory database.

Results

Internal surfaces of 31 (91%) pulse oximeter probes were contaminated with nine different pathogenic microorganisms pre-decontamination. *Acinetobacter baumannii*, *Klebsiella pneumoniae* and *Pseudomonas aeruginosa* were commonly endemic to both ICUs and were the most frequently isolated microorganisms. *Staphylococcus aureus* was the most endemic microorganism to both ICUs with only two pulse oximeter probes isolating *Staphylococcus aureus* on their internal surfaces. Of the internal surfaces of pulse oximeter probes, 6 (18%) remained contaminated post-decontamination, with a microorganism growth reduction of 80% (p=0.0001).

Conclusion

The internal surfaces of pulse oximeter probes may serve as “hot spots” for an array of pathogens with potential to cause infection and outbreaks in ICUs. Decontamination of the internal surfaces of pulse oximeter probes should be emphasised.

Publication

This draft article was submitted to the Southern African Journal of Critical Care (SAJCC) and has been published in this journal.

Table of Contents

List of figures

Figure

List of tables

Abbreviations

BICU	Burns intensive care unit
CDC	Centres for Disease Control and Prevention
CDW	Corporate Data Warehouse
CFUs	Colony forming units
CHBAH	Chris Hani Baragwanath Academic Hospital
CMJAH	Charlotte Maxeke Johannesburg Academic Hospital
CNS	Coagulase negative Staphylococcus
CI	Confidence interval
EPA	Environmental Protection Agency
FD	Farriel Desai
GNB	Gram-negative bacilli
HAIs	Hospital acquired infections
HCW	Healthcare worker
HIV	Human immunodeficiency virus
ICU	Intensive care unit
MICU	Multidisciplinary ICU
MRSA	Methicillin-resistant Staphylococcus aureus
RMDs	Reusable medical devices
SASA	South African Society of Anaesthesiologists
VRE	Vancomycin-resistant Enterococcus
WHO	World Health Organization

Statement

The Research Report consists of a literature review, draft article, study proposal and appendices. The study proposal is included for background reference and is not for examination.

The formatting of this Research Report complies with the University of the Witwatersrand's Style Guide for Theses, Dissertations and Research Reports. The formatting of the draft article may differ from the rest of the Research Report in order to comply with the author guidelines of the Southern African Journal of Critical Care, the journal to which it has been submitted.

Section 1: Review of the literature

1.1 Introduction

Hospital acquired infections (HAIs) play an important role in prolonging hospital stay and hinder patient safety (1). HAIs also contribute to bed-burden and antimicrobial resistance (2), increasing the cost for a hospital and ultimately the community at large (3). Methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *Enterococcus* (VRE) and *Clostridium difficile* are the main antibiotic resistant microorganisms worldwide (4).

Within South Africa specifically, gram-negative bacilli (GNB) are becoming increasingly resistant to available antibiotics (5). The genetic mutation, *mcr-1*, has placed a strain on the last resort antibiotic for GNB, Colistin (6). In 2008, Brink et al (5) published a report identifying strains of microorganisms from patients in seven hospitals across South Africa. This report noted that GNB, such as *Pseudomonas aeruginosa* and *Acinetobacter baumannii,* were known to be multi- and pan-drug resistant and that extensive-drug resistant strains of GNB were emerging, namely: *Klebsiella pneumoniae, Escherichia coli*, *Enterobacter* spp. and *Salmonella* spp. (5).

“Prior room occupancy” studies show that a contaminated healthcare environment enables microorganism transmission (7-9). Patients who are inoculated with antibiotic-resistant microorganisms (MRSA, VRE, *Clostridium difficile* and *Acinetobacter baumannii*) contaminate the healthcare environment with these microorganisms through a combination of direct shedding (10) and indirectly after being touched by healthcare workers’ (HCWs) hands (11). Any subsequent patient who is placed within this environment can be inoculated with the same antibiotic-resistant microorganism (9).

Another common source of HAIs is contaminated reusable medical devices (RMDs) (12). Any substandard cleaning of RMDs, prior to reuse in subsequent patients, can result in residue build-up that provides a medium for microorganism growth (10). The World Health Organization (13), the Centres for Disease Control and Prevention (CDC) (14), the U.S. Food and Drug Administration (15) and the South

African Society of Anaesthesiologists (16) guidelines utilise the traditional Spaulding approach (17) to classify RMDs as critical (in contact with sterile tissues, requiring sterilisation), semicritical (in contact with mucous membranes, requiring high-level disinfection) and noncritical (in contact with intact skin, requiring low-level disinfection). Pulse oximeter probes are classified as noncritical devices and while these devices may either require only low-level disinfection (if not soiled with blood) or high-level disinfection (if soiled with blood) (18), they may pose as a source of sepsis. In an intensive care unit (ICU) setting, where pulse oximeter probes are frequently used as part of standard monitoring equipment, this is concerning (19).

This literature review gives an overview of the epidemiology of HAIs, the potential influence pulse oximeter probes have on HAI transmission within an ICU setting and the decontamination of RMDs in general. The literature on microorganism growth on RMDs and the profile of common microorganisms isolated will also be discussed.

1.2 Epidemiology

The incidence of HAIs in developing countries is 15.5 per 100 patients, which is possibly an underestimate due to the paucity of high quality studies available from resource-poor developing countries (20). This incidence is higher than in a developed country such as the United States of America, with an estimated incidence of 4.5 per 100 patients (21) or a developed continent such as Europe with an average prevalence of 7.1 per 100 patients (22). The lack of recent and regional data from developing countries makes the application of the Surviving Sepsis Campaign (23), which advocates for the timeous initiation of antibiotics, in developing countries challenging (24, 25).

Furthermore, adult ICUs in developing countries have a pooled cumulative infection density of 47.9 per 1000 patient-days, compared with 13.6 per 1000 patient-days in the United States of America (20, 21). The pooled incidence of HAI for developing countries is 34.7 per 100 patients. In South African ICUs specifically, approximately 28% of patients have evidence of HAI at any one point in time (26). Research done in an ICU in Groote Schuur Hospital, Cape Town, South Africa showed that three-quarters of blood-stream infections were due to HAI. *Acinetobacter baumannii* was

the predominant microorganism cultured within their ICU between 2011 – 2012 (27).

In South Africa, approximately 29% of people are infected with Human immunodeficiency virus (HIV). HIV accounts for 26% of deaths of South Africans of all ages with 1000 people dying from HIV daily. HIV-positive patients account for 50% of hospital admissions and 60 – 70% of hospital costs in South Africa (28). Soweto, a rural township in South Africa, is a region with a high HIV-1 incidence and is an area where much research is being conducted to reduce the associated mortality (29).

Three microorganisms have been shown to significantly persist on inanimate surfaces, namely: *Clostridium difficille*, VRE and MRSA (30). Indirect evidence exists for contaminated surfaces and devices to result in HAIs (30). Hence the incidence of HAIs due to contaminated RMDs is unknown. To date, the literature contains ample evidence that inadequately reprocessed semicritical devices, for example, endoscopes, play a significant role in HAI transmission and infection outbreaks, despite processing prior to subsequent usage (12, 13, 18, 31). Furthermore, critical devices are associated with a 2 – 8 times higher pooled density of HAIs in developing countries compared to developing countries (20).

Worldwide, HAIs contribute toward antibiotic resistance. The 2012 Prevalence of Infection in South African Intensive Care Units study revealed that inappropriate practices exist for the prescription of antibiotics in both public and private South African ICUs. The point-prevalence of patients who received appropriate initial antibiotics and patients who received inappropriate initial antibiotics was 73.5% and 54.9%, respectively (26). The mortality associated with appropriate and inappropriate initial antibiotic prescription practices was 11% and 27%, respectively (26). While antibiotic prescription practices are dependent on many variables, the reduction in the spread of resistant microorganisms could aid in avoiding uncertain antibiotic prescription practices (32). Therefore, the need to identify and eradicate sources of HAIs and ultimately antibiotic resistance is of fundamental importance globally.

1.3 Pulse oximeter probes

Pulse oximeter devices are important continuous critical care monitors, which reflect the percentage of haemoglobin saturated with oxygen (33, 34). These devices may be overlooked as a source of HAI and antibiotic resistant infection as it is questionable whether their internal crevices that house the diodes are cleaned adequately, particularly in a busy hospital environment with a high turnover of patients (35).

Previously, it has been shown that the inner lumens of arthroscopic shavers harbour residual tissue despite decontamination procedures according to manufacturer guidelines (31). Similarly, the internal crevices of pulse oximeter probes may harbour significant pathogens.

Manufacturer guidelines emphasise the use of appropriately validated germicides that will not impair the functioning of the pulse oximeter probe. The sensor can be immersed in germicides but never sterilised. Cleaning prior to decontamination is stressed. Validated cleaning agents include: mild detergents and 1% salt solution. Validated germicides include: Metricide® 28, Metricide® Plus 30, Terralin® liquid, Incidin® liquid, Cidex® Plus (glutaraldehyde), Omnicide® 28, Kohrsolin® FF, Mucapur®-CD (1%) and Isopropranolol 70% (36).

Engineers have developed a polymer-based pulse oximeter probe as an alternative design to standard disposable pulse oximeter probes to reduce their risk of cross-contamination (37). Furthermore, researchers have evaluated the effectiveness of automated self-cleaning units for the decontamination of pulse oximeter stands and cables, amongst other equipment (38). This growing attention towards pulse oximeter probes suggests that contaminated pulse oximeter probes are thought to contribute towards cross-contamination and therefore HAI acquisition in general.

The prolonged contact a pulse oximeter device may have with an ICU patient's finger can lead to overheating and skin injury (34). Furthermore, the tight application may lead to necrosis (34). HIV-positive, paediatric and burns injury patients would naturally be at a higher risk of cross-contamination from these devices and ideally disposable RMDs should be used on these individuals to avoid

cross-contamination (39, 40). Additionally, the internal surfaces of pulse oximeters are frequently soiled with various materials, which can impede both the inactivation of microorganisms and enhance the inactivation of disinfectants used (41).

Monitoring equipment, including pulse oximeter probes, has been shown to be soiled with both visible and occult blood after cleaning (42). Soiling may be due to blood, serum, tissue or sebum. Sebum accumulation can occur when a patient's skin becomes excessively oily due to the prolonged contact with a pulse oximeter probe and can provide a protective medium for microorganisms (43).

Pulse oximeters are frequently handled devices, which may contaminate HCWs' hands therefore jeopardising HCW safety (44). They are regularly used as basic monitoring for transport of critical patients to and from ICU (33). At times, they may be exchanged or shared between patients in ICU to compensate for faulty or scarce devices. Furthermore, it is questionable whether their internal surfaces are adequately decontaminated, particularly within a busy healthcare environment of a developing country. These factors justify considering pulse oximeters as potential, possibly underestimated, reservoirs for HAIs. The identification of reservoirs for infection could help introduce targeted surface-sampling protocols for ICUs where it is not practical to have ICUs vacant for a prolonged period while an outbreak is being addressed (18). This could decrease costs for a hospital. No research could be identified in the literature addressing noncritical devices as potential reservoirs for HAIs in South Africa.

1.4 Contamination and colonisation of reusable medical devices

Contaminated RMDs contribute to the transfer of pathogens between HCWs and patients (12). RMDs are essentially obtained for the purpose of cost-effectiveness and any substandard cleaning of these devices, prior to reuse in subsequent patients, can result in residue build-up that provides a medium for microorganism growth (41).

Inadequate adherence to infection control measures does occur and is the main cause of contamination of RMDs and environmental surfaces (12, 18). Ensuring that RMDs are safe for use in subsequent patients should be a priority of HCWs as clean RMDs also prevent cross-contamination amongst HCWs themselves (45).

The cleaning compliance of RMDs by HCWs should be monitored regularly; however, no guidelines exist on how frequently this should be done (31) and poor cleaning compliance has been documented worldwide (18). Whether this is a feasible practice is also questionable. Alfa et al (46) have shown that a minimum cleaning compliance of at least 80% is required for the rates of HAIs to decrease (46). However, despite adhering to manufacturer guidelines, RMDs may still retain debris impeding any subsequent complete decontamination process (31, 41).

1.4.1 Decontamination of reusable medical devices

In general, RMDs are either cleaned, disinfected or sterilised based on their intended use and this should be specified by the appropriate healthcare policy for that hospital, as well as manufacturer guidelines (12, 41, 46). Traditionally, the Spaulding Classification (17), which categorises devices as critical, semicritical and noncritical, has been retained both internationally and locally as a guide towards disinfection and sterilisation (12, 16).

1.4.1.1 Critical devices

A critical device is any invasive surgical instrument or medical equipment in contact with sterile tissue or vasculature (18). Ideally, these devices should be acquired completely sterile or undergo a sterilisation process prior to each subsequent use, as the associated risk for infection is high if inadequately decontaminated (12, 16).

To date, critical devices pose no virtual risk of disease transmission as they have a high margin of safety after sterilisation (18). The CDC (12) recommends sterilisation processes for critical devices. Steam sterilisation at high temperatures (minimum of 40 minutes exposure-time) effectively removes all microorganisms, including bacterial spores (12, 18). Critical devices incompatible with steam may be sterilised with low temperature gases, namely ethylene oxide gas or hydrogen peroxide gas plasma, each requiring a minimum exposure-time of 15 hours and 50 minutes, respectively (12). A third option is chemical sterilisation, which is used if critical devices are incompatible with steam but compatible with liquid immersion. The limitations of chemical germicides include: numerous agents available, prior cleaning is mandatory, a set duration of exposure-time (3 – 12 hours) at a certain

temperature, a recommended pH and concentration is necessary and devices are prone to handling as they are processed unwrapped (12).

The 2014 SASA guidelines for Infection Control in Anaesthesia in South Africa (16) does not cover the reprocessing of critical devices.

1.4.1.2 Semicritical devices

Semicritical devices are defined as medical equipment in contact with either respiratory and gastrointestinal mucous membranes or nonintact skin, for example, endoscopes (12). The CDC (12) recommends that these devices receive high-level disinfection at the least, with either pasteurisation or chemical disinfectants to remove all microorganisms that may infect these mucous linings (12). Pasteurisation requires an exposure-time of 50 minutes; while that of chemical disinfectants varies between 10 – 45 minutes. Neither method, however, eliminates bacterial spores which are generally not harmful to intact membranes (12).

Chemical disinfectants include: peracetic acid, hydrogen peroxide, glutaraldehyde and *ortho*-phthalaldehyde. A limitation of chemical disinfectants is the incompatibility of devices with prolonged usage. Additionally, processing requires three essential steps according to the CDC (12): an initial rinse with water followed with alcohol and then air-drying (12). SASA guidelines (16) differ in that the initial rinse is with pressurised water and the immersion time in alcohol should follow the manufacturer's advice. The disinfectant should finally be rinsed off with water. SASA guidelines (16) detail a five-step reprocessing method for laryngoscope blades and handles as well as a nine-step reprocessing method for bronchoscopes (16).

Endoscopic devices have complicated designs that require high-level disinfection through a stringent five-step reprocessing method. They also possess a substantial microbial load even after the cleaning and disinfection process. Biofilms, which reinforce cells binding to surfaces, form within duodenoscopes if inadequately dried after cleaning, further impeding reprocessing. Hence these devices are persistently in the spotlight for improvement in decontamination guidelines (18).

1.4.1.3 Noncritical devices

Noncritical devices are defined as items making contact with intact skin (18). The risk of transmitting infection between patients is minimal, provided these devices are used as intended for intact skin only (12). There is a risk of cross contamination with HCW's hands or medical equipment that make contact with these RMDs and therefore noncritical RMDs should be decontaminated after each use (12, 47). Furthermore, within a burns ICU, the definition of noncritical devices no longer applies as pulse oximeters are used on lips, earlobes or body surfaces that may not have skin as an effective barrier and infection transmission could occur (18).

Noncritical RMDs not soiled with visible blood only require low-level disinfection with agents registered with the United States Environmental Protection Agency (EPA) (48). For low-level disinfection, agents are not required to be tuberculocidal and therefore do not remove mycobacteria or bacterial spores but only vegetative bacteria, most fungi and viruses. These agents include: chlorine-based agents, phenolics, quaternary ammonium compounds and 70 – 90% alcohol-based products (12).

Noncritical RMDs soiled with blood require intermediate-level disinfection with only two of the above EPA-approved agents, namely: chlorine-based or phenolic products, which must state tuberculocidal activity on their labels. These agents remove mycobacteria as well as vegetative bacteria, most fungi and viruses. A minimum exposure-time of 60 seconds is required for both intermediate- and low-level disinfection and noncritical RMDs can easily be decontaminated at the bedside (12). SASA guidelines (16) briefly reiterate that noncritical devices should undergo either low- or intermediate-level disinfection.

A systematic review by Schabrun and Chipchase (49) identified 23 eligible studies between 1972 – 2004 that investigated healthcare equipment contamination. A pooled mean of 86.8% with a range of 31 – 100% of healthcare equipment was contaminated. Twenty-seven per cent of microorganisms identified on healthcare equipment were pathogenic *Staphylococcus aureus*, of which 15% were MRSA. By definition, equipment harbouring at least 5 colony forming units (CFUs/cm^2) was considered contaminated according to French normalisation standards (50). The

number of CFUs identified from these studies ranged from 0–500 CFU/cm^2. The 23 studies were critiqued using appraisal tools and despite the majority of them having poor research designs, they do provide information on healthcare equipment being potential sources for HAI transmission (49).

Although the main focus of this literature review is to highlight pulse oximeter probes as a potential source for HAIs, previous research has shown other noncritical devices to be unsuspecting reservoirs housing significant numbers and strains of microorganisms (51-71). Three studies report noncritical devices to be responsible for outbreaks of pathogens (52-54).

Most research on noncritical devices has come from developed countries which has implicated sphygmomanometer cuffs (54-58), electrocardiograph leads (51, 59), stethoscopes (59-62) and temperature probes (63) as reservoirs. Other devices such as orthopaedic tourniquets (64, 65), sharps containers (67), computer keyboards (52, 68-70), gloves (71) and telephones (72) have also been implicated. Details of these studies are mentioned in Table 1.1.

Table 1.1: Summary of studies on noncritical devices and microorganism identification

Author	Year	Device	Microorganism(s)	Outbreak
Base-Smith (55)	1996	Sphygmomanometer cuffs	Coagulase negative *Staphylococci* *Corynebacterium* *Neisseria* spp. *Propionibacterium* *Bacillus* spp. Nonhemolytic *Streptococci*	No
Harnett et al (54)	2001	Sphygmomanometer cuffs	*Serratia liquefaciens*	Yes
Devine et al (73)	2001	Computer keyboards	MRSA	No
Guinto et al (61)	2002	Stethoscopes	*Staphylococcus aureus* *Enterococcus faecalis* *Pseudomonas* spp. *Acinetobacter* spp. *Escherichia coli* *Moraxella*	No
Maluf et al (62)	2002	Stethoscopes	*Staphylococcus aureus* Coagulase negative *Staphylococci* *Bacillus* sp.	No
Neely et al (66)	2003	Infectious waste containers	*Bacillus* sp. *Gram-negative rods* *Micrococcus* *Pseudomonas* sp. Coagulase negative *Staphylococci* *Staphylococcus aureus* (including MRSA) Alpha-haemolytic streptococci Non-haemolytic streptococci Fungi	No
Schulz et al (69)	2003	Computer keyboards	*Streptococcus* spp. *Clostridium perfringens* VRE *Staphylococcus aureus* Fungi Gram-negative organisms	No

de Gialluly et al (58)	2006	Sphygmomanometer cuffs	*Staphylococcus aureus* *Acinetobacter baumannii* *Pseudomonas aeruginosa* *Serratia marcescens* *Escherichia coli* Yeast	No
Walker et al (74)	2006	Sphygmomanometer cuffs	MRSA Methicillin-susceptible *Staphylococcus aureus* *Clostridium difficile*	No
Leitch et al (64)	2006	Phlebotomy Tourniquets	MRSA	No
Tunc & Olgun (72)	2006	Telephones	*Staphylococcus aureus* *Staphylococcus epidermidis* *Streptococcus pyogenes* *Streptococcus pneumoniae* *Salmonella enteritidis* *Klebsiella pneumoniae* *Neisseria gonorrhoeae* *Escherichia coli* *Pseudomonas aeruginosa* *Bacillus megaterium* *Clostridium perfringens* *Corynebacterium diphtheriae*	No
Gray et al (68)	2007	Computer keyboards	Methicillin-susceptible *Staphylococcus aureus*	No
Dumford et al (52)	2009	Computer keyboards	*Clostridium difficile*	Yes
Uneke et al (63)	2011	Sphygmomanometer cuffs Thermometers	*Staphylococcus aureus* *Pseudomonas aeruginosa* *Enterococcus faecalis*	No
Lestari et al (51)	2013	ECG leads	Coagulase negative *Staphylococcus* Aerobic spore forming bacteria	No
Grewal et al (57)	2013	Sphygmomanometer cuffs	MRSA VRE	No
Fafliora et al (59)	2014	Stethoscopes	Coagulase negative *Staphylococcus*	No

Alfandari et al (53)	2014	Sphygmomanometer cuffs	Carbapenem-resistant *Acinetobacter baumannii*	Yes
Campos-Murguia (60)	2014	Stethoscopes	MRSA	No
Zargaran et al (56)	2015	Sphygmomanometer cuffs	Coagulase-negative *Staphylococcus* Diptheroids	No

A few studies have found pulse oximeter probes to play a role in HAI transmission. In 1993, Wilkins (75) looked at pulse oximeters that were deemed ready-for-use for subsequent patients. Of the pulse oximeters sampled, 66% were contaminated with microorganisms. The specific microorganisms cultured were: *Staphylococcus aureus*, *Staphylococcus haemolyticus*, *Enterococcus faecalis* and *Klebsiella oxytoca*. This study is the earliest study found in the literature to investigate pulse oximeters as reservoirs for contamination (75).

Davis (35) investigated 17 unprocessed pulse oximeter probes within an emergency department in an Australian hospital. This sample size was limited to the actual number of pulse oximeter probes available. Two pulse oximeter probes grew *Staphylococcus aureus* and Bacillus species of significant potential pathogenicity; while 12 pulse oximeter probes grew non-pathological skin commensals. This study highlights that pulse oximeters contaminated with non-pathogenic skin commensals may pose a risk to suitably susceptible patients (35).

Morter et al (76) describe seasonal outbreaks of norovirus within a hospital in the United Kingdom. Through the utilisation of an environmental swabbing technique, hot spots of norovirus contaminants were identified after environmental cleaning of wards where infected patients were admitted. One of these hot spots included monitoring equipment where 66.7% of the pulse oximeters sampled were contaminated. After recleaning the environment, contamination in general was significantly lower for all hot spots and none of the previously sampled pulse oximeter probes were contaminated. This study emphasises that screening of

environmental contaminants not only identifies sources of sepsis but also aids effective cleaning practises (76).

A study by Parer et al (77) revealed an inner rubber lining of a pulse oximeter probe to be an unsuspecting source of a heterogeneous glycopeptide-intermediate *Staphylococcus aureus* outbreak within a 20-bed ICU in France. Despite strict infection control and targeted environmental cleaning practices within this ICU, an outbreak of this microorganism persisted in 12 patients.

The fact that these patients' nasal passages were not colonised with this microorganism and their acquisition time was longer than the usual incubation period for glycopeptide-intermediate *Staphylococcus aureus*, suggested that a significant reservoir of infection was present. With the targeted screening of items in cubicles, an inner rubber lining of a pulse oximeter probe was found to culture *Staphylococcus aureus* with six strains of *Staphylococcus aureus* found on subsequently tested pulse oximeter probes (77).

Pusch et al (78) describe an outbreak of vancomycin-resistant *Enterococcus faecium* (VREfm) within a neonatal ICU that was traced back to a pulse oximeter probe used in an adult ward. Through microorganism strain-identification, a birth mother of colonised twins was found to be colonised with the VREfm and through environmental cultures of shared equipment in the adult ward where this mother was admitted, a pulse oximeter was found to be the source. (78)

A study by Nandy et al (43) demonstrated that pulse oximeters soiled with artificial sebum conferred resistance of vegetative bacteria and spores to certain cleaning agents. The authors further state that strong agents containing sodium hypochlorite, hydrogen peroxide and o-phenylphenol became less effective in removing bacteria in the presence of sebum. They conclude that in the absence of sebum, however, the chloride-based agent (sodium hypochloride) removed the most bacteria and spores when compared to other cleaning agents (43)

1.4.2 New technologies

Non-touch methods of decontamination have been developed to improve room decontamination. Ultraviolet radiation, used within an effective wavelength range of 240 – 280 nm, can rapidly decontaminate rooms through cleaving DNA bonds of microorganisms. A disadvantage of this method is that furniture should be moved away from walls for it to be effective. Microorganisms removed include: MRSA, VRE, *Acinetobacter baumannii* and *Clostridium difficile* spores (18).

A hydrogen peroxide mist system is another method that has been shown to be effective in destroying microorganisms. In addition to the above, *Mycobacterium tuberculosis*, *Serratia* and *Clostridium botulinum* spores are also removed.

It requires a longer exposure time than UV radiation but does not require furniture to be moved from walls to be effective (18).

Both systems are reliable in removing microorganisms and therefore reduce the risk of HAI transmission, but they can only be used after a patient has been discharged and HCWs have vacated the room (terminal room decontamination). However, they are safe for long-term HCW exposure, as they do not deposit residues. Additionally, both systems require cubicles to be cleaned prior to decontamination and they are expensive systems to purchase (18).

Currently HCWs at Chris Hani Baragwanath Academic Hospital in South Africa have been utilising the hydrogen peroxide mist system to decontaminate cubicles in their BICU for more than a year. After discharge or death, HCWs clean the cubicles and the system is then applied. Endemic microorganisms that colonise the BICU include: *Pseudomonas aeruginosa* and *Acinetobacter baumannii*. Whether this decontamination system is effective in reducing the percentage of colonisation would be interesting to see.

1.5 Description of commonly isolated microorganisms

1.5.1 Gram negative microorganisms

Acinetobacter baumannii

Acinetobacter baumannii is an aerobic gram-negative microorganism. It colonises the skin and mucous membranes of humans. It is generally rod-shaped but can take on a diplococcal appearance resembling Neisseria. It originates in water and thrives in moist environments (79). The three clinically significant genospecies: *Acinetobacter baumannii*, *Acinetobacter* genomospecies 3 and *Acinetobacter* genomospecies 13TU are difficult to differentiate microscopically and are therefore grouped together as *Acinetobacter baumannii* Complex (80).

This microorganism often displays multi-drug resistance making treatment challenging. Colistin is a last-resort antibiotic to which *Acinetobacter baumannii* remains sensitive (79).

Acinetobacter baumannii usually causes device-associated bacteraemia from intravenous catheters and nosocomial pneumonia. It can act opportunistically in immunocompromised patients (HIV positive and burns) to cause sepsis (79).

Pseudomonas aeruginosa

Pseudomonas aeruginosa is an aerobic gram-negative microorganism. It colonises both skin and mucous membranes. Strains of *Pseudomonas aeruginosa* can cause infection in immunocompromised hosts (79).

Pathogenicity results from pili which facilitate adherence to host tissues. *Pseudomonas aeruginosa* can produce multiple exoenzymes and exotoxins which make it a potentially virulent microorganism. Particularly, exotoxin A causes lethal tissue necrosis. Treatment of infection usually requires a multiple-antibiotic-regime as *Pseudomonas aeruginosa* quickly becomes resistant to single antibiotic therapy (79). This microorganism grows in moist environments and thrives in high room temperatures (37 – 42°C). Biofilm formation can occur within the lumen of catheter devices. Common device-associated infections include ventilator-associated

pneumonia, meningitis after lumbar puncture and catheter-related urinary tract infections (79).

Klebsiella pneumoniae

Klebsiella pneumoniae colonises the respiratory tract and faeces of humans. It has the potential to become pathogenic and is a common cause of HAI in immunocompromised individuals (81).

This microorganism contains plasmids which code for resistance genes. Two strains of *Klebsiella pneumoniae* have recently been identified to display antibiotic resistance globally. The sequence type 16 strain produces extended spectrum

β-Lactamase conferring resistance to the penicillins and cephalosporins.

The sequence 258 strain displays resistance towards the carbapenems Infections range from urinary tract infections to bacteraemia and significant lung consolidation (81).

1.5.2 Gram positive microorganism

Staphylococcus aureus

Staphylococcus aureus is an aerobic gram-positive spherical microorganism. It colonises the skin, gastrointestinal and respiratory tracts, particularly the nares, of humans. It is also commonly found on environmental surfaces (82).

This microorganism can rapidly adapt to its environment by producing many pathogenic toxins and altering its genome. Its cell wall contains peptidoglycan, which facilitates its adherence to surfaces. It can produce β-Lactamase, which cleaves β-Lactam-containing antibiotics causing MRSA. It can also express the vancomycin resistance gene contributing to Vancomycin resistance (82).

It is heat-stable and can survive in temperatures as high as 50°C for 30 minutes, forming pigment at room temperatures of 20–25°C. Infection can range from exotoxin-induced food poisoning to bacteraemia and systemic organ suppuration with toxic shock syndrome (82).

1.6 Summary

This literature review puts forward pulse oximeter probes as potential reservoirs for tissue residuals and cocoons for microorganisms. The internal surfaces of pulse oximeter probes may play a role in cross-contamination and HAI transmission within an ICU setting. Effective cleaning and disinfection using appropriate agents is important to reduce contamination.

1.7 References

1. World Health Organization. World alliance for patient safety. Forward programme 2005. 2004 [22 August 2017]. Available from: https://www.who.int/patientsafety/en/brochure_final.pdf.

2. Mendelson M, Whitelaw A, Nicol M, Brink A. Wake up South Africa! The antibiotic 'horse' has bolted. SAMJ. 2012;102(7):607-8. doi: 10.7196/samj.5759

3. Graves N. Economics and preventing hospital-acquired Infection. Emerg Infect Dis. 2004;10(4):561-6. doi: 10.3201/eid1004.020754

4. Johnston BL, Bryce E. Hospital infection control strategies for vancomycin-resistant enterococcus, methicillin-resistant staphylococcus aureus and clostridium difficile. CMAJ. 2009;180(6):627-31. doi: 10.1503/cmaj.080195

5. Brink A, Feldman C, Richards GA, Moolman J, Senekal M. Emergence of extensive drug resistance (XDR) among gram negative bacilli in South Africa looms nearer. S Afr Med J. 2008;98(8):586-92. doi: http://0-search.ebscohost.com.innopac.wits.ac.za//login.aspx?direct=true&mdc&AN=18928032&site=ehost-live&scope=site.

6. Coetzee J, Corcoran C, Prentice E, Moodley M, Mendelson M, Poirel L, et al. Emergence of plasmid-mediated colistin resistance (MCR-1) among escherichia coli isolated from South African patients. S Afr Med J. 2016;106(5):449-50. doi: 10.7196/SAMJ.2016.v106i5.10710

7. Drees M, Snydman DR, Schmid CH, Barefoot L, Hansjosten K, Vue PM, et al. Prior environmental contamination increases the risk of acquisition of vancomycin-resistant enterococci. Clin Infect Dis. 2008;46(5):678-85. doi: 10.1086/527394

8. Shaughnessy MK, Micielli RL, DePestel DD, Arndt J, Strachan CL, Welch KB, et al. Evaluation of hospital room assignment and acquisition of clostridium difficile infection. Infect Control Hosp Epidemiol. 2011;32(3):201-6. doi: 10.1086/658669

9. Huang SS, Datta R, Platt R. Risk of acquiring antibiotic-resistant bacteria from prior room occupants. Arch Intern Med. 2006;166(18):1945-51. doi: 10.1001/archinte.166.18.1945

10. Otter JA, Yezli S, Salkeld JAG, French GL. Evidence that contaminated surfaces contribute to the transmission of hospital pathogens and an overview of strategies to address contaminated surfaces in hospital settings. Am J Infect Control. 2013;41(2013):S6-S11. doi: 10.1016/j.ajic.2012.12.004

11. Kundrapu S, Sunkesula V, Jury LA, Sitzlar BM, Donskey CJ. Daily disinfection of high-touch surfaces in isolation rooms to reduce contamination of healthcare workers' hands. Infect Control Hosp Epidemiol. 2012;33(10):1039-42. doi: 10.1086/667730

12. Rutala WA, Weber DA. Disinfection and sterilization in health care facilities: What clinicians need to know. Clin Infect Dis. 2004;29(5):702-9. doi: 10.1086/423182

13. Ducel G, Fabry J, Nicolle L. Prevention of hospital acquired infections: a practical guide. 2002 [22 August 2017]. Available from: http://apps.who.int/medicinedocs/documents/s16355e/s16355e.pdf.

14. Rutala WA, Weber DJ. Centers for Disease Control and Prevention. Guideline for disinfection and sterilization in healthcare facilities 2008 [18 June 2017]. Available from: https://www.cdc.gov/infectioncontrol/guidelines/disinfection/healthcare-equipment.html.

15. US Food and Drug Administration. Reprocessing of reusable medical devices in healthcare settings: validation methods and labeling. Guidance for industry and food and drug administration staff. 2015 [22 August 2017]. Available from: https://www.fda.gov/downloads/medicaldevices/deviceregulationandguidance/guidancedocuments/ucm253010.pdf.

16. Samuel R, Nel D, Joubert I, De Bruin J, Dwyer S, Fourie A, et al. South African society of anaesthesiologists (SASA) guidelines for infection control in anaesthesia in South Africa. South Afr J Anaesth Analg. 2014;20(3):S1-S39.

17. Spaulding EH. Chemical disnifection of medical and surgical materials. In: Lawrence C, Block SS, editors. Disinfection, sterilization, and preservation. Philadelphia: Lea & Febiger; 1968. p. 517-31.

18. Rutala WA, Weber DA. Disinfection and sterilization in health care facilities: An overview and current issues. Infect Dis Clin N Am. 2016;30(2016):609-37. doi: 10.1016/j.idc.2016.04.002

19. Hanson III CW. ICU Basics. In: Hanson C, editor. The ICU Room and Equipment. New York, NY: McGraw-Hill Education; 2009.

20. Allegranzi B, Nejad SB, Combescure C, Graafmans W, Attar H, Donaldson L, et al. Burden of endemic health-care-associated infection in developing countries: systematic review and meta-analysis. Lancet. 2011;377(9761):228-41. doi: 10.1016/S0140-6736(10)61458-4

21. Klevens RM, Edwards JR, Richards CL, Horan TC, Gaynes RP, Pollock DA, et al. Estimating health care-associated infections and deaths in U.S. hospitals, 2002. Public Health Rep. 2007;122(2):160-6. doi: 10.1177/003335490712200205

22. ECDC. Annual epidemiological report on communicable diseases in Europe 2008: Report on the state of communicable diseases in the EU and EEA/EFTA countries. 2008 [17 July 2017]. Available from: http://www.ecdc.europa.eu/en/publications/Publications/0812_SUR_Annual_Epidemiological_Report_2008.pdf.

23. Rhodes A, Evans LE, Alhazzani W, Mitchell MM, Antonelli M, Ferrer R, et al. Surviving sepsis campaign: International guidelines for management of sepsis and septic shock: 2016. Intensive Care Med. 2017;43(3):304-77. doi: 10.1007/s00134-017-4683-6

24. Bhagwanjee S, Ugarte S. Sepsis in vulnerable populations. Glob Heart. 2014;9(3):281-8. doi: 10.1016/j.gheart.2014.08.008

25. Mer M, Schultz M, Adhikari NK. Core elements of general supportive care for patients with sepsis and septic shock in resource-limited settings. Intensive Care Med. 2017;43(11):1690-4. doi: 10.1007/s00134-017-4831-z

26. Paruk F, Richards G, Scribante J, Bhagwanjee S, Mer M, Perrie H. Antibiotic prescription practices and their relationship to outcome in South African intensive care units: findings of the prevalence of infection in South African intensive care units (PISA) study. SAMJ. 2012;102(7):613-6. doi: 10.7196/samj.5833

27. McKay R, Bamford C. Community-versus healthcare-acquired bloodstream infections at Groote Schuur Hospital, Cape Town, South Africa. S Afr Med J. 2015;105(5):363-9. doi: 10.7196/SAMJ.8183

28. Crowther-Gibson P, Govender N, Lewis DA, Bamford C, Brink A, von Gottenberg A, et al. Part IV: Human infections and antibiotic resistance. S Afr Med J. 2011;101(8):567-78. doi: doi:10.7196/SAMJ.5102.

29. Visser A, Moore DP, Whitelaw A, Lowman W, Kantor G, Hoosen A, et al. PART VII: GARP: Interventions. S Afr Med J. 2011;101(8):587-95. doi: 10.7196/SAMJ.5106.

30. Weinstein RA, Hota B. Contamination, disinfection, and cross-colonization: Are hospital surfaces reservoirs for nosocomial infection? Clin Infect Dis. 2004;39(8):1182-9. doi: 10.1086/424667

31. Alfa MJ. Monitoring and improving the effectiveness of cleaning medical and surgical devices. Am J Infect Control. 2013;41(2013):S56-S9. doi: 10.1016/j.ajic.2012.12.006.

32. Ventola CL. The antibiotic resistance crisis. Part 2: management strategies and new agents. J Clin Pharm Ther. 2015;40(5):344-52.

33. Andrews FJ, Nolan JP. Critical care in the emergency department: Monitoring the critically ill patient. Emerg Med J. 2005;23(7):561-4. doi: 10.1136/emj.2005.029926

34. Ortega R, Hansen CJ, Elterman K, Woo A. Pulse oximetry. N Engl J Med. 2011;364(16):e33-e6. doi: 10.1056/NEJMvcm0904262

35. Davis C. Blood pressure cuffs and pulse oximeter sensors: A potential source of cross-contamination. Australas Emerg Nurs J. 2009;12:104-9. doi: 10.1016/j.aenj.2009.03.004

36. Philips. Reusable SpO2 Sensors. Instructions for Use: Koninklijke Philips Electronics N. V.; 2009.

37. Chuo Y, Omrane B, Landrock C, Patel JN, Kaminska B. Platform for all-polymer-based pulse-oximetry sensor. 2010 IEEE Sensors. 2010:155-9. doi: 10.1109/icsens.2010.5690678

38. Obasi C, Agwu A, Akinpelu W, Hammons R, Clark C, Etienne-Cummings R, et al. Contamination of equipment in emergency settings: an exploratory study with a targeted automated intervention. Ann Surg Innov Res. 2009;3(8):8. doi: 10.1186/1750-1164-3-8

39. Hanna D. Using pulse oximeters safely. Nursing. 1995;25(7):26.

40. Gilmore GK. Infection control advances decrease patient and staff risk. Nurse Manage. 2001;32(12):51-3. doi: 10.1097/00006247-200112000-00016

41. Sharbaugh RJ. Cleaning reusable equipment in the ICU. Crit Care Nurs Q. 2001;24(2):48-54. doi: 10.1097/00002727-200108000-00007

42. Hadavi M, Asar S, Rezaeian M. The frequency of visible and occult blood on anesthesia and monitoring equipment — A report from South East of Iran. Eg J Anaesth. 2006;22(1):68-70. doi:

43. Nandy P, Lucas AD, Gonzalez EA, Hitchins VM. Efficacy of commercially available wipes for disinfection of pulse oximeter sensors. Am J of Infect Control. 2016;44(3):304-10. doi: 10.1016/j.ajic.2015.09.028

44. Force HHT. Centers for disease control and Prevention. Guideline for hand hygiene in health-care settings. Recommendations of the healthcare infection control practices advisory committee and the HICPAC/SHEA/APIC/IDSA hand hygiene task force. 2002 [November 2017]. Available from: http://208.40.244.65/isdh/files/Tab_4_Resource_CD.pdf.

45. Perry SM, Monaghan WP. The prevalence of visible and/or occult blood on anesthesia and monitoring equipment. Am Assoc Nurse Anesth J. 2001;2001(69):44-8. doi: 10.21236/ad1012056

46. Alfa MJ, Lo E, Olson N, MacRae M, Buelow-Smith L. Use of a daily disinfectant cleaner instead of a daily cleaner reduced hospital-acquired infection rates. Am J Infect Control. 2015;43(2015):141-6. doi: 10.1016/ajic.2014.10.016

47. Samuel R, Nel D, Joubert I, De Bruin J, Dwyer S, Fourie A, et al. SASA Guidelines for Infection Control in Anaesthesia in South Africa. South Afr J Anaesth Analg. 2014;20(3):S1-S39.

48. United States Environmental Protection Agency. [3 June 2017]. Available from: https://www.epa.gov/environmental-topics/chemicals-and-toxics-topics.

49. Schabrun S, Chipchase L. Healthcare equipment as a source of nosocomial infection: a systematic review. J Hosp Infect. 2006;63(3):239-45. doi: 10.1016/j.jhin.2005.10.013

50. Bernard L, Kereveur A, Durand D, Gonot J, Goldstein F, Mainardi JL, et al. Bacterial contamination of hospital physicians' stethescopes. Infect Control Hosp Epidemiol. 1999;20(9):626-628. doi: 10.1086/501686

51. Lestari T, Ryll S, Kramer A. Microbial contamination of manually reprocessed, ready to use ECG lead wire in intensive care units. GMS Hyg Infect Control. 2013;8(1):Doc07. doi: 10.3205/dgkh000207

52. Dumford III DM, Nerandzic MM, Eckstein BC, Donskey CJ. What is on that keyboard? Detecting hidden environmental reservoirs of clostridium difficile during an outbreak associated with North American pulsed-field gel electrophoresis type 1 strains. Am J of Infect Control. 2009;37(1):15-9. doi: 10.1016/j.ajic.2008.07.009

53. Alfandari S, Gois J, Delannoy PY, Georges H, Boussekey N, Chiche A, et al. Management and control of a carbapenem-resistant acinetobacter baumannii outbreak in an intensive care unit. Med Mal Infect. 2014;44(5):229-31. doi: 10.1016/j.medmal.2014.03.005

54. Harnett SJ, Allen KD, Macmillan RR. Critical care unit outbreak of serratia liquefaciens from contaminated pressure monitoring equipment. J Hosp Infect. 2001;47(4):301-7. doi: 10.1053/jhin.2001.0941

55. Base-Smith V. Nondisposable sphygmomanometer cuffs harbor frequent bacterial colonization and significant contamination by organic and inorganic matter. AANA J. 1996;64(2):141-5. doi: 10.1016/S0001-2092(06)63633-8

56. Zargaran D, Hardwick S, Adel R, Hill G, Stubbins D, Salmasi AM. Sphygmomanometer cuffs: A potential source of infection! Angiology. 2015;66(2):118-21. doi: 10.1177/0003319714522855

57. Grewal H, Varshney K, Thomas LC, Kok J, Shetty A. Blood pressure cuffs as a vector for transmission of multi-resistant organisms: colonisation rates and effects of disinfection. Emerg Med Australas. 2013;25(3):222-6. doi: 10.1111/1742-6723.12076

58. De Gialluly C, Morange V, De Gialluly E, Loulergue J, van der Mee N, Quentin R. Blood pressure cuff as a potential vector of pathogenic microorganisms: A prospective study in a teaching hospital. Infect Control Hosp Epidemiol. 2006;27(9):940-3. doi: 10.1086/507284

59. Fafliora E, Bampalis VG, Lazarou N, Mantzouranis G, Anastassiou ED, Spiliopoulou I, et al. Bacterial contamination of medical devices in a Greek emergency department: Impact of physicians' cleaning habits. Am J Infect Control. 2014;42(2014):807-9. doi: 10.1016/j.ajic.2014.03.017

60. Campos-Murguia A, Leon-Lara X, Munoz JM, Macias AE, Alvarez JA. Stethescopes as potential intrahospital carriers of pathogenic microorganisms. Am J Infect Control. 2014;42(2014):82-3. doi: 10.1016/j.ajic.2013.06.015

61. Guinto C, Bottone E, Raffalli J, Montecalvo M, Wormser G. Evaluation of dedicated stethoscopes as a potential source of nosocomial pathogens. Am J Infect Control. 2002;30(8):499-502. doi: 10.1067/mic.2002.126427

62. Maluf M, Maldonado A, Bercial M-. Stethoscope: A friend or an enemy? . Sao Paulo Med J. 2002;120(1):13-5. doi: 10.1590/s1516-31802002000100004

63. Uneke CJ, Ijeoma PA. The potential for transmission of hospital-acquired infections by non-critical medical devices: the role of thermometers and blood pressure cuffs. World Health Popul. 2011;12(3):5-12. doi: 10.12927/whp.2011.22098

64. Leitch A, McCormick I, Gillespie T. Reducing the potential for phlebotomy tourniquets to act as a reservoir for methicillin-resistant staphylococcus aureus. J Hosp Infect. 2006;63(4):428-31. doi: 10.1016/j.jhin.2006.03.006

65. Walsh E, Ben-David D, Ritter M, Mechrefe A, Mermel L, DiGiovanni C. Microbial colonization of tourniquets used in orthopaedic surgery. Orthop. 2006;29(8):709-13. doi: PMID: 16924865

66. Neely AN, Maley MP, Taylor GL. Investigation of single-use versus reusable infectious waste containers as potential sources of microbial contamination. Am J nfect Control.31(1):13-7. doi: 10.1067/mic.2003.17

67. Runner J. Bacterial and viral contamination of reusable sharps containers in a community hospital setting. Am J Infect Control. 2007;35(8):527-30. doi: 10.1016/j.ajic.2006.09.017

68. Gray J, McNicholl B, Webb H, Hogg G. Mice in the emergency department: vector for infection or technological aid? Eur J Emerg Med. 2007;14(3):160-2. doi: 10.1097/MEJ.0b013e3280bef922

69. Schultz M, Gill J, Zubairi S, Huber R, Gordin F. Bacterial contamination of computer keyboards in a teaching hospital. Eur J Emerg Med. 2003;23(4):302-3. doi: 10.1086/502200

70. Devine J, Cooke R, Wright E. Is methicillin-resistant staphylococcus aureus (MRSA) contamination of ward-based computer terminals a surrogate marker for nosocomial MRSA transmission and handwashing complaince? J Hosp Infect. 2001;48(1):72-5. doi: 10.1053/jhin.2001.0955

71. Luckey J, Barfield R, Eleazer P. Bacterial count comparisons on examination gloves from freshly opened boxes and from examination gloves before treatment versus after dental dam isolation. J Endod. 2006;32(7):140-3. doi: 10.1016/j.jinf.2005.10.022

72. Tunc K, Olgun U. Microbiology of public telephones. J Infect. 2006;53(2):140-3. doi: 10.1016/j.jinf.2005.10.022

73. Devine J, Cooke R, Wright E. Is methicillin-resistant Staphylococcus aureus (MRSA) contamination of ward-based computer terminals a surrogate marker for nosocomial MRSA transmissionand handwashing complaince? J Hosp Infect. 2001;48:72-5. doi: 10.1053/jhin.2001.0955

74. Walker N, Gupta R, Cheesbrough J. Blood pressure cuffs: friend or foe? J Hosp Infect. 2006;63(2):167-9. doi: 10.1016/j.jhin.2005.10.019

75. Wilkins MC. Residual bacterial contamination on reusable pulse oximetry sensors. Respir Care. 1993;38(11):1155-60. doi:

76. Morter S, Bennet G, Fish J, Allen DJ, Nawaz S, Iturriza-Gomara M, et al. Norovirus in the hospital setting: virus introduction and spread within the hospital environment. J Hosp Infect. 2011;77(2011):106-12. doi: 10.1016/j.jhin.2010.09.035

77. Parer S, Lotthe A, Chardon P, Poncet R, Jean-Pierre H, Jumas-Bilak E. An outbreak of heterogeneous glycopeptide-intermediate staphylococcus aureus related to a device source in an intensive care unit. Infect Control Hosp Epidemiol. 2012;33(2):167-74. doi: 10.1086/663703

78. Pusch T, Kemp D, Trevino S, Button T, Sanchez P, Gander R, et al. Controlling outbreak of vancomycin-resistant enterococcus faecium among infants caused by an endemic strain in adult inpatients. Am J of Infect Control. 2013;41(1):51-6. doi: 10.1016/j.ajic.2012.01.034

79. Carroll KC, Hobden JA. Chapter 16: Pseudomonads and Acinetobacter. In: Carroll KC, Hobden JA, Miller S, Morse SA, Mietzner TA, Detrick B, et al., editors. Jawetz, Melnick, & Adelberg's Medical microbiology, 27th edition Section III: bacteriology. New York, NY: McGraw-Hill; 2016.

80. Zhang HZ, Zhang JS, Qiao L. The acinetobacter baumannii group: A systemic review. World J Emerg Med. 2013;4(3):169-74. doi: 10.5847/wjem.j.issn.1920–8642.2013.03.002

81. Carroll KC, Hobden JA. Chapter 15: Enteric gram-negative rods (enterobacteriaceae). In: Carroll KC, Hobden JA, Miller S, Morse SA, Mietzner TA, Detrick B, et al., editors. Jawetz, Melnick, & Adelberg's Medical microbiology, 27th edition Section III: bacteriology. New York, NY: McGraw-Hill; 2016.

82. Carroll KC, Hobden JA. Chapter 13: The staphylococci. In: Carroll KC, Hobden J, A., Miller S, Morse SA, Mietzner TA, Detrick B, et al., editors. Jawetz, Melnick, & Adelberg's Medical Microbiology, 27th edition Section III: bacteriology New York, NY: McGraw-Hill; 2016.

Section 2: Author's guidelines

Southern African Journal of Critical Care (SAJCC)

Author Guidelines

Please take the time to familiarise yourself with the policies and processes below. If you still have any questions, please do not hesitate to ask our editorial staff (tel.: +27 (0)21 532 1281, email: submissions@hmpg.co.za).

Scope of the Journal.

This Journal publishes scientific articles related to multidisciplinary critical and intensive medical care and the emergency care of critically ill humans.

To submit a manuscript, please proceed to the *SAJCC* Editorial Manager website:

www.editorialmanager.com/sajcc

Please view the Author Tutorial for guidance on how to submit on Editorial Manager.

Authorship

Named authors must consent to publication. Authorship should be based on: (*i*) substantial contribution to conceptualisation, design, analysis and interpretation of data; (*ii*) drafting or critical revision of important scientific content; or (*iii*) approval of the version to be published. These conditions must all be met for an individual to be included as an author (uniform requirements for manuscripts submitted to biomedical journals; refer to www.icmje.org)

If authors' names are added or deleted after submission of an article, or the order of the names is changed, all authors must agree to this in writing.

Please note that co-authors will be requested to verify their contribution upon submission. Non-verification may lead to delays in the processing of submissions. Author contributions should be listed/described in the manuscript.

Conflicts of interest

Conflicts of interest can derive from any kind of relationship or association that may influence authors' or reviewers' opinions about the subject matter of a paper. The existence of a conflict – whether actual, perceived or potential – does not preclude publication of an article. However, we aim to ensure that, in such cases, readers have all the information they need to enable them to make an informed assessment about a publication's message and conclusions. We require that both authors and reviewers declare all sources of support for their research, any personal or financial relationships (including honoraria, speaking fees, gifts received, etc) with relevant individuals or organisations connected to the topic of the paper, and any association with a product or

subject that may constitute a real, perceived or potential conflict of interest. If you are unsure whether a specific relationship constitutes a conflict, please contact the editorial team for advice. If a conflict remains undisclosed and is later brought to the attention of the editorial team, it will be considered a serious issue prompting an investigation with the possibility of retraction.

Research ethics committee approval

Authors must provide evidence of Research Ethics Committee approval of the research where relevant. Ensure the correct, full ethics committee name and reference number is included in the manuscript an accompanying documentation. A copy of the ethics approval letter must be uploaded as a supplementary file.

If the study was carried out using data from provincial healthcare facilities, or required active data collection through facility visits or staff interviews, approval should be sought from the relevant provincial authorities. For South African authors, please refer to the guidelines for submission to the National Health Research Database. Research involving human subjects must be conducted according to the principles outlined in the Declaration of Helsinki. Please refer to the National Department of Health's guideline on Ethics in Health research: principles, processes and structures to ensure that the appropriate requirements for conducting research have been met, and that the HPCSA's General Ethical Guidelines for Health Researchers have been adhered to.

Protection of rights to privacy

Research Participants

Information that would enable identification of individual research participants should not be published in written descriptions, photographs, radiographs and pedigrees unless the information is essential for scientific purposes and the patient (or parent or guardian) has given informed written consent for publication and distribution. We further recommend that the published article is disseminated not only to the involved researchers but also to the patients/participants from whom the data was drawn. Refer to Protection of Research Participants. The signed consent form should be submitted with the manuscript to enable verification by the editorial team.

Other individuals

Any individual who is identifiable in an image must provide written agreement that the image may be used in that context in the *SAJCC.*

Copyright notice

Copyright remains in the Author's name. The work is licensed under a Creative Commons Attribution - Noncommercial Works License. Authors are required to complete and sign an Author Agreement form that outlines Author and Publisher rights and terms of publication. The Agreement form should be uploaded along with other submissions files and any submission will be considered incomplete without it. Find it here: Author Agreement form

Material submitted for publication in the *SAJCC* is accepted provided it has not been published or submitted for publication elsewhere. Please inform the editorial team if the main findings of your paper have been presented at a conference and published in abstract form, to avoid copyright infringement. The *SAJCC* does not hold itself responsible for statements made by the authors. The corresponding author should also indicate if the research forms part of a postgraduate short report, dissertation or thesis.

Previously published images

If an image/figure has been previously published, permission to reproduce or alter it must be obtained by the authors from the original publisher and the figure legend must give full credit to the original source. This credit should be accompanied by a letter indicating that permission to reproduce the image has been granted to the author/s. This letter should be uploaded as a supplementary file during submission.

Privacy statement

The *SAJCC* is committed to protecting the privacy of its website and submission system users. The names, personal particulars and email addresses entered in the website or submission system will not be made available to any third party without the user's permission or due process. By registering to use the website or submission system, users consent to receive communication from the *SAJCC* or its publisher HMPG on matters relating to the journal or associated publications. Queries with regard to privacy may be directed to publishing@hmpg.co.za.

Ethnic/race classification

Use of racial or ethnicity classifications in research is fraught with problems. If you choose to use a research design that involves classification of participants based on race or ethnicity, or discuss issues with reference to such classifications, please ensure that you include a detailed rationale for doing so, ensure that the categories you describe are carefully defined, and that socioeconomic, cultural and lifestyle variables that may underlie perceived racial disparities are appropriately controlled for. Please also clearly specify whether race or ethnicity is classified as reported by the patient (self-identifying)

or as perceived by the investigators. Please note thatit is not appropriate to use self-reported or investigator-assigned racial or ethnic categories for genetic studies.

Manuscript preparation

Preparing an article for anonymous review

To ensure a fair and unbiased review process, submissions may include an anonymized version of the manuscript.

Submitting a manuscript that needs additional blinding can slow down your review process, so please be sure to follow these simple guidelines as much as possible:

- An anonymous version should not contain any author, affiliation or particular institutional details that will enable identification.
- Please remove title page, acknowledgements, contact details, funding grants to a named person, and any running headers of author names.
- Mask self-citations by referring to your own work in third person.

General article format/layout

Submitted manuscripts that are not in the correct format specified in these guidelines will be returned to the author(s) for correction prior to being sent for review, which will delay publication.

General:

- Manuscripts must be written in UK English (this includes spelling).
- The manuscript must be in Microsoft Word or RTF document format. Text must be 1.5 line spaced, in 12-point Times New Roman font, and contain no unnecessary formatting (such as text in boxes). Pages and lines should be numbered consecutively.
- Please make your article concise, even if it is below the word limit.
- Qualifications, ***full*** affiliation (department, school/faculty, institution, city, country) and contact details of ALL authors must be provided in the manuscript and in the online submission process.
- Abbreviations should be spelt out when first used and thereafter used consistently, e.g. 'intravenous (IV)' or 'Department of Health (DoH)'.
- Numbers should be written as grouped per thousand-units, i.e. 4 000, 22 160.
- Quotes should be placed in single quotation marks: i.e. The respondent stated: '...'
- Round brackets (parentheses) should be used, as opposed to square brackets, which are reserved for denoting concentrations or insertions in direct quotes.
- Medical drugs should be referred to by their generic name although the trade name may be used in brackets in the text once if unique.

If you wish material to be in a box, simply indicate this in the text. You may use the table format –this is the *only* exception. Please DO NOT use fill, format lines and so on.

Preparation notes by article type

Research

Guideline word limit: 3 000 words (excluding abstract and bibliography)

Research articles describe the background, methods, results and conclusions of an original research study. The article should contain the following sections: introduction, methods, results, discussion and conclusion, and should include a structured abstract (see below). The title of the manuscript should concisely describe the study but should not include the outcome. The introduction should be concise – no more than three paragraphs – on the background to the research question, and must include references to other relevant published studies that clearly lay out the rationale for conducting the study. Some common reasons for conducting a study are: to fill a gap in the literature, a logical extension of previous work, or to answer an important question. If other papers related to the same study have been published previously, please make sure to refer to them specifically. At the end of the introduction clearly state the aim or objective of the study. The primary and secondary outcomes should be specified.

In the Methods section describe in sufficient detail so that others would be able to replicate the study should they need to. Sections of the methods that have been described in previous publications need only be referenced. The statistical methods should be described. Where appropriate, sample size calculations should be included to demonstrate that the study is not underpowered.

Results should describe the study sample as well as the findings from the study itself, but all interpretation of findings must be kept in the discussion section. The conclusion should briefly summarise the main message of the paper and provide recommendations for further study.

The discussion should be confined to an interpretation of your results with respect to your stated aim and if applicable, a comparison to the results of similar studies. The strengths and weaknesses of your study should be discussed.

The conclusion should be confined to an interpretation of the results of the study and a recommendation if applicable.

- May include up to 6 illustrations or tables.
- References should only include the most recent and relevant articles. A maximum of 30 references is advised.

Structured abstract

- This should be no more than 250 words, with the following headings:

- **Background:** why the study is being done and how it relates to other published work.
- **Objectives:** what the study intends to find out
- **Methods:** must include study design, number of participants, description of the research tools/instruments, any specific analyses that were done on the data.
- **Results:** first sentence must be brief population and sample description; outline the results according to the methods described. Primary outcomes must be described first, even if they are not the most significant findings of the study.
- **Conclusion:** must be supported by the data, and be aligned with the conclusion in the main text.
- Please ensure that the structured abstract is complete, accurate and clear and has been approved by all authors. It should be able to be intelligible to the reader without referral to the main body of the article.
- Do not include any references in the abstracts.

Here is an example of a good abstract.

***Scientific letters*/short reports**

These are shorter length, scholarly research articles of no more than 1500 words, and include case reports.

Guideline word limit: 1500 words

- Abstract: Structured, maximum 250 words, with the following headings: Background, Objectives, Methods, Results, and Conclusion.
- May include only one illustration or table
- A maximum of 15 references

Editorials

Guideline word limit: 1 000 words

These opinion or comment articles are usually commissioned but we are happy to consider and peer review unsolicited editorials. Editorials should be accessible and interesting to readers without specialist knowledge of the subject under discussion and should have an element of topicality (why is a comment on this issue relevant now?) There should be a clear message to the piece, supported by evidence.

Please make clear the type of evidence that supports each key statement, e.g.:

- expert opinion
- personal clinical experience
- observational studies
- trials
- systematic reviews.

Review articles

Narrative review articles should always be discussed with the Editor prior to submission. (Structured reviews or meta-analyses' need not be).

Guideline word limit: 4 000 words

These are welcome, but should be either commissioned or discussed with the Editor before submission. A review article should provide a clear, up-to-date account of the topic and be aimed at non-specialist hospital doctors and general practitioners. They should be aligned to practice in South and/or sub-Saharan Africa and not a précis of reviews published in the international literature

Please ensure that your article includes:

- Abstract: unstructured, of about 100-150 words, explaining the review and why it is important
- Methods: Outline the sources and selection methods, including search strategy and keywords used for identifying references from online bibliographic databases. Discuss the quality of evidence.
- When writing: clarify the evidence you used for key statements and the strength of the evidence. Do not present statements or opinions without such evidence, or if you have to, say that there is little or no evidence and that this is opinion. Avoid specialist jargon and abbreviations, and provide advice specific to southern Africa.
- Personal details: Please supply your qualifications, position and affiliations address, telephone number and fax number, and your e-mail address; and a short personal profile (50 words) and a few words about your current fields of interest.

Correspondence (Letters to the Editor)

Guideline word limit: 400 words

Letters to the editor should relate either to a paper or article published by the SAJCC or to a topical issue of particular relevance to the journal's readership

- May include only one illustration or table
- Must include a correspondence address.

Obituaries

Guideline word limit: 400 words

Should be offered within the first year of the practitioner's death, and may be accompanied by a photograph.

Illustrations/photos/scans

- If illustrations submitted have been published elsewhere, the author(s) should provide evidence of consent to republication obtained from the copyright holder.
- Figures must be numbered in Arabic numerals and referred to in the text e.g. '(Fig. 1)'.

- Each figure must have a caption/legend: Fig. 1. Description (any abbreviations in full).
- All images must be of high enough resolution/quality for print.
- All illustrations (graphs, diagrams, charts, etc.) must be in PDF form.
- Ensure all graph axes are labelled appropriately, with a heading/description and units (as necessary) indicated. Do not include decimal places if not necessary e.g. 0; 1.0; 2.0; 3.0; 4.0 etc.
- Each image must be attached individually as a 'supplementary file' upon submission (not solely embedded in the accompanying manuscript) and named Fig. 1, Fig. 2, etc.

Tables

- Tables should be constructed carefully and simply for intelligible data representation. Unnecessarily complicated tables are strongly discouraged.
- Embed/include each table in the manuscript Word file - do not provide separately as supplementary files.
- Number each table in Arabic numerals (Table 1, Table 2, etc.) consecutively as they are referred to in the text.
- Tables must be cell-based (i.e. not constructed with text boxes or tabs) and editable.
- Ensure each table has a concise title and column headings, and include units where necessary.
- Footnotes must be indicated with consecutive use of the following symbols: * † ‡ § ¶ || then ** †† ‡‡ etc.

References

NB: *Only complete, correctly formatted reference lists in Vancouver style will be accepted. If reference manager software is used, the reference list and citations in text are to be unformatted to plain text before submitting.*

- Authors must verify references from original sources.
- Citations should be inserted in the text as superscript numbers between square brackets, e.g. These regulations are endorsed by the World Health Organization,[2] and others.[3,4-6]
- All references should be listed at the end of the article in numerical order of appearance in the Vancouver style (not alphabetical order).
- Approved abbreviations of journal titles must be used; see the List of Journals in Index Medicus.
- Names and initials of all authors should be given; if there are more than six authors, the first three names should be given followed by et al.
- Volume and issue numbers should be given.
- First and last page, in full, should be given e.g.: 1215-1217 **not** 1215-17.
- Wherever possible, references must be accompanied by a digital object identifier (DOI) link). Authors are encouraged to use the DOI lookup service offered by CrossRef:
  - On the Crossref homepage, paste the article title into the 'Metadata search' box.
  - Look for the correct, matching article in the list of results.
  - Click Actions > Cite
  - Alongside 'url =' copy the URL between { }.
  - Provide as follows, e.g.: https://doi.org/10.7196/07294.937.98x

Some examples:

- *Journal references:* Price NC, Jacobs NN, Roberts DA, et al. Importance of asking about glaucoma. Stat Med 1998;289(1):350-355. DOI:10.1000/hgjr.182
- *Book references:* Jeffcoate N. Principles of Gynaecology. 4th ed. London: Butterworth, 1975:96-101.

- *Chapter/section in a book:* Weinstein L, Swartz MN. Pathogenic Properties of Invading Microorganisms. In: Sodeman WA, Sodeman WA, eds. Pathologic Physiology: Mechanisms of Disease. Philadelphia: WB Saunders, 1974:457-472.
- *Internet references:* World Health Organization. The World Health Report 2002 - Reducing Risks, Promoting Healthy Life. Geneva: WHO, 2002. http://www.who.int/whr/2002 (accessed 16 January 2010).
- Legal references
- Government Gazettes:

  National Department of Health, South Africa. National Policy for Health Act, 1990 (Act No. 116 of 1990). Free primary health care services. Government Gazette No. 17507:1514. 1996.

  In this example, 17507 is the Gazette Number. This is followed by :1514 - this is the notice number in this Gazette.

- Provincial Gazettes:

  Gauteng Province, South Africa; Department of Agriculture, Conservation, Environment and Land Affairs. Publication of the Gauteng health care waste management draft regulations. Gauteng Provincial Gazette No. 373:3003, 2003.

- Acts:

  South Africa. National Health Act No. 61 of 2003.

- Regulations to an Act:

  South Africa. National Health Act of 2003. Regulations: Rendering of clinical forensic medicine services. Government Gazette No. 35099, 2012. (Published under Government Notice R176).

- Bills:

  South Africa. Traditional Health Practitioners Bill, No. B66B-2003, 2006.

- Green/white papers:

  South Africa. Department of Health Green Paper: National Health Insurance in South Africa. 2011.

- Case law:

  Rex v Jopp and Another 1949 (4) SA 11 (N)

  Rex v Jopp and Another: Name of the parties concerned

  1949: Date of decision (or when the case was heard)

  (4): Volume number

SA: SA Law Reports

11: Page or section number

(N): In this case Natal - where the case was heard. Similarly, (C) woud indicate Cape, (G) Gauteng, and so on.

NOTE: no . after the v

- *Other references (e.g. reports) should follow the same format:* Author(s). Title. Publisher place: Publisher name, year; pages.
- Cited manuscripts that have been accepted but not yet published can be included as references followed by '(in press)'.
- Unpublished observations and personal communications in the text must **not** appear in the reference list. The full name of the source person must be provided for personal communications e.g. '...(Prof. Michael Jones, personal communication)'.

From submission to acceptance

Submission and peer-review

To submit an article:

- Please ensure that you have prepared your manuscript in line with the SAJCC requirements.
- All submissions should be submitted via Editorial Manager
- The following are required for your submission to be complete:
  - Anonymous manuscript (unless otherwise stated)
  - Author Agreement form
  - Manuscript
  - Ethics Approval form (for research articles)
  - Any supplementary files: figures, datasets, patient consent form, permissions for published images, etc.
  - Once the submission has been successfully processed on Editorial Manager, it will undergo a technical check by the Editorial Office before it will be assigned to an editor who will handle the review process. If the author guidelines have not been appropriately followed, the manuscript may be sent back to the author for correcting.

Peer Review Process

All manuscripts are reviewed initially by two of the editors and only those that meet the scientific and editorial standards of the journal, and fit within the aims and scope of the journal, will be sent for external peer review. Each manuscript is reviewed by two reviewers selected on the basis of their expertise in the field.

A double blind review process is followed at SAJCC. The time period of the entire review process may vary however depending upon the quality of the manuscript submitted, reviewers' responses and the time taken by the authors to submit the revised manuscript.

Manuscripts from review may be accepted, rejected or returned to the author for revision or resubmission for review. Authors will be directed to submit revised manuscripts within two months of receiving the editor's decision, and are requested to submit a point by point response to the reviewers' comments. Manuscripts which authors are requested to revise and resubmit will be sent for a second round of peer review, often to the original set of reviewers. All final decisions on a manuscript are at the Editor's discretion

Article Processing Charges

There is currently no article-processing charge (APC), also known as page fees, for the publication of manuscripts. The publication costs are supported by the Critical Care Society of Southern Africa and advertisements in the print version.

Please refer to the section on 'Sponsored Supplements' regarding the publication of supplements, where a charge is currently applicable.

Production process

The following process should usually take between 4 - 6 weeks:

1. An accepted manuscript is passed to a Managing Editor to assign to a copyeditor (CE).
2. The CE copyedits in Word, working on house style, format, spelling/grammar/punctuation, sense and consistency, and preparation for typesetting.
3. If the CE has an author queries, he/she will contact the corresponding author and send them the copyedited Word doc, asking them to solve the queries by means of track changes or comment boxes.
4. The authors are typically asked to respond within 1-3 days. Any comments/changes must be clearly indicated e.g. by means of track changes. Do not work in the original manuscript - work in the copyedited file sent to you and make your changes clear.
5. The CE will finalise the article and then it will be typeset.
6. Once typeset, the CE will send a PDF of the file to the authors to complete their final check, while simultaneously sending to the 2nd-eye proofreader.
7. The authors are typically asked to complete their final check and sign-off within 1-2 days. No major additional changes can be accommodated at this point.
8. The CE implements the authors' and proofreader's mark-ups, finalises the file, and prepares it for the upcoming issue.

Changing contact details or authorship

Please notify the Editorial Department of any contact detail changes, including email, to facilitate communication.

Errata and retractions

Errata

Should you become aware of an error or inaccuracy in yours or someone else's contribution after it has been published, please inform us as soon as possible via an email to publishing@hmpg.co.za,including the following details:

- Journal, volume and issue in which published
- Article title and authors
- Description of error and details of where it appears in the published article
- Full detail of proposed correction and rationale

We will investigate the issue and provide feedback. If appropriate, we will correct the web version immediately, and will publish an erratum in the next issue. All investigations will be conducted in accordance with guidelines provided by the Committee on Publication Ethics (COPE).

Retractions

Retraction of an article is the prerogative of either the original authors or the editorial team of HMPG. Should you wish to withdraw your article before publication, we need a signed statement from all the authors.

Should you wish to retract your published article, all authors have to agree in writing before publication of the retraction.

Send an email to publishing@hmpg.co.za, including the following details:

- Journal, volume and issue to which article was submitted/in which article was published
- Article title and authors
- Description of reason for withdrawal/retraction.

We will make a decision on a case-by-case basis upon review by the editorial committee in line with international best practices. Comprehensive feedback will be communicated with the authors with regard to the process. In case where there is any suspected fraud or professional misconduct, we will follow due process as recommended by the Committee on Publication Ethics (COPE), and in liaison with any relevant institutions.

When a retraction is published, it will be linked to the original article.

Indexing

Published articles are covered by the following major indexing services. As such articles published in the *SAJCC* are immediately available to all users of these databases, guaranteed a global and African audience:

- DOAJ
- AIM
- AJOL
- Scopus
- EBSCO
- EMBASE
- Crossref
- Sabinet
- Scielo

Sponsored supplements

Contact the editor for information on submitting ad hoc/commissioned supplements, including guidelines, conference/congress abstracts, Festschrifts, etc.

Submission Preparation Checklist

As part of the submission process, authors are required to check off their submission's compliance with all of the following items, and submissions may be returned to authors that do not adhere to these guidelines.

1. The submission has not been previously published, nor is it before another journal for consideration.
2. The text complies with the stylistic and bibliographic requirements in **Author Guidelines**.
3. The manuscript is in Microsoft Word format. The text is single-spaced, in 12-point Times New Roman font, and contains no unnecessary formatting.
4. Illustrations/figures are high resolution/quality (not compressed) and in an acceptable format (Jpeg). These must be submitted as 'supplementary files' (not in the manuscript).
5. For illustrations/figures or tables that have been published elsewhere, the author has obtained written consent to republication from the copyright holder.
6. Where possible, references are accompanied by a digital object identifier (DOI) and PubMed ID (PMID)/PubMed Central ID (PMCID).
7. An abstract has been included where applicable.
8. The research was approved by a Research Ethics Committee (if applicable)
9. Any conflict of interest (or competing interests) is indicated by the author(s).

Copyright Notice

Copyright of published material remains in the Authors' name. This allows authors to use their work for their own non-commercial purposes without seeking permission from the Publisher, subject to properly acknowledging the Journal as the original place of publication.

Authors are free to copy, print and distribute their articles, in full or in part, for teaching activities, and to deposit or include their work in their own personal or institutional database or on-line website. Authors are requested to inform the Journal/Publishers of their desire/intention to include their work in a thesis or dissertation or to republish their work in any derivative form (but not for commercial use).

Material submitted for publication in the *SAJCC* is accepted provided it has not been published or submitted for publication elsewhere. Please inform the editorial team if the main findings of your paper have been presented at a conference and published in abstract form, to avoid copyright infringement.

Privacy Statement

The *SAJCC* is committed to protecting the privacy of the users of this journal website. The names, personal particulars and email addresses entered in this website will be used only for the stated purposes of this journal and will not be made available to third parties without the user's permission or due process. Users consent to receive communication

from the *SAJCC* for the stated purposes of the journal. Queries with regard to privacy may be directed to publishing@hmpg.co.za.

Section 3: Draft article

Contamination of pulse oximeter probes before and after decontamination in two intensive care units

Farriel Desai, BSc, MBBCh, DA (SA)

Juan Scribante, PhD

Helen Perrie, MSc

Maria Fourtounas, MBChB, DA (SA), FCA (SA), MMed (Anaes), Dip HIV Man (SA)

Department of Anaesthesiology, School of Clinical Medicine, Faculty of Health Sciences, University of the Witwatersrand

Corresponding Author

Dr. F. Desai

Department of Anaesthesiology
Rahima Moosa Mother and Child Hospital
Fuel Rd and Oudtshoorn St
Coronationville
Johannesburg
2112

farriels@icloud.com

011 470 9303

Key words: Contamination, decontamination, microorganisms, pulse oximeter probes, intensive care units

Abstract

Background

The internal surfaces of pulse oximeter probes may be overlooked as “hot spots” for pathogenic microorganisms in an intensive care unit (ICU), thereby contributing to the high incidence of hospital acquired infections.

Objectives

The objective of this study was to determine the growth and identification of microorganisms on pulse oximeter probes in the multidisciplinary ICU (MICU) at Charlotte Maxeke Johannesburg Academic Hospital and the burns ICU (BICU) at Chris Hani Baragwanath Academic Hospital before and after decontamination.

Methods

This was a cross-sectional, comparative and contextual study, using purposive sampling. Data was collected from the internal surfaces of 34 pulse oximeter probes in a MICU and BICU. Each pulse oximeter probe was swabbed before and after decontamination. The endemic microorganism profile for the two ICUs was obtained from a laboratory database.

Results

Internal surfaces of 31 (91%, 95% confidence interval (CI): 0.76 - 0.98) pulse oximeter probes were contaminated with nine different pathogenic microorganisms pre-decontamination. *Acinetobacter baumannii*, *Klebsiella pneumoniae* and *Pseudomonas aeruginosa* were commonly endemic to both ICUs and were the most frequently isolated microorganisms. *Staphylococcus aureus* was the most common microorganism endemic to both ICUs with only two pulse oximeter probes isolating *Staphylococcus aureus* on their internal surfaces. Of the internal surfaces of pulse oximeter probes, 6 (18%, 95% CI: 0.07 - 0.36) remained contaminated post-decontamination, with a microorganism growth reduction of 80% (p=0.0001).

Conclusion

The internal surfaces of pulse oximeter probes may serve as “hot spots” for an array of pathogens with potential to cause infection and outbreaks in ICUs. Decontamination of the internal surfaces of pulse oximeter probes should be emphasised.

Introduction

Pulse oximeter probes are noncritical devices and while they may either require only low-level disinfection if not soiled with blood or high-level disinfection if soiled with blood,[1] they may pose as a source of infection. Pulse oximeter probes are regularly used as part of basic monitoring during the transport of critical patients to and from intensive care unit (ICU) settings and form part of standard monitoring equipment within ICU.[2] It is questionable whether the internal crevices that house the diodes are cleaned adequately, particularly in a busy hospital environment with a high turnover of patients and limited time for adequate decontamination of equipment.[3] A patient's finger can occupy a pulse oximeter probe for a long duration of time while admitted to ICU, leading to sebum build-up and ultimately becoming a cocoon for microorganisms.[4] The internal surfaces of pulse oximeter probes are frequently soiled with various materials. Soiling can impede the inactivation of microorganisms and inhibit the activation of disinfectants used.[5] Prolonged contact of pulse oximeter probes with patients' skin may lead to overheating and skin injury.[6] Furthermore, the tight application may lead to necrosis[6] compromising the innate immunity offered by the skin.[7]

Previous research has shown noncritical devices to be unsuspecting reservoirs housing significant numbers and strains of microorganisms.[8-20] Studies have reported noncritical devices to be responsible for outbreaks of pathogens.[8, 10] Most research on noncritical devices has come from developed countries which has implicated sphygmomanometer cuffs,[12] electrocardiograph leads,[13] stethoscopes[14] and temperature probes[15] as reservoirs. Other devices such as orthopaedic tourniquets,[16] sharps containers,[17] computer keyboards,[18] gloves[19] and telephones[20] have also been implicated. A few studies have found pulse oximeter probes to play a role in hospital acquired infection (HAI) transmission.[4, 21-25] Three of these studies describe outbreaks traced back to pulse oximeter probes as unsuspecting sources of HAIs.[21,22,24]

Burns and human immunodeficiency virus (HIV) are two of the main causes of immunosuppression in patients admitted to ICU. In South Africa, burn injuries account for the most unnatural causes of death in children.[26] Furthermore, HIV-associated diseases accounted for 50% of hospital admissions in 2011 and it is predicted that HIV-positive patients will account for up to 70% of hospital costs in the future.[27] The innate immunity offered by the skin in patients with a burn injury is markedly reduced[28] and HIV-positive

patients are likely to have dry skin.[29] Therefore, the skin of these patients is more likely to be breached by microorganisms placing them at a higher risk of cross-contamination from contaminated pulse oximeter probes.[30] Ideally disposable devices should be used on these patients to avoid cross-contamination.[31] However, in a resource-limited country such as South Africa, disposable devices are not usually attainable in the public sector. In Johannesburg, South Africa, at Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) and Chris Hani Baragwanath Academic Hospital (CHBAH), the burden of HAI is of significance in the multidisciplinary (MICU) and burns ICUs (BICU), respectively, as both ICUs are occasionally closed down during outbreaks of extensive-drug resistant microorganisms. No research could be identified addressing noncritical devices, specifically pulse oximeter probes, as potential reservoirs for HAI in South Africa. The aim of this study was to determine the growth and identification of microorganisms on pulse oximeter probes in the MICU at CMJAH and the BICU at CHBAH before and after decontamination.

Methods

This was a cross-sectional, comparative and contextual study. An ethics waiver from the Human Research Ethics Committee (Medical) (W-CBP-180601-01) and approval from other relevant authorities was obtained.

The MICU at CMJAH and the BICU at CHBAH were chosen as they are known to experience outbreaks of *Acinetobacter baumannii*. All available pulse oximeter probes within the ICUs were sampled to formulate a pool of pulse oximeter probes to meet sample size. The growth of microorganisms between the two ICUs was not compared. Each pulse oximeter probe was given a study number. In consultation with a biostatistician, a sample size of at least 33 pulse oximeter probes for each group was determined to have a significance of 5% and statistical power of 90% with the proportion of contaminated pulse oximeter probes being estimated to be 0.6 pre-decontamination and 0.3 post-decontamination, based on proportions of contaminated and decontaminated pulse oximeter probes identified in the literature.[4, 23] Group 1 consisted of pulse oximeter probes pre-decontamination and group 2 consisted of the same pulse oximeter probes post-decontamination.

The unit nursing managers confirmed that no written protocols were available within the ICUs regarding the decontamination of equipment. The ICUs' standard decontamination

practices consisted of cleaning soiled pulse oximeter probes with a Webcol® swab (70% isopropyl alcohol) followed by disinfection with QualiClean® (a chlorine-based disinfectant) (Rafu, Sr. MICU CMJAH; Churu, Sr. Paediatric BICU CHBAH; Dlamini, Sr. Adult BICU CHBAH. Conversation with: Desai, Dr. 2017 Jun 20).

The characteristics (manufacturer, type of pulse oximeter probe, location, cleanliness, soiled with blood and visible cracks on diode) of the pulse oximeter probes were captured on a data collection sheet.

The author (FD) was the sole data collector. Without prior warning to unit nursing staff, all samples were collected on 4 September 2018. The internal surfaces of pulse oximeter probes housing the diode sensors, served as test surfaces. Test surfaces were swabbed in a standardised manner with a swabbing technique adapted from Nandy et al.[4] Strict barrier precautions were maintained. The author's (FD) hands were disinfected with D-Germ® hand antiseptic and sterile gloves were donned. Test surfaces were swabbed using sterile, M40-compliant transwabs® in Amies transport-medium. A continuous rolling method from point A to point B following the arrows as illustrated in Figure 1 was used until the entire test surface was covered. This process was repeated on the opposite test surface of the same pulse oximeter probe with the same swab. The swab was then cautiously placed back in the transport medium without touching the rim of the container. Old gloves were discarded and new sterile gloves were donned. Test surfaces were cleaned with a Webcol® swab (70% isopropyl alcohol) vertically, from top to bottom with three strokes.[4] Intermediate-level disinfection of the test surfaces was carried out using sterile gauze (folded 2 cm wide) soaked in Qualiclean® (30g sachet diluted in 10 litres cold water until a clear solution arose as per manufacturer instructions yielding a chlorine strength of 250 ppm) using three vertical strokes, from top to bottom.[4] Test surfaces were allowed to dry for 30 seconds (exposure-time for Qualiclean®). Old gloves were discarded and new sterile gloves were donned. The test surfaces of the decontaminated pulse oximeter probes were re-swabbed, using the technique described.

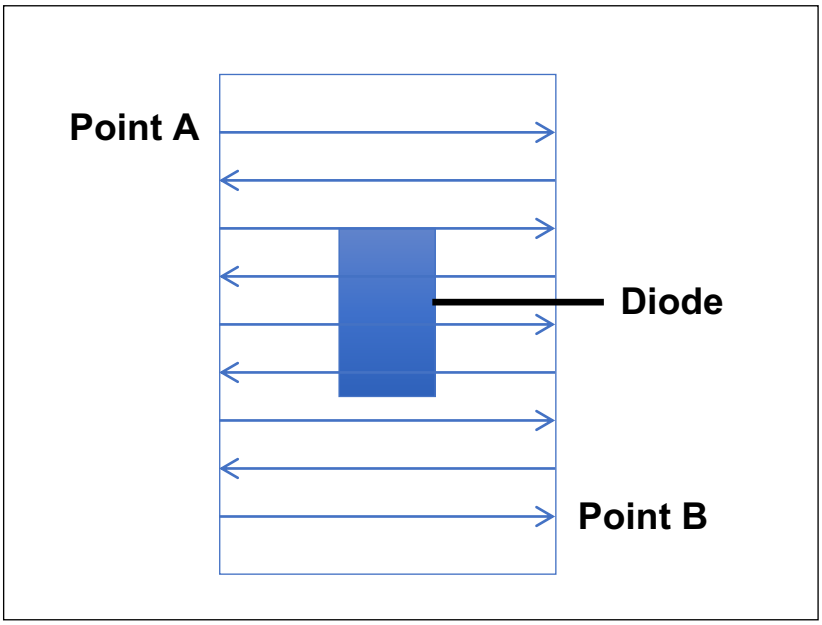


Figure 1: Method of swabbing pulse oximeter test surface

Samples were labelled according to the Vermaak and Partners Pathologists Laboratory's standardised form used to identify specimens and transported to the laboratory in Rosebank without delay. Samples were processed according to good laboratory practice. Following the identification of microorganisms, viable counts of microorganisms were determined using a colony count, which is a semiquantitative method of streaking out on miniature plates.

The laboratory defined colony count scores of 0+, 1+, 2+ and 3+ to reflect scanty growth, low-level contamination, medium-level contamination and high-level contamination, respectively. Sensitivity testing was not performed due to financial constraints.

The endemic microorganism profile for the two ICUs represented the four month period around data collection. All clinical specimens received by the National Health and Laboratory Service from the two ICUs for the period 1 June 2018 to 30 September 2018 were obtained from the National Health and Laboratory Service database. Culture-positive clinical specimens provided a reflection of the microbiological epidemiology for the ICUs for this period.

Data were entered into a Microsoft Excel spreadsheet and statistical analysis was performed in consultation with a biostatistician. Descriptive statistics (counts and percentages) was

used for categorical data. The proportion of pulse oximeter probes contaminated before and after disinfection were compared using McNemar's test. A p-value of ≤ 0.05 was considered to be statistically significant.

Results

A total of 34 pulse oximeter probes were sampled between the two ICUs. Of these, 26 (77%) were at the bedside and 8 (24%) were from portable monitors or found in storage. Nine (26%) pulse oximeter probes were sampled from the MICU at CMJAH and 25 (74%) were sampled from the BICU at CHBAH. Eleven (32%) pulse oximeter probes were sampled from the paediatric BICU and 14 (41%) were sampled from the adult BICU. Table 1 shows the characteristics of the pulse oximeter probes.

Table 1: The characteristics of the pulse oximeter probes.

Characteristic	N (%)
Manufacturer	
Philips®	11 (32)
Mindray®	9 (26)
PC 900®	6 (18)
Drager®	4 (12)
Beneview T8®	2 (6)
Matholo Healthcare®	2 (6)
Type of pulse oximeter probe	
Rubber-thimble type	20 (59)
Clam-shell type	12 (35)
Bandage-apparatus type	2 (6)
Location	
On patient	19 (56)
Storage	5 (15)
At patient bedside	4 (12)
Open bed space	3 (9)
Portable monitor at open bed space	2 (6)
Portable monitor on patient	1 (3)
Cleanliness	
Clean	23 (68)
Soiled	11 (32)
Soiled with blood	
No	7 (64)
Yes	4 (36)
Visible cracks on diode	
No	30 (88)
Yes	4 (12)

From the test surfaces of the 34 pulse oximeter probes sampled before decontamination, 31 (91%, 95% CI: 0.76 - 0.98) were contaminated. Of these, 8 out of 9 (89%, 95% CI: 0.52 - 0.99) and 23 out of 25 (92%, 95% CI: 0.74 - 0.99) pulse oximeter probes from the MICU and BICU were contaminated, respectively. Twenty-five (81%) contaminated pulse oximeter probes isolated one microorganism each and 6 (19%) contaminated pulse oximeter probes isolated two different microorganisms each.

From the test surfaces of the 34 pulse oximeter probes sampled after decontamination, only 6 (18%, 95% CI: 0.07 - 0.36) were contaminated. Of these, 2 out of 9 (22%) and 4 out of 25 (16%) were from the MICU and BICU, respectively.

The results of bacterial contamination of pulse oximeter probes before and after decontamination are present in Table 2.

Table 2: The bacterial contamination on the internal surfaces of pulse oximeter probes before and after decontamination.

Microorganism	Colony count (N)						Total positive growth	
	1+		2+		3+		N	N
	Before	After	Before	After	Before	After	Before	After
Acinetobacter baumannii complex*	2	0	4	1	6	0	12	1
Coagulase-negative *staphylococcus*	6	3	1	0	0	0	7	3
*Klebsiella pneumoniae**	1	0	1	0	1	0	3	0
*Pseudomonas aeruginosa**	0	0	0	0	3	0	3	0
Paenibacillus lautus	1	1	0	0	1	0	2	1
Arthrobacter globiformis	2	0	0	0	0	0	2	0
*Staphylococcus aureus**	0	0	2	0	0	0	2	0
Enterobacter cloacae complex*	0	1	0	0	1	0	1	1
Bacillus megaterium	0	0	0	0	1	0	1	0
*Candida auris**	1	0	0	0	0	0	1	0
Candida parapsilosis	0	0	0	0	1	0	1	0
*Escherichia coli**	0	0	0	0	1	0	1	0
*Enterococcus faecalis**	1	0	0	0	0	0	1	0
*Enterobacter hormacechei**	0	0	0	0	1	0	1	0

*Pathogenic microorganisms.

Microorganism growth was reduced by 80% after cleaning with a Webcol® swab and disinfection with Qualiclean®, which was statistically significant (p=0.0001).

The endemic microorganism profile and the microorganisms grown before decontamination of pulse oximeter probes in the MICU (Table 3) and BICU (Table 4) are shown. A total of 135 and 192 samples were cultured from the MICU and BICU, respectively, between 1 June 2018 to 30 September 2018. The tables represent the most common microorganisms isolated from pulse oximeters probes prior to decontamination within both ICUs.

Table 3: Endemic microorganism profile and number of contaminated pulse oximeter probes in the MICU.

Microorganism	Endemic microorganism N (%)	Pulse oximeter probe (N)
Staphylococcus aureus	29 (21)	1
Klebsiella pneumoniae	19 (14)	0
Pseudomonas aeruginosa	17 (13)	0
Acinetobacter baumannii complex	11 (8)	0
Candida albicans	8 (6)	0
Escherichia coli	8 (6)	0
Enterococcus faecium	7 (5)	0
Staphylococcus epidermidis	7 (5)	0
Proteus mirabilis	3 (2)	0
Coagulase negative *staphylococcus*	0	6
Candida auris	0	1

Table 4: Endemic microorganism profile and number of contaminated pulse oximeter probes in the BICU.

Microorganism	Endemic microorganism N (%)	Pulse oximeter probe (N)
Staphylococcus aureus	53 (28)	1
Acinetobacter baumannii complex	34 (18)	12
Pseudomonas aeruginosa	23 (12)	3
Coagulase negative *staphylococcus*	18 (9)	1
Klebsiella pneumoniae	13 (7)	3
Enterococcus faecalis	9 (5)	1
Proteus mirabilis	7 (4)	0
Escherichia coli	6 (3)	1
Enterococcus faecium	3 (2)	0

Discussion

HAIs hinder patient safety.[32] South Africa has a high HIV-prevalence, which increases the risk of HAI acquisition.[27] Infection control is important to prevent HAI transmission[33] and empirical antibiotic practices which could lead to antibiotic resistance.[34] A possible step towards reducing the risk of acquiring a HAI is the identification of "hot spots" through target-surface sampling of equipment. "Hot spot" identification could lead to the detection of overlooked reservoirs that harbour pathogenic microorganisms.[21]

The internal surfaces of pulse oximeter probes may be overlooked as "hot spots" for infection placing ICU patients at risk for HAI. Pulse oximeter probes contaminated with pathogenic microorganisms in close contact with the skin of susceptible ICU patients is concerning.[35]

In this study, 91% of the internal surfaces of pulse oximeter probes were contaminated before decontamination. Literature shows microorganism contamination of pulse oximeter probes to range from 66 – 80%.[23-25] In this study, the higher contamination of pulse oximeter probes and proportion of pathogenic microorganisms identified are difficult to equate to previous studies, which sampled pulse oximeter probes from different wards and ICUs. Furthermore, no previous studies could be identified to sample pulse oximeter probes within a BICU, which has favourable conditions (warm environment) for microorganism growth and persistence on environmental surfaces.[36]

Of the contaminated pulse oximeter probes prior to decontamination in this study, 68% isolated nine different pathogenic microorganisms with predominantly high-level contamination, namely: *Acinetobacter baumannii* complex, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Enterobacter cloacae* complex, *Candida auris*, *Escherichia coli*, *Enterococcus faecalis* and *Enterobacter hormacechei*. Wilkins[23] sampled pulse oximeter probes from various units in 15 different hospitals in the United States of America. Of the 44 pulse oximeter probes sampled, 29 (66%) were contaminated, of which only four (14%) isolated pathogenic microorganisms, namely: *Staphylococcus aureus*, *Staphylococcus haemolyticus*, *Enterococcus faecalis* and *Klebsiella oxytoca*. Three of these pulse oximeter probes were from ICUs.[23] Davis[25] sampled pulse oximeter probes in an emergency department within a rural hospital in

Australia. Of the 15 pulse oximeter probes sampled, 12 (80%) were contaminated, of which only two (13%) isolated pathogenic microorganisms, namely: *Staphylococcus aureus* and *Bacillus* species.[25] Morter et al[24] sampled various equipment from different wards in a hospital in the United Kingdom to isolate sources for a norovirus outbreak. Of the six pulse oximeter probes sampled, four (67%) were contaminated with the norovirus.[24]

Staphylococcus aureus was the most common endemic microorganism to both ICUs. In this study, however, only two pulse oximeter probes isolated *Staphylococcus aureus*, each with medium-level contamination. Previous studies have similarly shown only a few pulse oximeter probes to isolate *Staphylococcus aureus*.[23, 25] Considering that *Staphylococcus aureus* can persistently adhere to environmental surfaces with its peptidoglycan-containing cell wall[37] and that Parer et al[21] traced an outbreak-inducing heterogeneous glycopeptide-intermediate *Staphylococcus aureus* strain to the internal surface of a pulse oximeter probe within a trauma ICU; the mere growth of *Staphylococcus aureus* on pulse oximeter probes warrants alertness.

In this study, *Acinetobacter baumannii* complex was the most frequently isolated microorganism prior to decontamination with a contamination level ranging from low to high. This microorganism had a high endemic growth within the BICU (28%) and MICU (11%) and was present on five out of the six pulse oximeter probes that isolated two different pathogens each. *Klebsiella pneumonia* and *Pseudomonas aeruginosa* were among the most frequent pathogens endemic to both ICUs and the third most frequently isolated microorganisms on the internal surfaces of the pulse oximeter probes. One pulse oximeter probe soiled with blood had high-level contamination of both of these pathogenic microorganisms. These three microorganisms have the potential to cause HAIs in immunocompromised patients.[36-38] Their presence on the internal surfaces of pulse oximeter probes is clinically significant as they are responsible for frequent extensive-drug resistant outbreaks in the BICU at CHBAH (Wadula, Dr. Pathologist-In-Charge Clinical and Infectious Diseases CHBAH. Communication with: Desai, Dr. 2018 Mar 6), placing strain on last-resort antibiotics, such as colistin, and highlighting the emergence of antibiotic-resistant gram-negative bacilli within South Africa.[39]

In this study, six (19%) contaminated pulse oximeter probes isolated two different pathogenic microorganisms each, pre-decontamination. Additionally, six (18%) pulse

oximeter probes remained contaminated post-decontamination, of which four were contaminated with skin commensals, namely: coagulase-negative *staphylococcus* and *Paenibacillus lautus*. Of note, these decontaminated pulse oximeter probes were on patients' fingers pre-decontamination, three of which were visibly soiled with blood and two of which had visible cracks on their internal surfaces. These characteristics possibly reflect the build-up of tissue residuals (sebum, blood, debris) on pulse oximeter probes which impede terminal decontamination processes[40] and promote microorganism persistence on environmental surfaces,[4] despite adhering to the manufacturer and hospital guidelines. No previous studies could be identified to investigate the contamination of pulse oximeter probes after decontamination.

Following decontamination, microorganism growth was reduced by 80%. The reduction in contaminated pulse oximeter probes was statistically significant, reflecting the effectiveness of cleaning with a Webcol® swab followed by disinfecting with Qualiclean® (decontamination processes that are already employed within both ICUs during regular "scrub-down" processes). While an 80% reduction in contamination is acceptable, 20% of contaminated pulse oximeter probes still remains a risk to patients. In this study, attributable causes for remnant contamination could be the cracks and crevices present on pulse oximeter probes. In addition to following manufacturer and unit decontamination guidelines, possible improvements could be to omit using cracked pulse oximeter probes and to target the crevices around diodes more closely during decontamination processes.

The limitation of this study is that it was done contextually in CHBAH and CMJAH, therefore it cannot be generalised to ICUs in other hospitals. Sensitivity testing could not be done due to funding constraints. Future studies investigating the sensitivity of pathogens isolated from pulse oximeter probes is recommended.

Conclusion

This study shows that the internal surfaces of pulse oximeter probes may serve as "hot spots" for an array of pathogens with potential to cause infection. Cleaning and disinfecting the internal surfaces of pulse oximeter probes should be emphasised and possibly incorporated into a target-surface sampling protocol in an ICU setting where it is not practical to have cubicles vacant for prolonged periods while an outbreak is being addressed.

Conflict of interest

The authors declare that we have no financial or personal relationships which may have inappropriately influenced us in writing this paper.

Acknowledgement

The authors thank Dr. Warren Lowman for his substantial assistance with the microbiology data and Vermaak and Partners Pathologists Laboratory for the efficient processing of samples and the South African Society of Anaesthesiologists Jan Pretorius Research Fund for their financial assistance.

This research was completed in partial fulfilment of a Master of Medicine degree.

References

1. Rutala WA, Weber DA. Disinfection and sterilization in health care facilities: An overview and current issues. Infect Dis Clin N Am. 2016;30(2016):609-637. https://doi.org/10.1016/j.idc.2016.04.002

2. Andrews FJ, Nolan JP. Critical care in the emergency department: Monitoring the critically ill patient. Emerg Med J. 2005;23(7):561-564. https://doi.org/10.1136/emj.2005.029926

3. Davis C. Blood pressure cuffs and pulse oximeter sensors: A potential source of cross-contamination. Australas Emerg Nurs J. 2009;12:104-109. https://doi.org/10.1016/j.aenj.2009.03.004

4. Nandy P, Lucas AD, Gonzalez EA, Hitchins VM. Efficacy of commercially available wipes for disinfection of pulse oximeter sensors. Am J of Infect Control. 2016;44(3):304-310. https://doi.org/10.1016/j.ajic.2015.09.028

5. Sharbaugh RJ. Cleaning reusable equipment in the ICU. Crit Care Nurs Q. 2001;24(2):48-54. https://doi.org/10.1097/00002727-200108000-00007

6. Ortega R, Hansen CJ, Elterman K, Woo A. Pulse oximetry. N Engl J Med. 2011;364(16):e33-e36. https://doi.org/10.1056/NEJMvcm0904262

7. Adkinson NF, Bochner BS, Burks AW, Busse WW, Holgate ST, Lemanske RF, et al. Structure of the skin and cutaneous immunology. In: Plager DA, Bieber T, Pittelkow MR, eds. Middelton's allergy: Principles and practice Eighth edition. Philadelphia: Elsevier Saunders; 2014: 518-539.

8. Dumford III DM, Nerandzic MM, Eckstein BC, Donskey CJ. What is on that keyboard? Detecting hidden environmental reservoirs of clostridium difficile during an outbreak associated with North American pulsed-field gel electrophoresis type 1 strains. Am J of Infect Control. 2009;37(1):15-19. https://doi.org/10.1016/j.ajic.2008.07.009

9. Alfandari S, Gois J, Delannoy PY, Georges H, Boussekey N, Chiche A, et al. Management and control of a carbapenem-resistant acinetobacter baumannii

outbreak in an intensive care unit. Med Mal Infect. 2014;44(5):229-31. https://doi.org/10.1016/j.medmal.2014.03

10. Harnett SJ, Allen KD, Macmillan RR. Critical care unit outbreak of serratia liquefaciens from contaminated pressure monitoring equipment. J Hosp Infect. 2001;47(4):301-307. https://doi.org/10.1053/jhin.2001.0941

11. Devine J, Cooke R, Wright E. Is methicillin-resistant staphylococcus aureus (MRSA) contamination of ward-based computer terminals a surrogate marker for nosocomial MRSA transmission and handwashing complaince? J Hosp Infect. 2001;48(1):72-75. https://doi.org/10.1053/jhin.2001.0955

12. De Gialluly C, Morange V, De Gialluly E, Loulergue J, van der Mee N, Quentin R. Blood pressure cuff as a potential vector of pathogenic microorganisms: A prospective study in a teaching hospital. Infect Control Hosp Epidemiol. 2006;27(9):940-943. https://doi.org/10.1086/507284

13. Lestari T, Ryll S, Kramer A. Microbial contamination of manually reprocessed, ready to use ECG lead wire in intensive care units. GMS Hyg Infect Control. 2013;8(1):1-7. https://doi.org/10.3205/dgkh000207

14. Maluf M, Maldonado A, Bercial M. Stethoscope: a friend or an enemy? Sao Paulo Med J. 2002;120(1):13-15. https://doi.org/10.1590/S1516-31802002000100004

15. Uneke CJ, Ijeoma PA. The potential for transmission of hospital-acquired infections by non-critical medical devices: the role of thermometers and blood pressure cuffs. World Health Popul. 2011;12(3):5-12. https://doi.org/10.12927/whp.2011.22098

16. Walsh E, Ben-David D, Ritter M, Mechrefe A, Mermel L, DiGiovanni C. Microbial colonization of tourniquets used in orthopaedic surgery. Orthopaedics. 2006;29:709. PMID: 16924865

17. Runner J. Bacterial and viral contamination of reusable sharps containers in a community hospital setting. AJIC. 2007;35(8):527-530. https://doi.org/10.1016/j.ajic.2006.09.017

18. Gray J, McNicholl B, Webb H, Hogg G. Mice in the emergency department: vector for infection or technological aid? Eur J Emerg Med. 2007;14(3):160-162. https://doi.org/10.1097/MEJ.0b013e3280bef922

19. Luckey J, Barfield R, Eleazer P. Bacterial count comparisons on examination gloves from freshly opened boxes and from examination gloves before treatment versus after dental dam isolation. J Endod. 2006;32(7):646-648. https://doi.org/10.1016/j.joen.2005.09.017

20. Tunc K, Olgun U. Microbiology of public telephones. J Infect. 2006;53:140-143. https://doi.org/10.1016/j.jinf.2005.10.022

21. Parer S, Lotthe A, Chardon P, Poncet R, Jean-Pierre H, Jumas-Bilak E. An outbreak of heterogeneous glycopeptide-intermediate staphylococcus aureus related to a device source in an intensive care unit. Infect Control Hosp Epidemiol. 2012;33(2):167-174. https:/doi.org/10.1086/663703

22. Pusch T, Kemp D, Trevino S, Button T, Sanchez P, Gander R, et al. Controlling outbreak of vancomycin-resistant enterococcus faecium among infants caused by an endemic strain in adult inpatients. Am J of Infect Control. 2013;41(1):51-56. https://doi.org/10.1016/j.ajic.2012.01.034

23. Wilkins MC. Residual bacterial contamination on reusable pulse oximetry sensors. Respir Care. 1993;38(11):1155-1160. PMID: 10145923

24. Morter S, Bennet G, Fish J, Allen DJ, Nawaz S, Iturriza-Gomara M, et al. Norovirus in the hospital setting: Virus introduction and spread within the hospital environment. J Hosp Infect. 2011;77(2):106-112. https:/doi.org/10.1016/j.jhin.2010.09.035

25. Davis C. Blood pressure cuffs and pulse oximeter sensors: A potential source of cross-contamination. Australas Emerg Nurs J. 2009;12(3):104-109. https://doi.org/10.1016/j.aenj.2009.03.004

26. Rode AH, Cox SG, Numanoglu A, Berg AM. Burn care in South Africa: A micro cosmos of Africa. Pediatr Surg Int. 2014;30(7):699-706. https://doi.org/10.1007/s00383-014-3519-5

27. Crowther-Gibson P, Govender N, Lewis DA, Bamford C, Brink A, von Gottenberg A, et al. Part IV: Human infections and antibiotic resistance. S Afr Med J. 2011;101(8):567-578. https:/doi.org/10.7196/SAMJ.5102

28. Kravitz M. Immune consequences of burn injury. AACN Clin Issues Crit Care Nurs. 1993;4(2):399-413. https://doi.org/10.4037/15597768-1993-2017

29. Lee D, Benson CA, Lewis CE, Grunfeld C, Scherzer R. Prevalence and factors associated with dry skin in HIV infection: the FRAM study. AIDS. 2007;21(15):2051-7. https:/doi.org/10.1097/QAD.0b013e3282eea51a

30. Elfaki ME. Immunosuppression induced by HIV infection. Biol Med. 2014;6(3):111-112. https://doi.org/10.1097/00006247-200112000-00016

31. Gilmore GK. Infection control advances decrease pateint and staff risk. Nurse Manage. 2001;32(12):51-53. https://doi.org/10.1097/00006247-200112000-00016

32. World Health Organization. World alliance for patient safety. Forward programme 2005. Geneva: WHO, 2004. https://www.who.int/patientsafety/en/brochure_final.pdf (accessed 22 August 2017).

33. Huang SS, Datta R, Platt R. Risk of acquiring antibiotic-resistant bacteria from prior room occupants. Arch Intern Med. 2006;166(18):1945-1951. https://doi.org/10.1001/archinte.166.18.1945

34. Ventola CL. The antibiotic resistance crisis. Part 2: management strategies and new agents. P&T. 2015;40(5):344-52. PMID: 25987823

35. Brady RRW, Kalima P, Damani NN, Wilson RG, Dunlop MG. Bacterial contamination of hospital bed-control handsets in a surgical setting: a potential marker of contamination of the healthcare environment. Ann R Coll Surg Engl. 2007;89(7):656-660. https://doi.org/10.1308/003588407X209347

36. Carroll KC, Hobden JA. Chapter 16: Pseudomonads and Acinetobacter. In: Carroll KC, Hobden JA, Miller S, Morse SA, Mietzner TA, Detrick B, et al., eds. Jawetz, Melnick, & Adelberg's Medical microbiology, 27th edition Section III: bacteriology. New York:

McGraw-Hill; 2016: http://0-accessmedicine.mhmedical.com.innopac.wits.ac.za/content.aspx?bookid=1551&sectionid=94107120. Accessed May 18, 2019.

37. Carroll KC, Hobden JA. Chapter 13: The staphylococci. In: Carroll KC, Hobden J, A., Miller S, Morse SA, Mietzner TA, Detrick B, et al., editors. Jawetz, Melnick, & Adelberg's Medical Microbiology, 27th edition Section III: bacteriology New York: McGraw-Hill; 2016: http://0-accessmedicine.mhmedical.com.innopac.wits.ac.za/content.aspx?bookid=1551&sectionid=94106626. Accessed June 27, 2017.

38. Carroll KC, Hobden JA. Chapter 15: Enteric gram-negative rods (enterobacteriaceae). In: Carroll KC, Hobden JA, Miller S, Morse SA, Mietzner TA, Detrick B, et al., editors. Jawetz, Melnick, & Adelberg's Medical microbiology, 27th edition Section III: bacteriology. New York: McGraw-Hill; 2016: http://0-accessmedicine.mhmedical.com.innopac.wits.ac.za/content.aspx?bookid=1551&sectionid=94106931. Accessed May 18, 2019.

39. Brink A, Feldman C, Richards GA, Moolman J, Senekal M. Emergence of extensive drug resistance (XDR) among gram negative bacilli in South Africa looms nearer. S Afr Med J. 2008;98(8):586-592. http://0-search.ebscohost.com.innopac.wits.ac.za//login.aspx?direct=true&mdc&AN=18928032&site=ehost-live&scope=site.

40. Alfa MJ. Monitoring and improving the effectiveness of cleaning medical and surgical devices. Am J Infect Control. 2013;41(2013):S56-S59. https://doi.org/10.1016/j.ajic.2012.12.006.

Section 4: Proposal

Contamination of pulse oximeter probes before and after decontamination in two intensive care units

Farriel Desai

0500745N

Supervisor: Professor J Scribante

Department of Anaesthesiology

Supervisor: Ms. H Perrie

Department of Anaesthesiology

Supervisor: Dr. M Fourtounas

Department of Anaesthesiology

4.1 Introduction

Hospital acquired infections (HAIs) play an important role in prolonging hospital stay and ultimately increase the cost for a hospital (1). HAIs also contribute to the emerging problem of antibiotic resistance (2) affecting patient safety (3). The burden of HAI is higher in developing countries being 15.5 per 100 patients (4), compared to a developed country such as the United States of America being 4 per 100 patients (5) or a developed continent such as Europe with an average prevalence of 7.1 per 100 patients (6). This is possibly an underestimate due to the paucity of high quality studies available from resource-poor developing countries (4).

In South African intensive care units (ICUs) specifically, approximately 28% of patients have evidence of an HAI at any one point in time (7). The point-prevalence of patients in South African ICUs who received inappropriate initial antibiotics during 2012 was 54.9% with an associated mortality of 27% (7). The lack of recent and regional data from developing countries makes the application of the Surviving Sepsis Campaign (8), which advocates for the timeous initiation of antibiotics, in developing countries challenging (9).

Methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant *Enterococcus* and *Clostridium difficile* are the main antibiotic resistant microorganisms worldwide (10). In South African hospitals, gram-negative bacilli (GNB) are becoming increasingly resistant to available antibiotics (11). The genetic mutation, *mcr-1*, has placed a strain on the ”last resort” antibiotic, Colistin, used to treat GNB (12).

A contaminated healthcare environment plays an important role in the transmission of microorganisms (13-16). Patients who are inoculated with antibiotic-resistant microorganisms contaminate the healthcare environment through a combination of direct shedding (17) and indirectly after being touched by healthcare-workers’ hands (18). Subsequent patients placed within this environment can be inoculated with the same antibiotic-resistant microorganism (16).

Contaminated reusable medical devices (RMDs) are a common source of HAIs (19). Any substandard cleaning of RMDs, prior to reuse in subsequent patients, can

result in residue build-up that provides a perpetuating medium for microorganism growth (17).

The U.S. Food and Drug Administration (20), the World Health Organization (21), the Centers for Disease Control and Prevention (22) and the South African Society of Anaesthesiologists (23) guidelines utilise the traditional Spaulding approach (24) to classify RMDs as critical (in contact with sterile tissues, requiring sterilisation), semicritical (in contact with mucous membranes, requiring high-level disinfection) and noncritical (in contact with intact skin, requiring low level disinfection).

4. 2 Problem statement

Pulse oximeter probes are noncritical devices and while they may either require only low-level disinfection, if not soiled with blood, or high-level disinfection, if soiled with blood (25), they may pose as a source of infection. Pulse oximeter probes are regularly used as part of basic monitoring during the transport of critical patients to and from ICU and form part of standard monitoring equipment within ICU (26). It is questionable whether the internal crevices that house the diodes are cleaned adequately, particularly in a busy hospital environment with a high turnover of patients and limited time for adequate decontamination of equipment (27). A patient's finger can occupy a pulse oximeter probe for a long duration of time while admitted to ICU, leading to oil build-up and ultimately become a cocoon for microorganisms (28).

The internal surfaces of pulse oximeter probes are frequently soiled with various materials. Soiling can impede the inactivation of microorganisms and inhibit the activation of disinfectants used (29). Prolonged contact of pulse oximeter probes with patients' skin may lead to overheating and skin injury (30). Furthermore, the tight application may lead to necrosis (30) compromising the innate immunity offered by skin (31).

HIV-positive and burn patients would be at a higher risk of cross-contamination from these devices due to immunosuppression (32) and ideally disposable devices should be used on these individuals to avoid cross-contamination (33). However, in a resource-limited country such as South Africa, disposable devices are not usually attainable. In South Africa, patients with HIV-associated diseases accounted for

50% of hospital admissions in 2011 and it is predicted that HIV-positive patients will account for up to 70% of hospital costs in the future (34).

Previous research has shown noncritical devices to be unsuspecting reservoirs housing significant numbers and strains of microorganisms (35-55). Studies have reported noncritical devices to be responsible for outbreaks of pathogens (35, 36, 55). Most research on noncritical devices has come from developed countries which has implicated sphygmomanometer cuffs (36-39, 53), electrocardiograph leads (40, 54), stethoscopes (40, 41, 56, 57) and temperature probes (44) as reservoirs. Other devices such as orthopaedic tourniquets (58, 59), sharps containers (47, 60), computer keyboards (49-51, 55), gloves (61) and telephones (62) have also been implicated. A few studies have found pulse oximeter probes to play a role in HAI transmission (28, 63-67). Three of these studies describe outbreaks traced back to pulse oximeter probes as unsuspecting sources of HAIs (63, 64, 66).

In Johannesburg at Chris Hani Baragwanath Academic Hospital (CHBAH), the adult and paediatric Burns ICU (BICU) had 159 and 162 significant microorganism isolates on blood cultures for the period 2015 to 2016, respectively (68).

The burden of HAI is of significance in the BICU amongst paediatric patients where the unit is occasionally closed down for a period of time during outbreaks (Churu, Sr. Paediatric BICU CHBAH. Conversation with: Desai, Dr. 2017 Jun 20). Outbreaks of extremely drug-resistant *Acinetobacter baumannii, Klebsiella pneumoniae*, *Pseudomonas aeruginosa* and *Candida auris* are common (Wadula, Dr. Pathologist-in-Charge Clinical and Infectious Diseases CHBAH. Communication with: Desai, Dr. 2018 Mar 6).

No research could be identified addressing noncritical devices, specifically pulse oximeter probes, as potential reservoirs for HAI in South Africa.

4.3 Aim

The aim of this study is to determine the growth and identification of microorganisms on pulse oximeter probes in the multidisciplinary ICU (MICU) at

Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) and the BICU at CHBAH before and after decontamination.

4.4 Objectives

The primary objectives of this study are to:

- determine the endemic microorganism profile in the two ICUs
- determine the condition of the pulse oximeter probes (cleanliness, blood-soiled, visible diode cracks)
- determine the bacterial contamination on pulse oximeter probes before and after decontamination
- compare the proportion of contaminated pulse oximeter probes before and after decontamination.

4.5 Research assumptions

The following definitions will be used in this study.

Pulse oximeter probe is one of any make, reusable, in working order, both in use or not in use by a patient.

Test surface will refer to the internal surface of a pulse oximeter probe that houses the diode.

Decontamination: “a process of removing pathogenic microorganisms from an object or surface so that it is no longer capable of transmitting infectious particles. It is a combination of the processes of cleaning, disinfection, and/or sterilization” (69).

Cleaning: “a process of removing organic and inorganic material from an object or surface with water and enzymatic products or detergents. It is the first step in all decontamination processes” (69). In this study pulse oximeter probes will be cleaned with a detergent (70% isopropyl alcohol).

Disinfection: “a process that eliminates many or all pathogenic microorganisms except bacterial spores, on objects or surfaces. There are three levels of disinfection based on the antimicrobial spectrum and rapidity of action” (69). In this

study, intermediate-level disinfection will be performed with a tuberculocidal chlorine-based agent, QualiClean®.

Intermediate-level disinfection: “destroys mycobacteria, vegetative bacteria, most viruses and most fungi, but does not kill bacterial spores. Used for noncritical instruments and environmental surfaces when a tuberculocidal agent is necessary” (23).

Colony count: a semiquantitative method of streaking out on miniature plates. The Vermaak and Partners Pathologists Laboratory define colony count scores of 0+, 1+, 2+ and 3+ to reflect scanty growth, low-level contamination, medium-level contamination and high-level contamination, respectively.

4. 6 Demarcation of study field

This study will be conducted in the MICU of CMJAH and the BICU of CHBAH, affiliated to the University of the Witwatersrand.

CMJAH is a 1200-bed central hospital. Its MICU comprises 12 adult beds. CHBAH is a 2888-bed central hospital. Its BICU comprises six adult beds and seven paediatric beds. The facility design of both units is a cubicle layout.

4. 7 Ethical considerations

Approval for this study will be obtained from the Heads of Department of the MICU at CMJAH and the BICU at CHBAH to perform this study (Appendix A). A waiver will be requested from the Human Research Ethics Committee (Medical) of the University of the Witwatersrand as this study will not include any humans (Appendix B).

Approval will be obtained from the Graduate Studies Committee of the University of the Witwatersrand prior to starting this study. Further permission will be obtained from the CEO of CMJAH, the Medical Advisory Committee of CHBAH and the National Manager of the National Health Laboratory Service.

Only the researcher and supervisors will have access to the raw data thereby ensuring confidentiality. Data will be stored on a password-protected database for six years after completion of the study.

The results of this study will be communicated with the MICU and BICU as soon as they are available from the laboratory as this may impact on their infection control practices.

The study will be conducted according to the principles of the Declaration of Helsinki (70) and the South African Guidelines for Good Clinical Practice (71).

4. 8 Data collection

4. 8. 1 Research design

This study will be a cross-sectional, comparative and contextual research design.

Cross-sectional study: “studies are used to examine data at one point in time, that is, the data are collected on one occasion only with different participants, rather than on the same participants at several points in time” (72). This study is cross-sectional as samples will be collected from the same pulse oximeter probes before and after decontamination.

Comparative study: “a study in which intact groups are compared on some dependent variable. The researcher is not able to manipulate the independent variable, which is frequently some inherent characteristics of the subjects, such as age or educational level” (72). This study is comparative, as it will compare the microbial growth before and after decontamination of pulse oximeter probes.

Contextual study: de Vos et al (73) describes a contextual study as a study of “small-scale worlds”, such as: “gangs, hospital wards, public drinking places, school classrooms, restaurants, clubs and cults”. This study is contextual as it will be done in the context of the MICU setting at CMJAH and the BICU setting at CHBAH.

4. 8. 2 Study population

The study population will include all pulse oximeter probes in the MICU and BICU.

4. 8. 3 Sample method

In this study a purposive sampling method will be used. Purposive sampling is defined by Brink et al (72) as a “type of non-probability sampling”. This technique is based on the judgement of the researcher regarding participants or objects that are typical or representative of the study phenomenon, or who are especially knowledgeable about the question at hand. Purposive sampling has the advantage of allowing the researcher to select the sample based on knowledge of the phenomena being studied (72).

This study will use a purposive sampling method as all pulse oximeter probes available at the time of the study will be included in the sample.

4. 8. 4 Sample size

In consultation with a biostatistician, a sample size of at least 33 pulse oximeter probes for each group is determined to have a significance of 5% and statistical power of 90% with the proportion of contaminated pulse oximeter probes being estimated to be 0.6 pre-decontamination and 0.3 post-decontamination, based on proportions of contaminated and decontaminated pulse oximeter probes identified in the literature (28, 65).

All pulse oximeter probes present within the two units will be sampled. There are currently 35 pulse oximeter probes between the two units.

4. 8. 5 Inclusion and exclusion criteria

The inclusion criteria for this study are:

- pulse oximeter probes in MICU at CMJAH and BICU at CHBAH
- bedside pulse oximeter probes both in use and not in use by a patient
- pulse oximeter probes in storage within the units
- pulse oximeter probes present on portable monitors within the units
- pulse oximeter probes present in theatre in BICU
- all types of pulse oximeter probe brands available.

The exclusion criterion for this study are pulse oximeter probes on unstable patients requiring cardiopulmonary resuscitation at the time of sampling and therefore require continuous oxygen saturation monitoring.

4. 8. 6 Data collection

The endemic microorganism profile for the two units will be obtained from the National Health Laboratory Service. A printout detailing the microbiology profile for six months encompassing data collection will be obtained.

In consultation with the unit nursing managers (Rafu, Sr. MICU CMJAH; Churu, Sr. Paediatric BICU CHBAH; Dlamini, Sr. Adult BICU CHBAH. Conversation with: Desai, Dr. 2017 Jun 20) it was confirmed that there is no written protocol available regarding decontamination of equipment within the units. Only verbal confirmation was obtained from the unit nursing managers who confirm that the current standard practice for decontamination used in the units consists of cleaning soiled pulse oximeter probes with a Webcol® swab (70% isopropyl alcohol) followed by disinfecting the pulse oximeter probes with QualiClean® (a chlorine-based disinfectant).

According to these unit nursing managers, environmental surfaces and equipment “should be decontaminated daily” but are generally decontaminated only after discharge or death of a patient. Furthermore, the BICU utilises a hydrogen peroxide mist system in addition to the above decontamination process. This will not influence the results attained in the study as the primary aim of this study is to determine whether the internal surfaces of the pulse oximeter probes are contaminated or not. Neither will the growth and identification of microorganisms on pulse oximeter probes between the two units be compared, nor will the cleaning practices of nursing staff be assessed.

The pulse oximeter probes will be decontaminated and swabbed again in an attempt to determine if a specific attempt to decontaminate the internal surfaces of pulse oximeter probes will reduce the contamination level of pulse oximeter probes.

Sample collection

The researcher will use the current decontamination disinfectants used in the two units. The researcher will be the sole data collector. Each pulse oximeter probe will be given a study number.

Swabs will be taken in a standardised manner where the internal surfaces of pulse oximeter probes, including the diode sensors in direct contact with patients' skin or nails, will serve as test surfaces.

Samples taken before decontamination will be labeled pulse oximeter probe A (PopA) and those taken after decontamination will be labeled pulse oximeter probe B (PopB).

A standardised procedure will be followed for the swabbing technique, which is adapted from Nandy et al (28).

- The researcher will use strict barrier precautions before and after contact with each patient. The researcher will don a disposable plastic apron and a disposable facemask. Hands will be disinfected with D-Germ® hand antiseptic and sterile gloves donned (to conform to ICU infection control standards).
- All pulse oximeter probes will be swabbed using sterile swabs in a transport medium obtained from Vermaak & Partners Pathologists Laboratory.
- The swab will be taken using a continuous rolling method from point A to point B following the arrows as illustrated in Figure 1 until the entire test surface is covered. With the same swab, the process will be repeated on the opposite test surface of the same pulse oximeter.

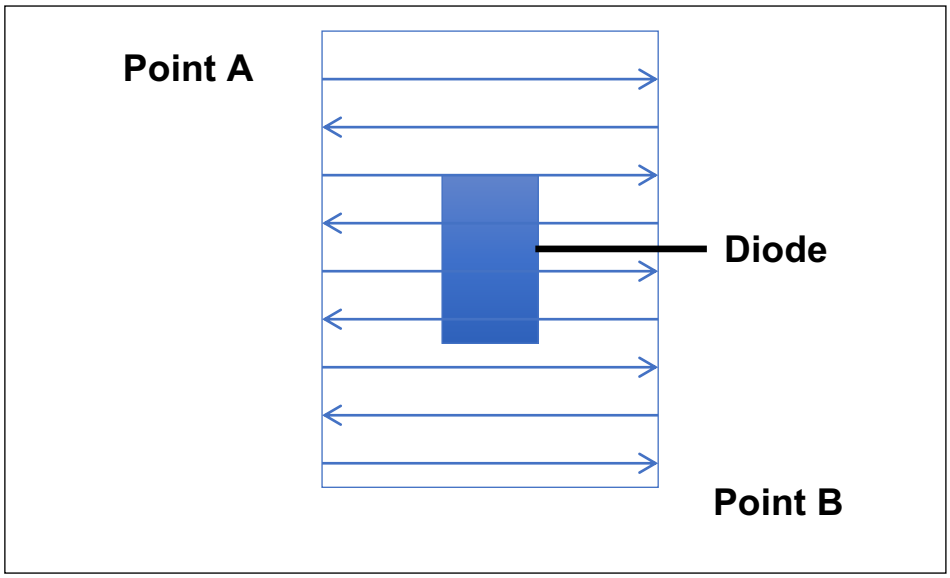


Figure 1: The method of swabbing the pulse oximeter test surface

- The swab will be placed back in the transport medium and labeled PopA, being cautious not to touch the outside of the transport medium container.
- The researcher will discard the used gloves and don new sterile gloves.
- Both test surfaces of the pulse oximeter probe will be cleaned by the researcher using a Webcol® swab (70% isopropyl alcohol) vertically, from top to bottom with three strokes (28).
- Intermediate-level disinfection will be carried out. The test surfaces will be disinfected by the researcher using sterile gauze, folded not more than 2 cm wide using three vertical strokes, from top to bottom (28). The gauze will be soaked in Qualiclean® (30g sachet diluted in 10 litres cold water until a clear solution arises as per manufacturer instructions yielding a chlorine strength of 250 ppm).
- The test surfaces will be allowed to dry for 30 seconds (exposure-time for Qualiclean®) after disinfection.
- The researcher will discard the used gloves and don new sterile gloves.
- The decontaminated pulse oximeter probe will be swabbed again, using the same technique described previously.
- The swab will be placed back in the transport medium and labeled PopB, being cautious not to touch the outside of the transport medium container.

Sample labeling

There will be two samples for each pulse oximeter probe.

- Samples will be labeled according to the Vermaak and Partners Pathologists Laboratory's standardised form used to identify specimens. The forms will be labeled in the following manner:

  Patient name: Mmed Student Project

  Patient ID number: PopA (Study number e.g. 01) and PopB (Study number e.g. 01)

  Ward: MICU or BICU

- A single sticker containing a unique bar code will be placed onto the samples and another will be placed onto the data collection sheet alongside the study number to enable result retrieval.

Sample storage and transport

Samples will be inserted into a transport box obtained from the laboratory and hand-delivered by the researcher to the laboratory for analysis. The laboratory does not require a specific time frame for delivery as swabs are placed in a transport medium. Specimens will be transported to the laboratory after sampling without delay.

Sample processing

Samples will be processed in an accredited microbiology laboratory, Vermaak and Partners Pathologists Rosebank Laboratory, according to standard microbiological procedures.

Colony count is a semiquantitative method of streaking out on miniature plates. This is a cost effective and faster way to determine viable counts of microorganisms compared to using the colony forming unit quantification technique. The Vermaak and Partners Pathologists Laboratory define colony count scores of 0+, 1+, 2+ and 3+ to reflect scanty growth, low-level contamination, medium-level contamination and high-level contamination, respectively.

Data collection sheet

The following data will be captured on a data collection sheet (Appendix C):

- characteristics of pulse oximeter probe:
    - pulse oximeter probe manufacturer
    - location of pulse oximeter probe (on patient/in storage/open bed-space)
    - cleanliness of pulse oximeter probe (clean or visibly soiled)
    - visible blood (yes or no)
    - visible cracks on diodes (yes or no)
    - microorganism(s) cultured and identified from PopA
    - microorganism(s) cultured and identified from PopB

4. 8. 7 Data analysis

All data will be entered into a Microsoft Excel spreadsheet, which will be used to perform a basic statistical analysis. Descriptive and inferential statistics will be used.

Data analysis will be done in consultation with a biostatistician. Categorical variables will be described using numbers and percentages. The proportion of pulse oximeter probes contaminated before and after disinfection will be compared using McNemar's test. A p-value of ≤ 0.05 will be considered statistically significant.

4. 9 Significance of the study

The identification of reservoirs for infection could help introduce targeted surface-sampling protocols for ICUs where it is not practical to have cubicles vacant for prolonged periods of time while an outbreak is being addressed (74). This could cut costs for a hospital. The identification of hot-spot surfaces through targeted screening of items in cubicles may allow for convenient and goal-directed decontamination processes for the future (63). If a cubicle is contaminated, it is generally closed for decontamination processes (e.g. fumigation) to occur. This delays patient turn-over time and may not be effective in removing all pathogens from all environmental surfaces.

Identifying and removing sources of HAI are of fundamental importance globally to reduce antibiotic resistance. Pulse oximeters are frequently used devices and possibly overlooked as reservoirs for pathogens, particularly in an ICU setting where the burden of preventing and treating HAIs is an ongoing problem and there is a busy hospital environment with a high turnover of patients (27). A patient's finger can occupy a pulse oximeter probe for a long duration of time leading to oil build-up and ultimately become a cocoon for microorganisms (28). Therefore, all probes (whether visibly soiled or not) should be cleaned prior to disinfection. Pinpointing one of many sources of HAIs within a cubicle is potentially a step closer to aid HAI eradication.

4. 10 Validity and reliability of the study

Botma et al (75) define validity as "the degree to which a measurement represents a true value". A study can be considered valid based on the way it is designed and interpreted. Reliability, as defined by Botma et al (75), "represents the consistency of the measure achieved". If the same results can be reproduced using a valid measuring device, which is applied to different groups under different situations, a study is considered reliable (75).

Validity and reliability in this study will be ensured by the following measures:

- an appropriate study design being chosen
- a single researcher performing sampling and collecting data to limit human error and cross-contamination.
- sampling and transport of the samples will be done in a standardised manner
- the samples will be processed in a laboratory adhering to good clinical practices
- a standardised data collection sheet will be used
- data will be analysed in consultation with a biostatistician.

4. 11 Potential limitations of the study

Contextual studies are limited by the assumption that the sample population reflects the true general population (73).

The sample of pulse oximeters in the MICU at CMJAH and the BICU at CHBAH does not provide for a general representation of pulse oximeter probes at other academic hospitals affiliated to the University of the Witwatersrand as well as countrywide. The results of this study may not be reproducible in another setting.

A financial constraint may limit the number of pulse oximeter probes sampled.

4. 12 Project time-line

	Jul. 2017	Aug. 2017	Sept. 2017	Mar. 2018	Apr. 2018	May 2018	Jun. 2018	Jul. 2018	Aug. 2018	Sept. 2018	Oct.-Nov. 2018
Literature review											
Protocol preparation											
Protocol assessment											
Ethics approval											
Post-graduate approval											
Data collection											
Data analysis											
Write-up report											
Completion of research report											

4. 13 Financial planning

Detergent, sterile gloves and gauze to be used will be funded at the researcher's own expense.

A quote for the necessary quantity of swabs and processing of samples was obtained from Vermaak and Partners Pathologists Laboratory (Appendix D). This quote will be submitted to the South African Society of Anaesthesiologists Jan Pretorius Research Fund and funding will be requested.

The Department of Anaesthesiology will bear the cost of printing and paper for the proposal, ethics and post-graduate approvals.

Budget

Item	Cost per item	Total
D-Germ®	R50 x 1 bottle	R50
Sterile gloves (box of 100 gloves)	R100 x 2 boxes	R200
Sterile gauze (100)	R100 x 1 pack	R100
Qualiclean®	R50 x 2 sachets	R100
Paper and printing	R1 per page x 900	R900
Binding	3 copies at R200	R600
Standard swabs in transport medium Sample processing (manual culture and identification)	R295.50 per microorganism identified per swab x 70 swabs (R454.60 less 35% per swab)	R20 685
Total		**R 22 635**

4. 14 References

1. Graves N. Economics and preventing hospital-acquired Infection. Emerg Infect Dis. 2004;10(4):561-6. doi: 10.3201/eid1004.020754

2. Mendelson M, Whitelaw A, Nicol M, Brink A. Wake up South Africa! The antibiotic 'horse' has bolted. SAMJ. 2012;102(7):607-8. doi: 10.7196/samj.5759

3. World Health Organization. World alliance for patient safety. Forward programme 2005. 2004 [22 August 2017]. Available from: https://www.who.int/patientsafety/en/brochure_final.pdf.

4. Allegranzi B, Nejad SB, Combescure C, Graafmans W, Attar H, Donaldson L, et al. Burden of endemic health-care-associated infection in developing countries: systematic review and meta-analysis. Lancet. 2011;377(9761):228-41. doi: 10.1016/S0140-6736(10)61458-4

5. Klevens RM, Edwards JR, Richards CL, Horan TC, Gaynes RP, Pollock DA, et al. Estimating health care-associated infections and deaths in U.S. hospitals, 2002. Public Health Rep. 2007;122(2):160-6. doi: 10.1177/003335490712200205

6. ECDC. Annual epidemiological report on communicable diseases in europe 2008: report on the state of communicable diseases in the EU and EEA/EFTA countries. 2008 [17 July 2017]. Available from: http://www.ecdc.europa.eu/en/publications/Publications/0812_SUR_Annual_Epidemiological_Report_2008.pdf.

7. Paruk F, Richards G, Scribante J, Bhagwanjee S, Mer M, Perrie H. Antibiotic prescription practices and their relationship to outcome in South African intensive care units: findings of the prevalence of infection in South African intensive care units (PISA) study. SAMJ. 2012;102(7):613-6. doi: 10.7196/samj.5833

8. Rhodes A, Evans LE, Alhazzani W, Mitchell MM, Antonelli M, Ferrer R, et al. Surviving sepsis campaign: International guidelines for management of sepsis

and septic shock: 2016. Intensive Care Med. 2017;43(3):304-77. doi: 10.1007/s00134-017-4683-6

9. Bhagwanjee S, Ugarte S. Sepsis in vulnerable populations. Glob Heart. 2014;9(3):281-8. doi: 10.1016/j.gheart.2014.08.008

10. Johnston BL, Bryce E. Hospital infection control strategies for vancomycin-resistant enterococcus, methicillin-resistant staphylococcus aureus and clostridium difficile. CMAJ. 2009;180(6):627-31. doi: 10.1503/cmaj.080195

11. Brink A, Feldman C, Richards GA, Moolman J, Senekal M. Emergence of extensive drug resistance (XDR) among gram negative bacilli in South Africa looms nearer. S Afr Med J. 2008;98(8):586-92. doi: http://0-search.ebscohost.com.innopac.wits.ac.za//login.aspx?direct=true&mdc&AN=18928032&site=ehost-live&scope=site.

12. Coetzee J, Corcoran C, Prentice E, Moodley M, Mendelson M, Poirel L, et al. Emergence of plasmid-mediated colistin resistance (MCR-1) among escherichia coli isolated from south african patients. S Afr Med J. 2016;106(5):449-50. doi: 10.7196/SAMJ.2016.v106i5.10710

13. Boyce JM. Environmental contamination makes an important contribution to hospital infection. J Hosp Infect. 2007;65(2):50-4. doi: 10.1016/S0195-6701(07)60015-2

14. Drees M, Snydman DR, Schmid CH, Barefoot L, Hansjosten K, Vue PM, et al. Prior environmental contamination increases the risk of acquisition of vancomycin-resistant enterococci. Clin Infect Dis. 2008;46(5):678-85. doi: 10.1086/527394

15. Shaughnessy MK, Micielli RL, DePestel DD, Arndt J, Strachan CL, Welch KB, et al. Evaluation of hospital room assignment and acquisition of clostridium difficile infection. Infect Control Hosp Epidemiol. 2011;32(3):201-6. doi: 10.1086/658669

16. Huang SS, Datta R, Platt R. Risk of acquiring antibiotic-resistant bacteria from prior room occupants. Arch Intern Med. 2006;166(18):1945-51. doi: 10.1001/archinte.166.18.1945

17. Otter JA, Yezli S, Salkeld JAG, French GL. Evidence that contaminated surfaces contribute to the transmission of hospital pathogens and an overview of strategies to address contaminated surfaces in hospital settings. Am J Infect Control. 2013;41(2013):S6-S11. doi: 10.1016/j.ajic.2012.12.004

18. Kundrapu S, Sunkesula V, Jury LA, Sitzlar BM, Donskey CJ. Daily disinfection of high-touch surfaces in isolation rooms to reduce contamination of healthcare workers' hands. Infect Control Hosp Epidemiol. 2012;33(10):1039-42. doi: 10.1086/667730

19. Rutala WA, Weber DA. Disinfection and sterilization in health care facilities: What clinicians need to know. Clin Infect Dis. 2004;29(5):702-9. doi: 10.1086/423182

20. The Food and Drug Administration. Reprocessing of reusable medical devices in healthcare settings: Validation methods and labeling. Guidance for Industry and Food and Drug Administration Staff. 2015 [Accessed 22 August 2017]. Available from: https://www.fda.gov/downloads/medicaldevices/deviceregulationandguidance/guidancedocuments/ucm253010.pdf.

21. Ducel G, Fabry J, Nicolle L. Prevention of hospital acquired infections: a practical guide. 2002 [22 August 2017]. Available from: http://apps.who.int/medicinedocs/documents/s16355e/s16355e.pdf.

22. Rutala WA, Weber DJ. Centers for Disease Control and Prevention. Guideline for disinfection and sterilization in healthcare facilities 2008 [18 June 2017]. Available from: https://www.cdc.gov/infectioncontrol/guidelines/disinfection/healthcare-equipment.html.

23. Samuel R, Nel D, Joubert I, De Bruin J, Dwyer S, Fourie A, et al. South African society of anaesthesiologists (SASA) guidelines for infection control in

anaesthesia in South Africa. South Afr J Anaesth Analg. 2014;20(3):S1-S39. doi: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=2ahUKEwixzKnVkdfhAhU1TRUIHVOtCAUQFjAAegQIABAC&url=http%3A%2F%2Fanaesthetics.ukzn.ac.za%2FLibraries%2FDocuments2011%2FNaidu_-_Infection_Control_Guidelines_SASA_3.sflb.ashx&usg=AOvVaw19SHDjsYUqi_Pg-lXcxzdn

24. Spaulding EH. Chemical disnifection of medical and surgical materials. In: Lawrence C, Block SS, editors. Disinfection, sterilization, and preservation. Philadelphia: Lea & Febiger; 1968. p. 517-31.

25. Rutala WA, Weber DA. Disinfection and sterilization in health care facilities: An overview and current issues. Infect Dis Clin N Am. 2016;30(2016):609-37. doi: 10.1016/j.idc.2016.04.002

26. Andrews FJ, Nolan JP. Critical care in the emergency department: Monitoring the critically ill patient. Emerg Med J. 2005;23(7):561-4. doi: 10.1136/emj.2005.029926

27. Davis C. Blood pressure cuffs and pulse oximeter sensors: A potential source of cross-contamination. Australas Emerg Nurs J. 2009;12:104-9. doi: 10.1016/j.aenj.2009.03.004

28. Nandy P, Lucas AD, Gonzalez EA, Hitchins VM. Efficacy of commercially available wipes for disinfection of pulse oximeter sensors. Am J of Infect Control. 2016;44(3):304-10. doi: 10.1016/j.ajic.2015.09.028

29. Sharbaugh RJ. Cleaning reusable equipment in the ICU. Crit Care Nurs Q. 2001;24(2):48-54. doi: 10.1097/00002727-200108000-00007

30. Ortega R, Hansen CJ, Elterman K, Woo A. Pulse oximetry. N Engl J Med. 2011;364(16):e33-e6. doi: 10.1056/NEJMvcm0904262

31. Adkinson NF, Bochner BS, Burks AW, Busse WW, Holgate ST, Lemanske RF, et al. Structure of the skin and cutaneous immunology. In: Plager DA, Bieber

T, Pittelkow MR, editors. Middelton's allergy: Principles and practice Eighth edition. 1. Eighth Edition ed. Philadelphia: Elsevier Saunders; 2014. p. 518-39.

32. Elfaki ME. Immunosuppression induced by HIV infection. Biol Med. 2014;6(3):111-2. doi: 10.1097/00006247-200112000-00016

33. Gilmore GK. Infection control advances decrease pateint and staff risk. Nurse Manage. 2001;32(12):51-3. doi: 10.1097/00006247-200112000-00016

34. Crowther-Gibson P, Govender N, Lewis DA, Bamford C, Brink A, von Gottenberg A, et al. Part IV: Human infections and antibiotic resistance. S Afr Med J. 2011;101(8). doi: 10.7196/SAMJ.5102

35. Alfandari S, Gois J, Delannoy PY, Georges H, Boussekey N, Chiche A, et al. Management and control of a carbapenem-resistant acinetobacter baumannii outbreak in an intensive care unit. Med Mal Infect. 2014;44(5):229-31. doi: 10.1016/j.medmal.2014.03.005

36. Harnett SJ, Allen KD, Macmillan RR. Critical care unit outbreak of serratia liquefaciens from contaminated pressure monitoring equipment. J Hosp Infect. 2001;47(4):301-7. doi: 10.1053/jhin.2001.0941

37. Base-Smith V. Nondisposable sphygmomanometer cuffs harbor frequent bacterial colonization and significant contamination by organic and inorganic matter. AANA J. 1996;64(2):141-5. doi: 10.1016/S0001-2092(06)63633-8

38. Zargaran D, Hardwick S, Adel R, Hill G, Stubbins D, Salmasi AM. Sphygmomanometer cuffs: A potential source of infection! Angiology. 2015;66(2):118-21. doi: 10.1177/0003319714522855

39. Grewal H, Varshney K, Thomas LC, Kok J, Shetty A. Blood pressure cuffs as a vector for transmission of multi-resistant organisms: colonisation rates and effects of disinfection. Emerg Med Australas. 2013;25(3):222-6. doi: 10.1111/1742-6723.12076

40. Fafliora E, Bampalis VG, Lazarou N, Mantzouranis G, Anastassiou ED, Spiliopoulou I, et al. Bacterial contamination of medical devices in a Greek

emergency department: Impact of physicians' cleaning habits. Am J Infect Control. 2014;42(2014):807-9. doi: 10.1016/j.ajic.2014.03.017

41. Campos-Murguia A, Leon-Lara X, Munoz JM, Macias AE, Alvarez JA. Stethescopes as potential intrahospital carriers of pathogenic microorganisms. Am J Infect Control. 2014;42(2014):82-3. doi: 10.1016/j.ajic.2013.06.015

42. Guinto C, Bottone E, Raffalli J, Montecalvo M, Wormser G. Evaluation of dedicated stethoscopes as a potential source of nosocomial pathogens. Am J Infect Control. 2002;30(8):499-502. doi: 10.1067/mic.2002.126427

43. Maluf M, Maldonado A, Bercial M-. Stethoscope: A friend or an enemy? . Sao Paulo Med J. 2002;120(1):13-5. doi: 10.1590/s1516-31802002000100004

44. Uneke CJ, Ijeoma PA. The potential for transmission of hospital-acquired infections by non-critical medical devices: the role of thermometers and blood pressure cuffs. World Health Popul. 2011;12(3):5-12. doi: 10.12927/whp.2011.22098

45. Leitch A, McCormick I, Gillespie T. Reducing the potential for phlebotomy tourniquets to act as a reservoir for methicillin-resistant staphylococcus aureus. J Hosp Infect. 2006;63(4):428-31. doi: 10.1016/j.jhin.2006.03.006

46. Walsh E, Ben-David D, Ritter M, Mechrefe A, Mermel L, DiGiovanni C. Microbial colonization of tourniquets used in orthopaedic surgery. Orthop. 2006;29(8):709-13. doi: PMID: 16924865

47. Neely AN, Maley MP, Taylor GL. Investigation of single-use versus reusable infectious waste containers as potential sources of microbial contamination. Am J nfect Control.31(1):13-7. doi: 10.1067/mic.2003.17

48. Runner J. Bacterial and viral contamination of reusable sharps containers in a community hospital setting. Am J Infect Control. 2007;35(8):527-30. doi: 10.1016/j.ajic.2006.09.017

49. Gray J, McNicholl B, Webb H, Hogg G. Mice in the emergency department: vector for infection or technological aid? Eur J Emerg Med. 2007;14(3):160-2. doi: 10.1097/MEJ.0b013e3280bef922

50. Schultz M, Gill J, Zubairi S, Huber R, Gordin F. Bacterial contamination of computer keyboards in a teaching hospital. Eur J Emerg Med. 2003;23(4):302-3. doi: 10.1086/502200

51. Devine J, Cooke R, Wright E. Is methicillin-resistant staphylococcus aureus (MRSA) contamination of ward-based computer terminals a surrogate marker for nosocomial MRSA transmission and handwashing complaince? J Hosp Infect. 2001;48(1):72-5. doi: 10.1053/jhin.2001.0955

52. Luckey J, Barfield R, Eleazer P. Bacterial count comparisons on examination gloves from freshly opened boxes and from examination gloves before treatment versus after dental dam isolation. J Endod. 2006;32(7):140-3. doi: 10.1016/j.jinf.2005.10.022

53. De Gialluly C, Morange V, De Gialluly E, Loulergue J, van der Mee N, Quentin R. Blood pressure cuff as a potential vector of pathogenic microorganisms: A prospective study in a teaching hospital. Infect Control Hosp Epidemiol. 2006;27(9):940-3. doi: 10.1086/507284

54. Lestari T, Ryll S, Kramer A. Microbial contamination of manually reprocessed, ready to use ECG lead wire in intensive care units. GMS Hyg Infect Control. 2013;8(1):Doc07. doi: 10.3205/dgkh000207

55. Dumford III DM, Nerandzic MM, Eckstein BC, Donskey CJ. What is on that keyboard? Detecting hidden environmental reservoirs of clostridium difficile during an outbreak associated with North American pulsed-field gel electrophoresis type 1 strains. Am J of Infect Control. 2009;37(1):15-9. doi: 10.1016/j.ajic.2008.07.009

56. Guinto C, Bottone E, Raffalli J, Montecalvo M, Wormser G. Evaluation of dedicated stethoscopes as a potential source of nosocomial pathogens. AJIC. 2002;30(8):499-502. doi: 10.1067/mic.2002.126427

57. Maluf M, Maldonado A, Bercial M. Stethoscope: a friend or an enemy? Sao Paulo Med J. 2002;120(1):13-5. doi: 10.1590/S1516-31802002000100004

58. Leitch A, McCormick I, Gillespie T. Reducing the potential for phlebotomy tourniquets to act as a reservoir for methicillin-resistant Staphylococcus aureus. J Hosp Infect. 2006;63:428-31. doi: 10.1016/j.jhin.2006.03.006

59. Walsh E, Ben-David D, Ritter M, Mechrefe A, Mermel L, DiGiovanni C. Microbial colonization of tourniquets used in orthopaedic surgery. Orthopaedics. 2006;29:709. doi:

60. Runner J. Bacterial and viral contamination of reusable sharps containers in a community hospital setting. AJIC. 2007;35(8):527-30. doi: 10.1016/j.ajic.2006.09.017

61. Luckey J, Barfield R, Eleazer P. Bacterial count comparisons on examination gloves from freshly opened boxes and from examination gloves before treatment versus after dental dam isolation. J Endod. 2006;32(7):646-8. doi: 10.1016/j.joen.2005.09.017

62. Tunc K, Olgun U. Microbiology of public telephones. J Infect. 2006;53:140-3. doi: 10.1016/j.jinf.2005.10.022

63. Parer S, Lotthe A, Chardon P, Poncet R, Jean-Pierre H, Jumas-Bilak E. An outbreak of heterogeneous glycopeptide-intermediate staphylococcus aureus related to a device source in an intensive care unit. Infect Control Hosp Epidemiol. 2012;33(2):167-74. doi: 10.1086/663703

64. Pusch T, Kemp D, Trevino S, Button T, Sanchez P, Gander R, et al. Controlling outbreak of vancomycin-resistant enterococcus faecium among infants caused by an endemic strain in adult inpatients. Am J of Infect Control. 2013;41(1):51-6. doi: 10.1016/j.ajic.2012.01.034

65. Wilkins MC. Residual bacterial contamination on reusable pulse oximetry sensors. Respir Care. 1993;38(11):1155-60. doi:

66. Morter S, Bennet G, Fish J, Allen DJ, Nawaz S, Iturriza-Gomara M, et al. Norovirus in the hospital setting: Virus introduction and spread within the hospital environment. J Hosp Infect. 2011;77(2):106-12. doi: 10.1016/j.jhin.2010.09.035

67. Davis C. Blood pressure cuffs and pulse oximeter sensors: A potential source of cross-contamination. Australas Emerg Nurs J. 2009;12(3):104-9. doi: 10.1016/j.aenj.2009.03.004

68. Samsodien DN. CHB Antibiograms. [Powerpoint presentation]. In press 2016.

69. Association of Anaesthetists of Great Britain and Ireland. Infection control in anaesthesia. Anaesthesia. 2008;63(9):1027-36. doi: 10.1111/j.1365-2044.2008.05657.x

70. World Medical Association. WMA Declaration of Helsinki — Ethical Principles for medical research involving human subjects. 2013 [Available from: https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/.

71. Department of Health. Guidelines for good practice in the conduct of clinical trials in human participants in South Africa. 2008 [Available from: www.kznhealth.gov.za/research/guideline1.pdf.

72. Brink H, van der Walt C, van Rensburg G. Fundamentals of research methodology for healthcare professionals. Third edition. In: Ristic D, editor. Cape Town, South Africa: Juta & Company Ltd; 2012. p. 102, 40, 209-11.

73. de Vos AS, Strydom AS, Fouche CB, Poggenpoel M, Schurink E, Schurink W. Research at grass roots. A primer for the caring professions. In: de Vos AS, editor. Hatfield, Pretoria: Van Schaik Publishers; 2000. p. 281.

74. Rutala WA, Weber DA. Disinfection and Sterilization in Health Care Facilities: An Overview and Current Issues. Infect Dis Clin N Am. 2016;30(3):609-37. doi: 10.1016/j.idc.2016.04.002

75. Botma Y, Greeff M, Mulaudzi FM, Wright SCD. Chapter 4: Quantitative research. In: Merrington D, editor. Research in health sciences. Cape Town, South Africa: Pearson Education South Africa (Pty) Ltd; 2010. p. 174-8.

4.15 Appendices

Appendix A: Letters to Heads of Department requesting permission

Farriel Desai

Registrar in Anaesthesia • Department of Anaesthesia • University of the Witwatersrand
Phone: 073 155 0765 • E-Mail: farriels@icloud.com

Date: 8 March 2018

Professor G. Richards
Intensive Care Unit
Charlotte Maxeke Johannesburg Academic Hospital
Jubilee Road
Johannesburg
2196

Dear Professor Richards

Re: Permission to conduct a research study in the main burns intensive care unit at Charlotte Maxeke Johannesburg Academic Hospital for Master of Medicine (MMed) in Anaesthesia.

Thank you for taking the time to read this letter.
I am writing to request permission to conduct a research study at your main intensive care unit. I am currently a second year registrar in Anaesthesia and I am registered with the University of the Witwatersrand to do my MMed. The study is entitled: Contamination of pulse oximeter probes before and after decontamination in two intensive care units at a central hospital.

I have attached a copy of my protocol for the study I wish to perform. Your approval to conduct this study will be greatly appreciated. Separate letters have been sent to and permission granted from Dr. R. Moore (involved in adult burns unit from a research perspective) and Professor J. Loveland (paediatric burns unit) to perform the study in their respective units.

If you agree, kindly sign below. Alternatively, kindly submit a signed letter of permission on your institution's letterhead granting your permission for me to conduct this study at your institution.

Sincerely,

Dr. Farriel Desai
BSc, MBBCH, DA (SA)

Approved by:

29/3/18

Name and title | Signature | Date

Farriel Desai

Registrar in Anaesthesia • Department of Anaesthesia • University of the Witwatersrand
Phone: 073 155 0765 • E-Mail: farriels@icloud.com

Date: 21 June 2018

Prof. Adelin Muganza
Adult Burns Unit
Chris Hani Baragwanath Academic Hospital
26 Chris Hani Road
Diepkloof 319-Iq
Johannesburg
1860

Dear Professor A. Muganza

Re: Permission to conduct a research study in the adult burns intensive care unit at Chris Hani Baragwanath Academic Hospital (CHBAH) for Master of Medicine (MMed) in Anaesthesia.

Thank you for taking the time to read this letter.
I am writing to request permission to conduct a research study at your burns intensive care unit. I am currently a second year registrar in Anaesthesia and I am registered with the University of the Witwatersrand to do my MMed. The study is entitled: Contamination of pulse oximeter probes before and after decontamination in two intensive care units.

I have attached a copy of my protocol for the study I wish to perform. Your approval to conduct this study will be greatly appreciated.

If you agree, kindly sign below. Alternatively, kindly submit a signed letter of permission on your institution's letterhead granting your permission for me to conduct this study at your institution.

Sincerely,

Dr. Farriel Desai
BSc, MBBCH, DA (SA)

Approved by:

Prof. MUGANZA RA — 28/05/2018

Name and title | Signature | Date

Farriel Desai

Registrar in Anaesthesia ● Department of Anaesthesia ● University of the Witwatersrand
Phone: 073 155 0765 ● E-Mail: farriels@icloud.com

Date: 8 March 2018

Dr Rachel Moore
Burns Unit
Chris Hani Baragwanath Academic Hospital
26 Chris Hani Road
Diepkloof 319-Iq
Johannesburg
1860

Dear Doctor Moore

Re: Permission to conduct a research study in the adult burns intensive care unit at Chris Hani Baragwanath Academic Hospital (CHBAH) for Master of Medicine (MMed) in Anaesthesia.

Thank you for taking the time to read this letter.
I am writing to request permission to conduct a research study at your burns intensive care unit. I am currently a second year registrar in Anaesthesia and I am registered with the University of the Witwatersrand to do my MMed. The study is entitled: Microorganisms cultured before and after decontamination of reusable pulse oximeter probes in a Burns Intensive Care Unit and a Main Intensive Care Unit at Chris Hani Baragwanath Academic Hospital.

I have attached a copy of my protocol for the study I wish to perform. Your approval to conduct this study will be greatly appreciated.

If you agree, kindly sign below. Alternatively, kindly submit a signed letter of permission on your institution's letterhead granting your permission for me to conduct this study at your institution.

Sincerely,

Dr. Farriel Desai
BSc, MBBCH, DA (SA)

Approved by:

Dr RL Moore 

Name and title Signature

26 March 2018

Date

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL
Directorate: Paediatric Surgery
Enquiries: Prof. J.A. Loveland
Tel. number: (011)933 8138; Email: Loveland@wol.co.za

15th March 2018

Dr. Farriel Desai
Chris Hani Baragwanath Academic Hospital

Dear Dr. Desai

RE: PERMISSION TO CONDUCT A STUDY

Your request to conduct a study titled "**Contamination of pulse oximeter probes before and after decontamination in two intensive care units at a central hospital**.", intended for your Ethics application, on Paediatric Surgery Patients at Chris Hani Baragwanath Academic Hospital is granted.

You therefore can obtain relevant information from patient files, as well as access the Paediatric Surgery database.

Regards,

2018/03/15

Professor JA Loveland
Academic Head
Department of Paediatric Surgery
School of Clinical Medicine
University of the Witwatersrand

Date

Farriel Desai

Registrar in Anaesthesia • Department of Anaesthesia • University of the Witwatersrand
Phone: 073 155 0765 • E-Mail: farriels@icloud.com

Prof. Rudo Mathivha
Paediatric Burns Unit
Chris Hani Baragwanath Academic Hospital
26 Chris Hani Road
Diepkloof 319-Iq
Johannesburg
1860

Dear Professor R. Mathivha

Re: Permission to conduct a research study in the paediatric burns intensive care unit at Chris Hani Baragwanath Academic Hospital (CHBAH) for Master of Medicine (MMed) in Anaesthesia.

Thank you for taking the time to read this letter.
I am writing to request permission to conduct a research study at the paediatric burns intensive care unit. I am currently a second year registrar in Anaesthesia and I am registered with the University of the Witwatersrand to do my MMed. The study is entitled: Contamination of pulse oximeter probes before and after decontamination in two intensive care units.

I have attached a copy of my protocol for the study I wish to perform. Your approval to conduct this study will be greatly appreciated.

If you agree, kindly sign below. Alternatively, kindly submit a signed letter of permission on your institution's letterhead granting your permission for me to conduct this study at your institution.

Sincerely,

Dr. Farriel Desai
BSc, MBBCH, DA (SA)

Approved by:

Prof L.R. Mathivha		02/7/2018
Name and title	Signature	Date

Appendix B : Request for ethics waiver

Farriel Desai

Registrar in Anaesthesia • Department of Anaesthesia • University of the Witwatersrand

Phone: 073 155 0765 • E-Mail: farriels@icloud.com

Date: 16 March 2018

Att: Professor Peter Cleaton-Jones

Chair: Human Research Ethics Committee

Dear Professor Cleaton-Jones

Thank you for taking the time to read this letter.

I am a registrar in the Department of Anaesthesiology at the University of the Witwatersrand. The research component of my MMed is a non-human study. I propose to sample pulse oximeter probes in the main intensive care unit at Charlotte Maxeke Academic Hospital (CMJAH) and in the adult and paediatric burns intensive care units at Chris Hani Baragwanath Academic Hospital (CHBAH).

The sampling of the pulse oximeter probes will be done in a standardised manner, before and after decontamination. All samples will be processed in an accredited laboratory. The proportion of contaminated pulse oximeter probes before and after decontamination will be compared using appropriate statistical analysis.

The endemic microorganism profile for the two units will be obtained from the microbiologists at CHBAH and CMJAH, respectively.

The pulse oximeter probes will be the focus of the study and no patient or medical staff information will be recorded. I would like to request an ethics waiver for this study.

Sincerely,
Dr. Farriel Desai (BSc, MBBCH, DA (SA)

Appendix C: Data collection sheet

Study number	Manufacturer	Location (on patient/in storage/open bed-space)	Cleanliness (cleaned/ soiled)	Soiled with blood (yes/no)	Visible crack on diode? (yes/no)	PopA barcode	PopB barcode	Microorganism(s) cultured & identified PopA	Microorganism(s) Cultured & identified PopB
01									
02									
03									
04									
05									
06									
07									
08									
09									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									

Appendix D: Quote from laboratory

Quote

vermaak and partners pathologists

PathCare

Microbiology

Lifestyle Management Park,
Unit 1, Lyttleton
Tel: (012) 644-0891
Fax: (012) 644-0857
Emergency Tel: (071) 687-8857

Pr 0520000047368

Quote ID	: 112565
Client Name	: Mmed Student Project
Client ID Number	: 09/03/2018
Client Contact Number	: 2077111
Fund	: PRIVATE PATIENT

Test	Billing Code	Standard Price	Discount Price (- 35 %)
Biochemical Extended Manual ID (MMEXTID)	3924	R 302.10	R 196.40
Bacterial Aerobic Culture (MO2) *	3893	R 152.50	R 99.10
Discount	**- 35 %**		**R 159.10**
Total		**R 454.60**	**R 295.50**

** Test may incur additional charges.*

35% discount if account is settled within 30 days

Terms and Conditions

All prices include VAT. This estimate is only applicable to the tests requested by the patient's doctor. The amounts may change if the doctor or the pathologist considers additional tests necessary. The account holder accepts responsibility for payment of all outstanding fees not settled by a medical aid.

Banking details

Nedbank, Acc nr 104 5466 433, Branch Code 198 765 Ref: Initials and Surname

Accounts Call Centre

(T): 012 404 2300 (F): 086 682 8212 (E): accounts@vpath.co.za

Issued By Kleinhans, Vicky (VK) Ms on 2018/03/09 11:22
Skylims 2018/03/09 11:21

Page 1 of 1

Section 5: Annexures

5.1 Approval from Heads of Department

Farriel Desai

Registrar in Anaesthesia • Department of Anaesthesia • University of the Witwatersrand
Phone: 073 155 0765 • E-Mail: farriels@icloud.com

Date: 21 June 2018

Prof. Adelin Muganza
Adult Burns Unit
Chris Hani Baragwanath Academic Hospital
26 Chris Hani Road
Diepkloof 319-Iq
Johannesburg
1860

Dear Professor A. Muganza

Re: Permission to conduct a research study in the adult burns intensive care unit at Chris Hani Baragwanath Academic Hospital (CHBAH) for Master of Medicine (MMed) in Anaesthesia.

Thank you for taking the time to read this letter.
I am writing to request permission to conduct a research study at your burns intensive care unit. I am currently a second year registrar in Anaesthesia and I am registered with the University of the Witwatersrand to do my MMed. The study is entitled: Contamination of pulse oximeter probes before and after decontamination in two intensive care units.

I have attached a copy of my protocol for the study I wish to perform. Your approval to conduct this study will be greatly appreciated.

If you agree, kindly sign below. Alternatively, kindly submit a signed letter of permission on your institution's letterhead granting your permission for me to conduct this study at your institution.

Sincerely,

Dr. Farriel Desai
BSc, MBBCH, DA (SA)

Approved by:

Prof. MUGANZA RA — 28/05/2018

Name and title | Signature | Date

Farriel Desai

Registrar in Anaesthesia • Department of Anaesthesia • University of the Witwatersrand
Phone: 073 155 0765 • E-Mail: farriels@icloud.com

Prof. Rudo Mathivha
Paediatric Burns Unit
Chris Hani Baragwanath Academic Hospital
26 Chris Hani Road
Diepkloof 319-Iq
Johannesburg
1860

Dear Professor R. Mathivha

Re: Permission to conduct a research study in the paediatric burns intensive care unit at Chris Hani Baragwanath Academic Hospital (CHBAH) for Master of Medicine (MMed) in Anaesthesia.

Thank you for taking the time to read this letter.
I am writing to request permission to conduct a research study at the paediatric burns intensive care unit. I am currently a second year registrar in Anaesthesia and I am registered with the University of the Witwatersrand to do my MMed. The study is entitled: Contamination of pulse oximeter probes before and after decontamination in two intensive care units.

I have attached a copy of my protocol for the study I wish to perform. Your approval to conduct this study will be greatly appreciated.

If you agree, kindly sign below. Alternatively, kindly submit a signed letter of permission on your institution's letterhead granting your permission for me to conduct this study at your institution.

Sincerely,

Dr. Farriel Desai
BSc, MBBCH, DA (SA)

Approved by:

Prof L.R. Mathivha _____ 02/7/2018

Name and title Signature Date

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL
Directorate: Paediatric Surgery
Enquiries: Prof. J.A. Loveland
Tel. number: (011)933 8138; Email: Loveland@wol.co.za

15th March 2018

Dr. Farriel Desai
Chris Hani Baragwanath Academic Hospital

Dear Dr. Desai

RE: PERMISSION TO CONDUCT A STUDY

Your request to conduct a study titled "**Contamination of pulse oximeter probes before and after decontamination in two intensive care units at a central hospital**.", intended for your Ethics application, on Paediatric Surgery Patients at Chris Hani Baragwanath Academic Hospital is granted.

You therefore can obtain relevant information from patient files, as well as access the Paediatric Surgery database.

Regards,

2018/03/15

Professor JA Loveland
Academic Head
Department of Paediatric Surgery
School of Clinical Medicine
University of the Witwatersrand

Date

UNIVERSITY
OF THE
WITWATERSRAND,
JOHANNESBURG

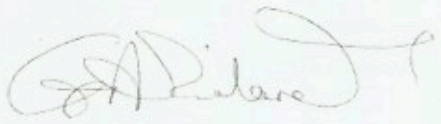
+27832668378
+27114883654
Fax +27114884675
6/7 /18

.To whom it may concern:

Re the study "**Contamination of pulse oximeter probes before and after decontamination in two intensive care units**".

I am aware that this study will be performed in my unit and have read the protocol. I have previously approved this study as well,

Yours



GA Richards

MBBCh PhD FCP (SA) FRCP FCCP

Academic Head and Professor Division of Critical Care University of the Witwatersrand

Director Critical Care Charlotte Maxeke Johannesburg Academic Hospital and

Chief Physician Departments Medicine and Pulmonology University of the Witwatersrand

5.2 Ethics waiver

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

Office of the Deputy Vice-Chancellor (Research & Post Graduate Affairs)

TO: Dr F Desai et al
School: Clinical Medicine
Department: Anaesthesia
Rahima Moosa Mother and Child Hospital

E-mail: farriels@icloud.com

CC: Supervisor: Professor J Scribante <Juan.Scribante@wits.ac.za>
and <HREC-Medical.ResearchOffice@wits.ac.za>

FROM: Iain Burns
Human Research Ethics Committee (Medical)
Tel: 011 717 1252

E-mail: Iain.Burns@wits.ac.za

DATE: 01/06/2018

REF: *R14/49*

PROTOCOL NO: W-CBP-180601-01 (This is your ethics application study reference number. Please quote this reference number in all correspondence relating to this study)

PROJECT TITLE: *Contamination of pulse oximeter probes before and after decontamination in two intensive care units*

Please find attached the Clearance Certificate for the above project. I hope it goes well and that an article in a recognized publication comes out of it. This will reflect well on your professional standing and contribute to the Government funding of the University.

MSWorks2000/Iain0007/ClearScanWaiver.wps

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

01/06/2018

Ref: W-CBP-180601-01

TO WHOM IT MAY CONCERN:

Waiver: This certifies that the following research does not require clearance from the Human Research Ethics Committee (Medical).

Investigator: Dr F Desai et al
Student No. (if appropriate): 05 0074 5N
Staff No. (if appropriate):

Supervisor: Professor J Scribante

School: Clinical Medicine
Department: Anaesthesia
Rahima Moosa Mother and Child Hospital

Project title: *Contamination of pulse oximeter probes before and after decontamination in two intensive care units*

Reason: Laboratory analysis.
No human participants will be involved in the study.

Professor CB Penny
Chairperson: Human Research Ethics Committee (Medical)

Copy – HREC (Medical) Secretariat: Zanele Ndlovu and Rhulani Mkansi.

Research Office Secretariat:
Physical address: Phillip Tobias Building, 3rd Floor, Office 302, Corner York Road and Princess of Wales Terrace, Parktown, Johannesburg 2193.
Postal address: Private Bag 3, Wits 2050
Tel Nos. +27 (0)11-717-1234/2656/2700/1252
Office E-mail: HREC-Medical.ResearchOffice@wits.ac.za.
Website:http://www.wits.ac.za/research/about-our-research/ethics-and-research-integrity/

5.3 Graduate studies approval

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

Private Bag 3 Wits, 2050
Fax: 027117172119
Tel: 02711 7172076

Reference: Mrs Sandra Benn
E-mail: sandra.benn@wits.ac.za

12 June 2018
Person No: 0500745N
PAG

Dr F Desai
Po Box 261572
Excom
2023
South Africa

Dear Dr Desai

Master of Medicine: Approval of Title

We have pleasure in advising that your proposal entitled *Contamination of pulse oximeter probes before and after decontamination in two intensive care units* has been approved. Please note that any amendments to this title have to be endorsed by the Faculty's higher degrees committee and formally approved.

Yours sincerely

Mrs Sandra Benn
Faculty Registrar
Faculty of Health Sciences

5.4 Approval from CEOs

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

MEDICAL ADVISORY COMMITTEE

CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL

PERMISSION TO CONDUCT RESEARCH

Date: 2nd July 2018

TITLE OF PROJECT:

Contamination of pulse oximeter probes before and after decontamination in two intensive care units.

UNIVERSITY: Witwatersrand

Principal Investigator: Dr Farriel Desai

Department: Department of Anaesthesiology

Supervisor : Professor J Scribante

Permission Head Department (where research conducted): Yes

The Medical Advisory Committee recommends that the said research be conducted at Chris Hani Baragwanath Academic Hospital. The CEO / management of Chris Hani Baragwanath Academic Hospital is accordingly informed and the study is subject to:-

- Permission having been granted by the Committee for Research on Human Subjects of the University of the Witwatersrand.
- The Hospital will not incur extra costs as a result of the research being conducted on its patients within the hospital
- The MAC will be informed of any serious adverse events as soon as they occur
- Permission is granted for the duration of the Ethics Committee Approval.

.....
Recommended
(On behalf of the MAC)
Date: 2/7/2018

.....
Approved/Not Approved
Hospital Management
Date: 04/07/18

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

CHARLOTTE MAXEKE JOHANNESBURG ACADEMIC HOSPITAL

Enquiries:
Ms. N. Mzila
Office of the Clinical Director
Tell: (011): 488-4812
Email: Nolwazi.Mzila@gautemg.gov.za
16th July 2018

GP_201806_0270

Dear Dr. F. Desai

STUDY TITLE: contamination of pulse oximeter probes before and after decontamination in two intensive care units

Permission is granted for you to conduct the above recruitment activities as described in your request provided:

1. Charlotte Maxeke Johannesburg Academic Hospital will not anyway incur or inherit costs as result of the said study.
2. Your study shall not disrupt services at the study sites.
3. Strict confidentiality shall be observed at all times.
4. Informed consent shall be solicited from patients participating in your study.

Please liaise with the HOD and Unit Manager or sister in charge to agree on the dates and time that would suit all parties.

Kindly forward this office with the results of your study on completion of the research.

Supported / not supported

Dr. M. Mabunda

Dr. M.I. Mofokeng
Clinical Director
DATE: 18/07/2018

Approved/~~not approved~~

Ms. G. Bogoshi
Chief Executive Officer
Date: 2018/07/19

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

CHARLOTTE MAXEKE JOHANNESBURG ACADEMIC HOSPITAL

Enquiries: Ms. N. Mzila
Office of the Clinical Director
011 488 4812

GP_201806_0270

Dear Dr. F. Desai

STUDY TITLE: contamination of pulse oximeter probes before and after decontamination in two intensive care units

DEPARTMENT: Intensive care Unit (567)

	DOCUMENTS REQUIRED FOR STUDENT RESEARCH	TICK
1.	Covering letter from the APPLICANT	X
2.	Research protocol	X
3.	Support letter from the Head of Department	X
4.	Ethics clearance certificate	X
5.	NHRD Registration	X
	DOCUMENTS REQUIRED FOR COMPANY RESEARCH	
1.	Covering letter from the APPLICANT/COMPANY	
2.	Research protocol	
3.	Support letter from the Head of Department	
4.	Ethics clearance certificate	
5.	Approval from the Department of Health	

CHECKED BY: Ms. N. Mzila **SIGNATURE:** _____ **DATE:** 16/07/2018

CHECKED BY: _____ **SIGNATURE:** _____ **DATE:** _____

RECEIVED CEO
19 -07- 2018
CMJAH

5.5 Southern African Society of Anaesthesiologists Jan Pretorius Funding Approval

SASA
SOUTH AFRICAN SOCIETY OF ANAESTHESIOLOGISTS

SOUTH AFRICAN SOCIETY OF ANAESTHESIOLOGISTS
Official Group Of SAMA
Association Not For Gain
T: +27 (0) 86 010 3137 (toll free) T: +27 (0) 908 1489 F +27 (0) 86 242 9804
E: sasa@sasaweb.com
PO Box 22511, Glenashley, 4022 South Africa
www.sasaweb.com
VAT Registration Number: 4680223379

29 June 2018

Dr Farriel Desai
Department of Anaesthesiology
WITS

Dear Dr Desai

APPLICATION: SASA JAN PRETORIUS RESEARCH FUND

Your application has been re-evaluated by the JPRF Committee and it is my pleasure to inform you that your application has been successful.

A grant of **R20 000** has been awarded.

Please complete the attached contract and return to me and our CEO, Ms Natalie Zimmelman, by return e-mail. Please note the conditions of the grant - if these conditions are not fulfilled it may lead to funds being withheld/re-claimed by SASA.

Once again, congratulations and we wish you success in this research project.

Yours sincerely

Prof Pierre Fourie
SASA National Secretary

5.6 National Health Laboratory Service Approval

NATIONAL HEALTH LABORATORY SERVICE

Academic Affairs and Research
Modderfontein Road, Sandringham, 2031
Tel: +27 (0)11 386 6142
Fax: +27 (0)11 386 6296
Email: babatyi.kgokong@nhls.ac.za
Web: www.nhls.ac.za

22 February 2019

Applicant: Dr Farriel Desai
Institution: University of the Witwatersrand
Department: Anaesthesia
Email: farriels@icloud.com
Cell: 073 155 0765

Re: Approval to access National Health Laboratory Service (NHLS) Data

Your application to undertake a research project **"Contamination of pulse oximeter probes before and after decontamination in two intensive care units"** using data from the NHLS database has been reviewed. This letter serves to advise that the application has been approved and the required data will be made available to you ***without patient names*** to conduct the proposed study as outlined in the submitted application.

Please note that final approval is granted on your compliance with the NHLS conditions of service and that the study can only be undertaken provided that the following conditions have been met.

- Processes are discussed with the relevant NHLS departments (i.e. Information Management Unit and Operations Office) and are agreed upon.
- Confidentiality is maintained at participant and institutional level and there is no disclosure of personal information or confidential information as described by the NHLS policy.
- A final report of the research study and any published paper resulting from this study are submitted and addressed to the NHLS Academic Affairs and Research office and the NHLS has been acknowledged appropriately.
- NHLS Data cannot be used to track patients as no pre-approval/consent is obtained from Patients.

Please note that this letter constitutes approval by the NHLS Academic Affairs and Research Office. Any data related queries may be directed to NHLS Corporate Data Warehouse, contact number: 011 386 6074 email: zarina.sabat@nhls.ac.za

Dr Babatyi Malope-Kgokong
National Manager: Academic Affairs and Research

5.7 Turnitin report

WITS UNIVERSITY

DEPARTMENT OF ANAESTHESIOLOGY
UNIVERSITY OF THE WITWATERSRAND,
JOHANNESBURG
Tel.(011)933-9334/5 / Fax (011)933-1843

FACULTY OF HEALTH SCIENCES

18th April, 2019

The Chairperson
Graduate Studies Committee
Faculty of Health Sciences University of the
Witwatersrand

Dear Madam,

Re: M Med: **Contamination of pulse oximeter probes before and after decontamination in two intensive care units**

Dr Farriel Desai, student number: 0500745N, has submitted her research report to Turnitin which revealed a similarity index of 7%. These similarities appear not to be plagiarism but mainly the use of common terminology and phrases specific to the topic of the research.

Yours sincerely,

Juan Scribante
Supervisor

0500745n:Literature_review_final!with_draft.docx

ORIGINALITY REPORT

7%	5%	5%	2%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to University of Witwatersrand Student Paper	<1%
2	Nandy, Poulomi, Anne D. Lucas, Elizabeth A. Gonzalez, and Victoria M. Hitchins. "Efficacy of commercially available wipes for disinfection of pulse oximeter sensors", American Journal of Infection Control, 2016. Publication	<1%
3	K TUNC, U OLGUN. "Microbiology of public telephones", Journal of Infection, 2006 Publication	<1%
4	"Antimicrobial Drug Resistance", Springer Nature, 2017 Publication	<1%
5	download.e-pubs.nl Internet Source	<1%
6	medcraveonline.com Internet Source	<1%
7	link.springer.com Internet Source	<1%