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Microbial contamination of hands of healthcare providers in the operating theatre of a central hospital

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Microbial contamination of hands of healthcare providers in the operating theatre of a central hospital

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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, 2019

Declaration

I, Kylesh Devnarain Pegu, 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 October 2019

Abstract

Background

Effort is invested in maintaining sterility of the operating field, but less attention is paid to potential healthcare associated infection (HAIs) sources through patient contact by non-scrubbed healthcare providers (HCPs). A single microbiological assessment of hands can provide a good assessment of the potential dynamic transmission of microorganisms. The aim of this study was to identify and quantify the microbial growth on the hands of HCPs in the operating theatres of Chris Hani Baragwanath Academic Hospital.

Methods

A prospective, contextual and descriptive study design was followed. Seventy five samples were collected using convenience sampling from an equal number of surgeons, anaesthetists and nurses. Specimens were taken using agar plates and underwent semi-quantitative analysis.

Results

All hands of HCPs displayed growth, of which 82% of HCPs hands grew commensals and 80% grew pathogens. Twelve commensal microorganisms and 27 pathological organisms were noted. Two or more organisms were cultured on 76% of HCPs' hands. Comparisons of commensal, pathological and combined levels of contamination among the three groups were not statistically significant ($p=0.266$, $p=0.673$, $p=0.180$). There was no significant difference between the growth of combined microorganisms ($p=0.927$) and pathological microorganisms ($p=0.499$) among the groups. Surgeons had significantly more commensal growth ($p=0.019$) than anaesthetists and nurses. There was no statistically significant difference between sexes.

Conclusion

It was concerning that 100% of the hands of HCPs who were about to commence with the surgical list had microbial growth. These HCPs could have already been in contact with patients and equipment in the theatre environment. Microorganisms cultured on hands are a source of cross-transmission which may result in HAIs. Institutions require the implementation of a multidimensional model to amend guidelines, implement guidelines and increase awareness of hand hygiene.

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Abbreviations

CFU	Colony forming units
CHBAH	Chris Hani Baragwanath Academic Hospital
HAI	Healthcare associated infection
HCP	Healthcare provider
MRSA	Methicillin-resistant *Staphylococcus aureus*
MSSA	Methicillin-sensitive *Staphylococcus aureus*
OT	Operating theatre
USA	United States of America
VRE	Vancomycin-resistant *Enterococcus*

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 is inkeeping with the rest of the Research Report thus may not comply with the author guidelines of the South African Journal of Anaesthesia and Analgesia, the journal to which it is intended to be submitted.

Section 1: Review of the literature

1.1.1 Introduction

In this section information regarding the impact of healthcare associated infections (HAIs), physiology of normal skin, normal microbial flora present on the skin, pathological organisms on the hands of healthcare providers (HCPs), organisms present on the hands of HCPs, organisms present on the hands of anaesthetists, organisms present on the hands of nurses, transmission to the surrounding equipment in the environment, poor practice of recommended hand hygiene guideline and difficulties with implementation of hand hygiene models will be discussed.

1.1.2 Impact of healthcare associated infections

HAIs are “infections that occur in patients under medical care in the hospital or other healthcare facility which was absent at the time of admission” (1). HAIs increase hospital stay, long term disability, antimicrobial resistance, socio-economic disturbance and mortality rate (1). The complications of HAIs cause an increase in both legal and litigation costs in an already constrained environment (2). Out of every 100 hospitalised patients, seven patients in developed countries and ten patients in developing countries acquire a HAI (3). There is a scarcity of information on the spectrum of HAIs in sub-Saharan Africa (4). A systematic review done in 2011, analysing the limited information on HAIs, found a rate of 2.5% – 14.8% as the overall prevalence for the African continent (5). There is limited HAI information from South Africa, however a study conducted in 2008 across six healthcare facilities found a surgical site infection rate of 3% (6). A South African study conducted at a paediatric hospital and over a 12 month period had HAIs complicate 24% of their admissions (7). A study conducted in Kimberly, South Africa in 2018 had HAIs prevalence rate of 7.67% at their hospital complex (8).

In the theatre setting much effort is invested in maintaining sterility of the operating field, but less attention is paid to potential HAI sources through patient contact with non-scrubbed staff (9). Skin commensals have evolved to multidrug resistant

bacteria and are associated with a significant increase in patient morbidity and mortality (10).

1.2: Skin

1.2.1 Physiology of normal skin

A brief understanding of the skin is important to understand the basis of hand contamination (11). The skin accounts for more than 15% of the body weight of an adult. The skin is composed of three layers: the epidermis, dermis and subcutaneous tissue (11). The epidermis is comprised of two cell types of keratinocytes and dendritic cells (11). On the palms of hands the epidermis can be subdivided into five layers namely, stratum basale, stratum spinosum, stratum granulosum, stratum lucidum and stratum corneum (12). The epidermis is dynamic tissue in which cells undergo dynamic movement. It is the stratum corneum that provides mechanical protection to the skin, prevents invasion by foreign substances and prevents water loss (11). The stratum corneum lipids have inhibitory effects on pathogenic organisms (13). Maintenance of a constant epidermal layer is dependent on apoptosis which is a major homeostatic function (11). Apoptosis is also necessary for regulating cell numbers and defending against mutated or damaged cells (11). Non-keratinocyte cells are melanocytes, Merkel cells and Langerhans cells. The epidermal appendages are sweat glands, hair follicles and nails. The latter provides further protection to the skin among their other functions (11).

The dermal-epidermal junction is formed by a porous basement membrane zone that allows the exchange of cells and fluid and holds the two layers together. The dermis provides elasticity, pliability and tensile strength to the skin (11). The dermis forms a mechanical protection barrier, binds water, assists in thermoregulation, and contains sensory receptors (11). The dermis interacts with the epidermis in maintaining the properties of both tissues (11). Collagen is the stress-resistant material present in the dermis and elastic fibres allow for elasticity (12). The vessels, muscles, nerves and mast cells of the skin are also present in this layer. Below the dermis is a layer of subcutaneous tissue (11).

1.2.2 Normal microbial flora present on the skin

The flora are determined by several environmental and physiological factors such as anatomic location, local humidity, the production of sebum and sweat and the hormonal status and age of the host (14). Microbes present are further influenced by the balance between the properties of the microbes and the human host defence mechanisms (14). The skin is a complex ecosystem comprising resident and transient flora (15). Resident flora can be found on the surface of the skin or under a few layers of the stratum corneum where they live as microcolonies (16). The following organisms make up the skin resident flora: *micrococci* with coagulase-negative *staphylococci, Peptococcus* spp*., Micrococcus* spp*.,* diphtheroids with *corynebacteria* and *Brevibacterium* spp*., propionibacteria* and gram-negative rods (17). The protective functions of the resident flora include microbial antagonism and competition for nutrients (16). The resident flora can cause infection if they enter a sterile body cavity (16). The relationship between skin and the microbes have various features ranging from mutualistic and commensal to saprophytic and parasitic relationships (14).

Transient bacteria occupy the superficial layer of skin where they sporadically multiply and are amenable to being removed by handwashing (12). Transient bacteria are acquired occupationally on the hands of HCPs which may be permanently colonised and are often associated with HAIs (18).

1.2.3 Pathological organisms on the hands of HCPs

Pathological microorganisms vary vastly in different patient populations, medical facilities and differ in the healthcare environment (1). The microbiome of each individual's hand flora is in a constant state of flux with 8 – 24 families of microbes being present at any time (19). Patients at risk include children, the elderly, immunocompromised patients and those in long-term care facilities (20).

Bacteria are the most common organisms present and examples include *Acinetobacter, Clostridium difficile, Enterobacteriaceae* and methicillin-resistant *Staphylococcus aureus* (MRSA) *(1)*. Natural flora are able to cause infection in immunocompromised patients (20). Methicillin-sensitive *Staphylococcus aureus*

and MRSA can be present on the skin of a healthy individual, however carriage is a risk factor for infection in surgical patients (20). Coagulase-negative *Staphylococci* have multiple strains inhabiting the skin and are one of the most common organisms causing HAIs (21). These bacteria have the ability to form a biofilm and are able to cause infection in patients with indwelling devices (22). *Enterococci* have shown emerging antibiotic resistance patterns (20). *Enterococci* have been associated with increased hospital costs as well as length of stay in hospital (23). Gram-negative bacteria implicated in HAIs are *Klebsiella pneumonia, Enterobacter* spp*., Acinetobacter baumannii, Pseudomonas aeruginosa* and *Klebsiella oxytoca* (1).These organisms are implicated in increased resistance, increased length of stay in hospital as well as costs (20). The extended-spectrum beta-lactamase producing *Enterobacteriaceae* are types of gram-negative organisms that inactivate beta-lactam antibiotics by hydrolysing the beta-lactam ring (24). Carbapenemase producing *Enterobacteriaceae* are carbapenem-hydrolysing beta-lactamases which also cause antibiotic resistance (24). *Clostridium difficile* are part of the normal intestinal flora, however, they can cause a range of clinical infections (25). This organism is resistant to alcohol-based cleaning solutions and rapidly disseminates from sources of contamination (25). A systemic review done in 2019 which analysed 59 hand contamination studies assessing the prevalence of multidrug resistant organisms found that the prevalence for MRSA, *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, and vancomycin-resistant *Enterococcus* were 4.26%, 4.59%, 6.18% and 9.03%, respectively (26).

Fungal parasites may also be present and do cause infection in the immunocompromised patients and include *Aspergillus, Candida albicans* and *Cryptococcus neoformans (20). Candida* is the most common fungus causing nosocomial infection *and* can occur in immunocompetent individuals (27). Viruses including *hepatitis*, *influenza* and *rotavirus* can be transmitted through direct contact (1).

1.3. Organisms present on the hands of HCPs

In this section summaries are analysed on studies conducted on the microbial contamination on the hands of HCPs, with a special focus on anaesthetists and

nurses. No study could be found for specific assessment of surgeons. Tables include the study reference, sample size, location, whether hand hygiene was performed, organism growth, organisms isolated and the number of colony forming units (CFU).

1.3.1 Healthcare providers

Comparing the number of CFUs per study was not possible as differing methods were used to collect samples resulting in different units for the CFUs. From Table 1 there was no difference noted between growth in studies conducted in developing or developed countries. Growth assessed prior to hand washing ranged from 28 –100%. In the studies where a distinction was made between nurse and doctor no significant difference was noted between growth rate and microorganisms grown. The significant finding from the study conducted by Rocha et al (28) was that HCPs with damaged skin have a greater quantity of pathogenic microorganisms despite washing their hands.

Key of terms

A. baumannii – Acinetobacter baumannii	MRSA – methicillin-resistant *Staphylococcus aureus*
A. iwoffii – Acinetobacter iwoffii	*MSSA* – methicillin-sensitive *Staphylococcus aureus*
B. cereus – Bacillus cereus	NICU - neonatal intensive care unit
B. subtilis – Bacillus subtilis	OT - operating theatre
C. albicans – Candida albicans	OPD – outpatient department
C. difficile - Clostridium difficile	*P. aeruginosa – Pseudomonas aeruginosa*
C. diphtheriae – Corynebacterium diphtheriae	*P. alcaligens – Pseudomonas alcaligens*
C. krusei – Candida krusei	*P. putida – Pseudomonas putida*
C. tropicalis – Candida tropicalis	*S. aureus – Staphylococcus aureus*
CONS - Coagulase negative *staphylococci*	*S. epidermis – Staphylococcus epidermis*
D. acidovorans - Delftia acidovorans	*S. fonticola – Serratia fonticola*
E. coli - Escherichia coli	*S. haemolyticus – Staphylococcus haemolyticus*
E. faecalis – Enterococcus faecalis	Spp. - species
ICU – intensive care unit	*S. saprophyticus – Staphylococcus saprophyticus*
K. oxytoca - Klebsiella oxytoca	*S. warneri – Staphylococcus warneri*
K. pneumoniae – Klebsiella pneumoniae	VRE - vancomycin-resistant *Enterococcus*

Table 1 Studies detailing hand contamination in HCPs

Year, Author, country, reference	Sample size	Location	Hand hygiene performed	Level of growth	Organism isolated	Number of CFUs
2008 Al-Allak et al Wales (29)	10 surgeons	OT	Yes	100%	CONS 100%, *Candida* 5 %	4.75 CFU of CONS per hand 100 CFU candida on 1 hand
	9 anaesthetists			100%	CONS 100%	39.6 CFU per hand
2009 Rocha et al Brazil (28)	30 undamaged skin	Ward	No	Not specified	*S. aureus* 10%, *S. epidermis* 46.7%, *S. warneri* 6.7% *S. saprophyticus* 6.7%, other CONS 30%, *Serratia* 6.7%, gram-positive bacteria 6.7%, *C. tropicalis* 3.3%, *Candida* spp. 6.7%, other yeasts 10%	3.55 $\log^{10}$ CFU
			Yes		*S. aureus* 6.7%, *S. epidermis* 43.3%, *S. warneri* 16.7%, *S. haemolyticus* 10%, other CONS 23.3%, *Serratia* spp. 3.3%, *Enterobacter spp*. 3.3%, gram-positive bacteria 20%, *C. krusei* 3.3%, *Candida* spp. 3.3%, other yeasts 6.7%	3.35 $\log^{10}$ CFU
	30 damaged skin		No		*S. aureus* 16.7%, *S. epidermis* 23.3%, *S. warneri* 13.3%, *S. haemolyticus* 16.7%, *S. saprophyticus* 6.7%, other CONS 23.3%, *Serratia spp.* 3.3%, *Enterobacter* spp. 10%, nonfermenter 6.7%, gram-positive bacteria 16.7%, *C. krusei* 6.7%, *Candida* spp. 6.7%, other yeasts 63.3%	4.28 $\log^{10}$ CFU
			Yes		*S. aureus* 20%, *S. epidermis* 20%, *S. warneri* 30% *S. haemolyticus* 3.3%, *S. saprophyticus* 6.7%, other CONS 23.3%, *Serratia* spp. 6.7%, *Enterobacter* spp. 6.7%, gram-positive bacteria 16.7%, *Candida* spp. 6.7%, other yeasts 6.7%	3.75 $\log^{10}$ CFU
2010 Fagernes and Lingaas Norway (30)	465	Ward	No	100%	*S. aureus* 25.8%, *Enterobacteriacea* 16.1%, non-fermentative gram-negative rods 35.3% (these 3 specifically identified)	Median bacterial count 2 075 000
2011 Khodavaisy et al Iran (31)	126	ICU	No	Total 63.5% Doctor 56.2% Nurse 64.7%	Before patient contact: *Staphylococci* 15%, *Klebsiella* spp. 5%, *Pseudomonas* 5%, *Candida* spp 15%, *A. flavus* 2.5%	Not specified
					After patient contact: *Staphylococci* 10%, *Klebsiella* spp. 5%, *Pseudomonas* 2.5%, *Enterobacter* spp. 10%, *Acinetobacter* spp. 5% *Candida* spp. 20% *Rhodotorula* spp. 2.5%, *A. flavus* 5%	
2011 Paul et al India (32)	44 doctors	Ward	No	Entry to ward: 59.1%	*S. aureus* 27.27%, CONS 31.81%	Not specified
				Exit to ward: 90.1%	*S. aureus* 54.54%, CONS 31.81%, *E. coli* 4.54%, *P. aeruginosa* 4.54%, *Enterococci spp.* 13.63%, *K. pneumoniae* 9.09%, *Candida spp*. 4.54%	

Year, Author, country, reference	Sample size	Location	Hand hygiene performed	Level of growth	Organism isolated	Number of CFUs
2013 Wong et al Malaysia (33)	100	Ward and ICU	No	100%	ICU: *Staphylococcus* spp. 96%, *S. aureus* 12%, fungal 48%, *Acinetobacter* spp. 10%, *A. iwoffii* 4%, *Enterobacter* spp. 8%, *P. putida* 4%, *Klebsiella* spp. 4%, *D. acidovorans* 2%, *Pantoea* spp. 8%	37 samples>50 CFUs 7 samples 25-50 CFUs 6 samples<25 CFUs
					Ward: *Staphylococcus* spp. 98%, fungal 46%, *Acinetobacter* spp. 8%, *A. iwoffii* 4%, *Enterobacter* spp. 2%, *P. alcaligens* 2%, *S. fonticola* 2%, *Moraxella* spp. 6%	34 samples>50 CFUs 5 samples 25-50 CFUs 11 samples<25 CFUs
2013 Sasahara et al Japan (34)	71	Ward	No	76.1%	*B. subtilis* 52.1%	307 CFU per hand
					B. cereus 50.7%	138 CFU per hand
					C. difficile 1.4%	50 CFU per hand
					Enterococcus spp. 19.7%	
					Pseudomonas spp. 13.7%	155.6 CFU per hand
					E. coli 4.2%	41.7 CFU per hand
					K. oxytoca 1.4%	325 CFU per hand
					E. faecalis 1.4%	300 CFU per hand
2014, Visalachy India (35)	157	Ward	No	45.5% doctor	*B. subtilis* 9%, *Micrococci* spp. 30.3%, MSSA 3%, MRSA 3%	Not specified
				45.1% nurse	*B. subtilis* 8.8%, *Micrococci* spp. 32.3%, MSSA 4.9% MRSA 0.9%, *Pseudomonas* spp. 3.9%, *Acinetobacter* spp. 0.9%	Not specified
2014 Longtin et al USA (36)	489	Ward	No	100%	*Anaerobes* 100%, MRSA 76%	Fingertip 467 cfu/25cm^2 Thenar eminence 37cfu/25cm^2 Hypothenar eminence 34cfu/25cm^2 Hand dorsum 8 cfu/25cm^2
2014 Rosenthal et al USA (16)	34	Icu	No	Not specified	*S. aureus* 41.2-52.9%, *Enterococcus* spp. 52.9-70.6%, *C. albicans* 2.9-8.8%, MRSA 2.9-5.9%	Not specified

Year, Author, country, reference	Sample size	Location	Hand hygiene performed	Level of growth	Organism isolated	Number of CFUs
2015 Kirk USA (37)	46	Outpatient	No	28.3%	MRSA 13%, VRE 2.2 %, *Acinetobacter* 2.2%, *C. difficile* 15.2%	Not specified
2015 Sarfraz et al India (38)	101 clinical staff	Hospital	No	62.37%	*S. aureus* 10.9%, *A. baumannii* 9.9%, *P. aeruginosa* 8.9%, CONS 8.9% *A. iwoffii* 7.9%, *E. coli* 2.9%, *Corynebacterium* spp. 1.9%, *C. diphtheriae* 1.9%	Not specified
	99 non-clinical			72.72%	*A. iwoffii* 20.2%, CONS 16.2%, *S. aureus* 12.1%, *A. baumannii* 12.1%, *P. aeruginosa* 7.1%, *Micrococcus* spp. 4%	Not specified
2015 Sharma et al India (39)	183	Ward and ICU	No	Not specified	CONS 73%, *S. aureus* 34%, *B. subtilis* 82%, *Micrococci* 20%	5532
2016 Castro et al Portugal (40)	169	Medical and surgical ward	No	8.9%	*S. Aureus* (only organism tested for)	
2016 Singh and Singh India (41)	200	Ward	No	47.5%	Doctor: *S. aureus* 20%, MRSA 8%, CONS 60%, *Acinetobacter* spp. Nurse: *S. aureus* 70%, MRSA 40%, CONS 40%, *Acinetobacter* spp. 20%, *Klebsiella* spp. 12%	Not specified
2016 Chaka Ethiopia (42)	100 doctors and nurses	OPD, ward, NICU	No	Resident 78.1% Nurse 67.6% Intern 93.8%	*S. aureus* 56.4%, CONS 34.6%, *Acinetobacter* spp. 11.5%, *Pseudomonas* spp. 8.8% *Enterobacter* spp. 2.6%, *Citrobacter* spp. 1.6%, *K. pneumonia* 5.1%, *S. viridans* 1.3%	Not specified
			Yes	18% in total	*S. aureus* 20.1%, CONS 18.5%	
2016 Bingham et al USA (43)	17	Ward	No	17.4% before a clean procedure	*MRSA* 4.4%, VRE 2.2%, *C. difficile* 10.9%	Not specified
			No	28.3% post patient encounter	MRSA 13%, VRE 2.2%, *Acinetobacter* 2.2%, *C. difficile* 15.2%	
2018 Sureshkumar et al India (44)	130	Ward	No	100% bacterial 8.2% fungal	Bacterial growth: *S. aureus* 15%, CONS 24%, *Diphtheroids* 29%, *Micrococcus* 7%, *E. coli* 6%, *Klebsiella* spp. 4%, *Proteus* spp. 2%, *Pseudomonas* spp. 13% fungal growth: *Candida* spp. 50%, *Mucor* 12.5%, *Aspergillis* spp. 25%, *Microsporum* spp. 12.5%	Not specified

Year, Author, country, reference	Sample size	Location	Hand hygiene performed	Level of growth	Organism isolated	Number of CFUs
2017 Senthil India (45)	70	Ward	No	91.45% medical students	*S. aureus* 57.14%, MRSA 20%, CONS 28.6%	Not specified
				77.1% interns	*S. aureus* 51.42%, MRSA 28.6%, CONS 22.9%	
2018 Pimpalkar et al, India (46)	110	Ward	No	63.63%	*S. epidermidis* 63.6%, *S. aureus* 0.9%, *E. coli* 1.8%, *Klebsiella* 9.09%, *Acinetobacter* 8.18%, *Pseudomonas* 2.72%, *Enterococci* 4.54%	Not specified
2018 Matuka et al South Africa (47)	70	OT	No	Not specified	*S. aureus* 41%, *E. coli* 1.4%	3.28 $\log^{10}$ CFU
			Yes	Not specified	*S. aureus* 29%, *E. coli* 0%	2.7 $\log^{10}$ CFU

1.3.2 Anaesthetists

All the studies were conducted in theatre. In 2009 Gunasekera et al (48) conducted a study in Sri Lanka on 45 anaesthesists. No hand hygiene was performed and 71% of anaesthetists displayed growth. Organisms cultured included MRSA 22%, MSSA 33%, CONS 2.2%, *Micrococci* 8.8%, *Enterococci* 4.4%, *E. cloacae* 2.2% and *K. pneumonia* 2.2%. Loftus et al (49, 50) conducted two studies in the USA in 2010. In the one study (50) assessing the hands of anaesthesists as a risk factor for intraoperative transmission without hand hygiene being performed, there was a growth rate of 66% from 164 samples. Organisms grown included MRSA 7%, MSSA 11%, VRE 2%, *Enterococcus* (non VRE) 0.6%, other *Staphylococcus* 100%, *Micrococcus* 67%, *Corynebacterium* 9%, *Streptococcus* 78% and gram-negative 49% (50). The other study (49) assessed reservoirs contributing to intraoperative bacterial transmission with 274 samples being taken. The total growth was not stated; the organisms grown with no hand hygiene being performed were MRSA 0.8%, MSSA 5%, VRE 1.2%, gram-negative 56.3% and methicillin-sensitive *Staphylococcus epidermidis* 15.4%. The organisms cultured from anaesthetists was in keeping with those from HCPs working in the ward. The microorganisms isolated were similar to cultures done in wards (49).

1.3.3 Nurses

Walaszek et al (51) found that nurses with long nails and nail polish had both a higher commensal and pathological growth when compared to nurses with short nails and natural nails. Larson et al (52) found that nurses with damaged skin had similar growth counts but a higher incidence of colonising organisms when compared to nurses with undamaged skin.

Table 2 Studies detailing hand contamination in nurses

Year Author Location Reference	Sample size	Hand hygiene performed	Level of growth	Organism isolated	Number of CFUs
1998 Larson USA (52)	20 damaged skin	Yes	Not specified	*S. epidermidis 100%, S. hominis 75%, S. warneri 50%, o*ther CONS *90%, S. aureus 25% Micrococci 55%*, liphophilic diphtheroids *60%, l*arge colony *diphtheroids 25%, Candida* spp *40%* other yeasts *20%,* gram-negative rods *40%, Bacillus* spp. *35%, Enterococci 10%, Streptococci 20%*	5.6 $\log^{10}$ CFU
	20 undamaged skin			*S. epidermidis 90%, S. hominis 55%, S. warneri 65%,* other CONS *70%, S. aureus 20%, Micrococci 50%,* liphophilic diphtheroids *45%,* large colony diphtheroids *35%, Candida spp. 20%,* other yeasts *5%,* gram-negative rods *20%, Bacillus* spp. *30%, Streptococci 30%*	5.63 $\log^{10}$ CFU
2018 Walaszek et al Poland (51)	99	No	Short nails: Pathological 5.1% Commensal 66.1%	*S. aureus* 1.7%, *E. faecium* 1.7%, *C. freundii* 1.7% CONS 66.1%	Not specified
			Long nails: Pathological 27.5% Commensal 77.5%	*S. aureus* 7.5%, *S. mitis* 5%, *E. faecalis* 7.5% *C. freundii* 2.5%, *E. coli* 2.5%, *Klebsiella* spp. 2.5%, CONS 77.5%	
			Natural nails: Pathological 4.4% Commensal 26.7%	*S. aureus* 2.2%, *S. mitis* 2.2%, CONS 26.7%	
			Nail polish: Pathological 27.3% Commensal 42.2%	*S. aureus* 4.5%, *S. mitis* 2.3%, *E. faecalis* 9.1%, *E. faecium* 4.5%, *C. freundii* 1% *E. coli* 1%, *Klebsiella* spp. 1%, CONS 42.2%	

1.4. Transmission of organisms from hands to surrounding equipment in environment

The transmission of microorganisms can contaminate the surrounding environment leading to transmission to the patient or the recontamination of clean hands (50). Loftus et al (50) conducted a study to assess intraoperative contamination of stopcocks and found that environmental transmission occurred in

89% of cases with HCPs being identified as the origin of this transmission in 12% of cases.

Routine practice may result in pathogens contaminating the surrounding environment (53). Mahida et al (53) conducted a study in the United Kingdom in 2015 assessing reservoirs for intraoperative microorganism transmission. Microbial swabs performed at the end of theatre cases found growth on switches of 34% of the ventilators and 72% of flowmeter knobs. Swabs were carried out on syringes left on the anaesthetic trolley either for reuse or prior to being discarded. A median of four syringes were found on the trolley per theatre case, syringe tips showed growth in 46% of the samples while the syringe contents showed growth in 15%. The organisms cultured from syringe tips and contents were coagulase-negative *Staphylococci*, *Staphylococcus epidermidis*, *Micrococci*, *Kocuria* and *Streptococci viridans*. The overall contamination of the intravenous line extension was 9%. The organisms cultured included *Staphylococcus capitis*, *Staphylococcus epidermis* and *Micrococcus luteus* (53).

Hospital design can also influence the spread of nosocomial infections (54). Wojgani et al (54) conducted a study assessing the contamination of door handles with regards to the design, location and intensity of use. Microbial swabs were taken from the door handles following each use. Contamination was assessed using total viable counters per movement (TVCs/movement). Lever handles showed the highest level of contamination with 6.38 TVCs/movement, followed by pull handles with 2.24 TVCs/movement and lastly push plates with 1.2 TVCs/movement. Although a specific value not stated the growth was higher on the inside door handles than on the outside. No value was given but door handles used to enter theatre displayed more growth than the door handle used to exit theatre which suggests poor hand hygiene upon entering theatre (54).

Heat generated by mobile phones and not cleaning mobile phones creates an environment for growth of microrganisms (55). A study conducted by Pal et al (56) in India in 2015 looked at mobile phones as a reservoir for transmission of nosocomial pathogens amongst HCPs. Microbial swabs were taken of the dominant hand and the mobile phone with a total of 772 samples. Growth was recorded in 80% of hands and 81.8% of mobile phones. Organisms cultured from

the hands included CONS, MSSA, MRSA, *Micrococcus* spp., diptheroids and *Enterococcus* spp.. The organisms cultured from the mobile phones were CONS, MSSA, *E. coli*, *Acinetobacter* spp., *Micrococcus* spp., diptheroids, *Enterococcus* spp., *Citrobacter* spp., *Enterobacter* spp., *K. pneumoniae* and MRSA. The growth of pathological microorganisms on mobile phones concurs their potential as reservoirs for HAIs. The recovery of similar bacteria from hands and mobile phones suggests that hands may be the source of contamination of mobile phones and vice versa (56).

1.5. Poor practice of a recommended hand hygiene guideline

HCP compliance with hand hygiene guidelines is an important measure for HAI prevention but overall compliance across all healthcare settings remains low (57). Fernandez et al (57) conducted a study in the USA in 2011 assessing knowledge on hand hygiene in anaesthesia providers. One or more knowledge deficits occurred with 81.6% of survey respondents. Zakeri et al (58) conducted a study at two hospitals in Iran where knowledge on hand hygiene was assessed. Of the total participants, 21% scored poorly with less than 50% and 68% scored moderately between 50 – 75%.

The World Health Organization (59) has composed a guideline for hand hygiene. The aim of the guideline was for simplicity and easy assimilation into the work area. This evidence-based model was called “My five moments for hand hygiene”. The first moment is before touching the patient. This moment refers to the point of last contact with the healthcare area and the first contact within the patient zone. The second moment occurs within the patient zone and refers to hand hygiene prior to performing a clean or aseptic procedure. This is after contact with the patient’s intact skin or clothes and before contact with a clean or aseptic procedure resulting in infectious risk to the patient. The third moment is after exposure to body fluids. The fourth moment is after touching the patient. This occurs on completion of the contact with the patient and prior to contact with areas outside the patient zone. Hand hygiene at this point decreases the chance of spread to the healthcare environment and significantly decreases contamination of the HCPs hands. The fifth moment is after touching the patient’s surroundings. This occurs

after contact with surfaces in the patient zone and prior to contact to any surface in the healthcare area (59).

1.6. Difficulties with implementation of a hand hygiene model

Healthcare-related practices is the consequence of biopsychosocial influences from our home environment (59). Hand hygiene behaviour is developed from infancy and soon becomes established (59). Improving hand hygiene compliance for HCPs means modifying behaviour patterns that have been present since childhood and have been reinforced by community and social standards (59). There are two types of behavioural patterns with regards to hand hygiene (60). The first is inherent hand hygiene which drives the majority of community handwashing behaviour (60). The second type of behaviour is elective hand hygiene which is described as contacts not being "perceived to pose a threat and does not trigger an intrinsic response with an immediate desire to wash hands". The healthcare setting presents situations where elective hand hygiene is required (60).

Low HCP hand hygiene compliance can be due to low prioritisation, insufficient time, inconvenience of handwash equipment placement, allergy and intolerance to antiseptics and lack of leadership in management (61). Education alone is not sufficient (62). Programmes to improve hand hygiene compliance in HCPs cannot rely solely on awareness and must attempt to correct a HCPs pre-existing hand hygiene behaviour (59). Interventions tailored to the population that cause changes to social and cognitive factors for hand hygiene are superior to a standard education intervention (62).

Attempting to implement a hand hygiene model requires a multidimensional model targeting knowledge, attitude and clinical skills (63). Knowledge requires education on guidelines, rules, scientific evidence and legal implications. Adjusting attitudes is an integral component. Behavioural imitation, improving self-efficacy in performing hand hygiene and effectiveness of positive feedback are suggested mechanisms. Clinical skills required in the healthcare setting can be used as the benchmark requirement for implementing the hand hygiene standards. To institute a model in the clinical context requires enablers, promotors and being able to

overcome barriers. Enablers are defined as necessary preconditions required for hygienic work to be performed and include competent clinical personnel, material and spatial structures necessary for hand hygiene and guidelines to be implemented. Promoters are defined as factors that improve hand hygiene implementation. Promoters include continuing education, communication seminars, increasing awareness and reinforcing attitudes through role models and experts. Barriers are the factors that impede hand hygiene. Barriers are high workloads, too few personnel, unfavourable materials and structures, negative role models and high infection risk activities (63).

1.7. Summary

The hands of HCPs are colonised with multiple commensal and pathological microorganisms. These microorganisms can serve as a reservoir for HAI. High levels of contamination have been noted in developing and developed countries. Poor knowledge of a hand hygiene model may also contribute to the microbial burden in an already constrained setting.

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Acknowledgements

In a separate section, acknowledge any financial support received or possible conflict of interest. This section may also be used to acknowledge substantial contributions to the research or preparation of the manuscript made by persons other than the authors.

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Tables should be self-explanatory, clearly organised, and supplemental to the text of the manuscript. Each table should include a clear descriptive title on top and numbered in Roman numerals (I, II, etc) in order of its appearance as called out in text. Tables must me inserted in the correct position in the text. Authors should place explanatory matter in footnotes, not in the heading. Explain in footnotes all non-standard abbreviations.

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Section 3: Draft article

Microbial contamination of hands of healthcare providers in the operating theatre of a central hospital

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Key words: hands, healthcare providers, commensal, pathogen, microorganism

Abstract

Background

Effort is invested in maintaining sterility of the operating field, but less attention is paid to potential healthcare associated infection (HAIs) sources through patient contact by non-scrubbed healthcare providers (HCPs). A single microbiological assessment of hands can provide a good assessment of the potential dynamic transmission of microorganisms. The aim of this study was to identify and quantify the microbial growth on the hands of HCPs in the operating theatres of Chris Hani Baragwanath Academic Hospital.

Methods

A prospective, contextual and descriptive study design was followed. Seventy five samples were collected using convenience sampling from an equal number of surgeons, anaesthetists and nurses. Specimens were taken using agar plates and underwent semi-quantitative analysis.

Results

All hands of HCPs displayed growth, of which 82% of HCPs hands grew commensals and 80% grew pathogens. Twelve commensal microorganisms and 27 pathological organisms were noted. Two or more organisms were cultured on 76% of HCPs' hands. Comparisons of commensal, pathological and combined levels of contamination among the three groups were not statistically significant ($p=0.266$, $p=0.673$, $p=0.180$). There was no significant difference between the growth of combined microorganisms ($p=0.927$) and pathological microorganisms ($p=0.499$) among the groups. Surgeons had significantly more commensal growth ($p=0.019$) than anaesthetists and nurses. There was no statistically significant difference between sexes.

Conclusion

It was concerning that 100% of the hands of HCPs who were about to commence with the surgical list had microbial growth. These HCPs could have already been in contact with patients and equipment in the theatre environment. Microorganisms cultured on hands are a source of cross-transmission which may result in HAIs. Institutions require the implementation of a multidimensional model to amend guidelines, implement guidelines and increase awareness of hand hygiene.

Introduction

Healthcare acquired infections (HAIs) are infections that appear in a patient under medical care that was not present at the time of admission (1). The incidence of HAIs in developed countries ranges from 3.5 – 12% while in developing countries the range is from 5.7 – 19.1% (5). Patients who develop a HAI remain in hospital two and a half times longer, with hospital costs nearly three times higher, and incur further medical costs after discharge from hospital when compared to uninfected patients (3). The most frequent types of HAI include central line associated blood stream infections, catheter associated urinary tract infections, surgical site infections and ventilator associated pneumonia (1). The risk factors for developing a HAI include poor hygienic conditions of the healthcare setting, increased patient susceptibility, inadequate hand hygiene and poor knowledge of infection control policies (4).

In the operating theatre (OT), much effort is invested in maintaining sterility of the operating field, but less attention is paid to potential HAI sources through patient contact by non-scrubbed healthcare providers (HCP) (5). The microorganisms present on the hands of HCPs serves as a reservoir for potential contamination. In the OT, contamination of the hands of HCPs can independently increase the risk of patients being contaminated (6). Loftus et al (7) conducted a study where the phenotypes of *Staphylococcus aureus* isolated from HCPs' hands were linked phenotypically to patients' 30-day postoperative cultures. Pathogenic microorganisms cultured from the hands of HCPs include coagulase-negative *Staphylococci, Acinetobacter baumannii, Klebsiella pneumoniae, Proteus mirabilis, Enterobacter cloacae, Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli* and methicillin-resistant *Staphylococcus aureus* (8). Microorganisms can pass directly from contaminated surfaces to the hands of HCPs and serve as a microbial reservoir until patient contact occurs (9, 10). The infective dose for many pathogens appears to be very low and slight contamination of the environment is sufficient to cause infection (11).

Ineffective hand hygiene is being practiced globally (1-5, 12). The duration of microorganism survival on hands differs with various microorganisms, some able to survive for more than an hour (11). Inadequate hand hygiene often leads to the

survival of these microorganisms leading to an increased risk of cross-transmission (11). Hand contamination has increased sequelae beyond the intraoperative risk of transmission (13). Directly observed behaviour of hand hygiene has shown low compliance to institutionally developed protocols (5, 14, 15).

A single microbiological assessment of hands can provide a good assessment of the potential transmission (16). Limited South African studies reporting hand contamination of HCPs have been identified, either nationally or at Chris Hani Baragwanath Academic Hospital (CHBAH). The aim of this study was to identify and quantify the microbial growth on the hands of HCPs in the OTs of CHBAH.

Methods

A prospective, contextual and descriptive study design was followed. Approval to conduct the study was obtained from the Human Research Ethics Committee (Medical) and other relevant authorities.

The study population consisted of HCPs (surgeons, anaesthetists and nurses) in the OTs of CHBAH. Convenience sampling was used and due to financial constraints, 75 samples were collected to allow an equal number of participants in each of the three groups. After consultation with a biostatistician a sample size of 75 participants at an expected contamination rate of 80% in all HCPs, with an average of 65% contamination found in the literature (17-23), will give a power of 84% at a significance level of 5%. All HCPs who consented to participate in the study were included and were only enrolled once.

In consultation with a microbiologist, it was decided to use a low budget, high volume process. Agar plates were used to collect specimens. This form of semi-quantitative analysis is cheap, requires minimal microbiological analysis and logistical support (24). Samples were collected on isolated days over one month to prevent HCPs from changing their practices of hand washing. The study was explained to HCPs and signed consent was obtained prior to specimen collection. Agar plating was done in the morning prior to the commencement of the surgical list. The collection process consisted of HCPs pressing their fingertips of their

dominant hand, followed by the base of their hand into the agar plate for five seconds each (24-26).

Samples were collected by one author (KP) and a standard laboratory request form was used to enter each specimen's differentiating information**.** Samples collected were stored at room temperature and were delivered to the laboratory at the earliest possible time on the same day. The samples were processed by the accredited laboratory, Vermaak and Partners Pathologists.

Samples were incubated for 48 hours, after which the colonies were examined, tallied and detailed. For this study, a standard semi-quantitative criterion was used with assigned scores given to microorganisms:

- 1+ = rare
- 2+ = few
- 3+ = moderate
- 4+ = many

The distinction between pathological and commensal microorganisms was made; however, this was difficult as some commensal microorganisms can result in a nosocomial infection and some pathological microorganisms can also be commensals in the appropriate setting. Participants could ask for their microbial results and if a participant grew pathological organisms they were informed of the growth.

Data were analysed with Stata version 16 (StataCorp USA). Categorical variables were described using frequencies and percentages. Comparisons between the level of contamination among the groups were done using Fisher's exact tests. Kruskal Wallis tests were used to compare the number of microorganisms among the three groups. Dunn tests were applied to any significant difference. A p-value of <0.05 was considered statistically significant.

Results

Seventy-seven HCPs were approached but two declined. Samples were collected from 75 participants which included 25 anaesthetists, 25 surgeons and 25 nurses. Of the participants, 52 were female and 23 were male. The identity and quantity of the microorganisms present on the hands of HCPs prior to the commencement of the surgical list in the morning are shown in Table 1. Twelve commensal microorganisms and 27 pathological microorganisms were grown. All hands of the HCPs displayed growth, of which 82% cultured commensals and 80% cultured pathogens. No 4+ growth was noted.

Table 1 Identity and quantity of organisms grown

Organism	No of times grown (%)	Level of growth		
		1+	2+	3+
Commensal organisms				
Corynebacterium amycolatum	1 (1.3)	1	0	0
Corynebacterium aurimucosum	1 (1.3)	0	1	0
Klebsiella oxytoca	1 (1.3)	0	1	0
Kocuria kristinae	1 (1.3)	1	0	0
Neisseria flava	3 (4.0)	2	1	0
Staphylococcus capitis	10 (13.3)	5	4	1
Staphylococcus cohnii	4 (5.3)	1	2	1
Staphylococcus epidermidis	41 (54.7)	22	17	2
Staphylococcus haemolyticus	5 (6.6)	1	3	1
Staphylococcus hominis	4 (5.3)	2	2	0
Staphylococcus wameri	6 (8.0)	5	1	0
Streptococcus mitis/oralis	2 (2.7)	1	1	0
Pathological organisms				
Acinetobacter baumanni	2 (2.7)	1	1	0
Acinetobacter iwoffii	4 (5.3)	4	0	0
Acinetobacter ursingii	1 (1.3)	0	1	0
Bacillus cereus	24 (32)	16	7	1
Bacillus circulans	1 (1.3)	1	0	0
Bacillus pumilis	1 (1.3)	1	0	0
Brevundimonas diminuta	1 (1.3)	0	1	0
Brevundimonas vesicularis	1 (1.3)	0	1	0
Clostridium sporogenes	1 (1.3)	1	0	0
Enhydrobacter aerosaccus	2 (2.7)	2	0	0
Enterobacter cloacae complex	2 (2.7)	0	2	0
Enterobacter hormaechei	1 (1.3)	0	1	0
Haematobacter massiliensis	1 (1.3)	0	1	0
Klebsiella aerogenes	1 (1.3)	1	0	0
Klebsiella pneumonia	2 (2.7)	0	2	0
Leclercia adecarboxylata	3 (4.0)	0	1	2
Lysinibacillus fusiformis	4 (5.3)	3	1	0
Micrococcus luteus	21(28)	6	12	3
Paenibacillus lautus	2 (2.7)	2	0	0
Paenibacillus spp	1 (1.3)	1	0	0
Paenibacillus thiaminolyticus	1 (1.3)	1	0	0
Pantoea agglomerans	1 (1.3)	0	1	0
Proteus mirabilis	2 (2.7)	1	1	0
Sphingobacterium multivorum	1 (1.3)	0	1	0
Staphylococcus aureus	9 (12)	5	3	1
Staphylococcus saprophyticus	2 (2.7)	0	1	1
Streptococcus agalactiae	1 (1.3)	1	0	0

The growth according to sex is shown in Table 2. A p-value of 0.611 was calculated which was not statistically significant for commensal, pathological and combined growth between the two sexes.

Table 2 Growth according to sex

Professional designation	Total	Male	Female	Growth					
				Commensal		Pathological		Combined	
				Male	Female	Male	Female	Male	Female
Anaesthetist	25	8	17	2	2	1	2	5	13
Nurse	25	0	25	0	4	0	8	0	13
Surgeon	25	15	10	5	5	2	0	8	5
Total	**75**	**23**	**52**	**7**	**11**	**3**	**10**	**13**	**31**

The number of microorganisms cultured on the hands of HCPs is shown in Table 3. Seventy-six percent of HCPs had two or more microorganisms on their hands.

Table 3 Number of organisms on HCP hands

Number of organisms	Number of HCPs	Percentage of HCPs
1	18	24
2	30	40
3	20	26.7
4	3	4
5	2	2.7
6	2	2.7

Figure 1 shows the pathological microorganisms and the number of times it was grown in each group.

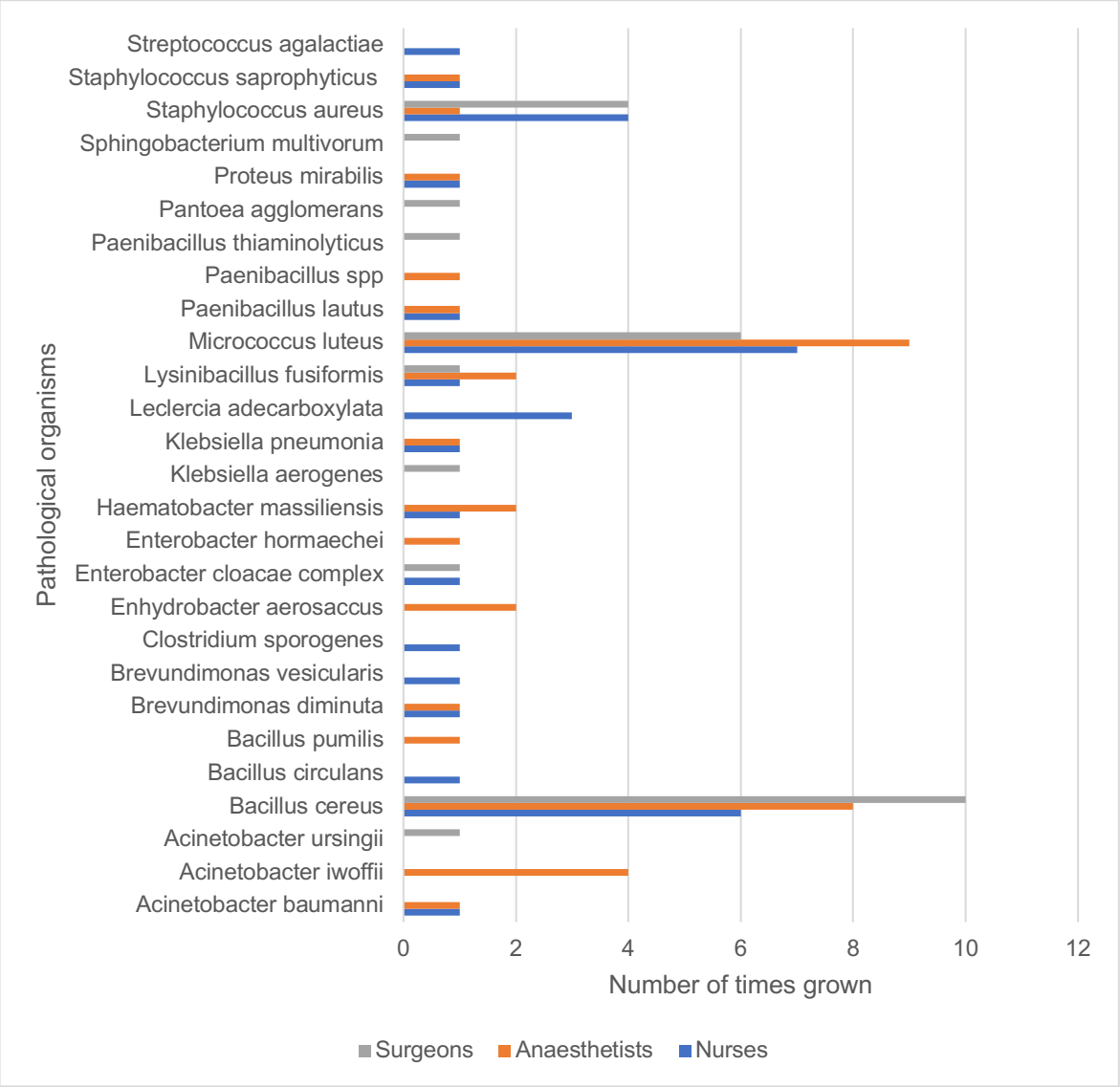

Figure 1 Pathological growth among each group

Figure 2 shows the commensal microorganisms and the number of times it was grown in each group.

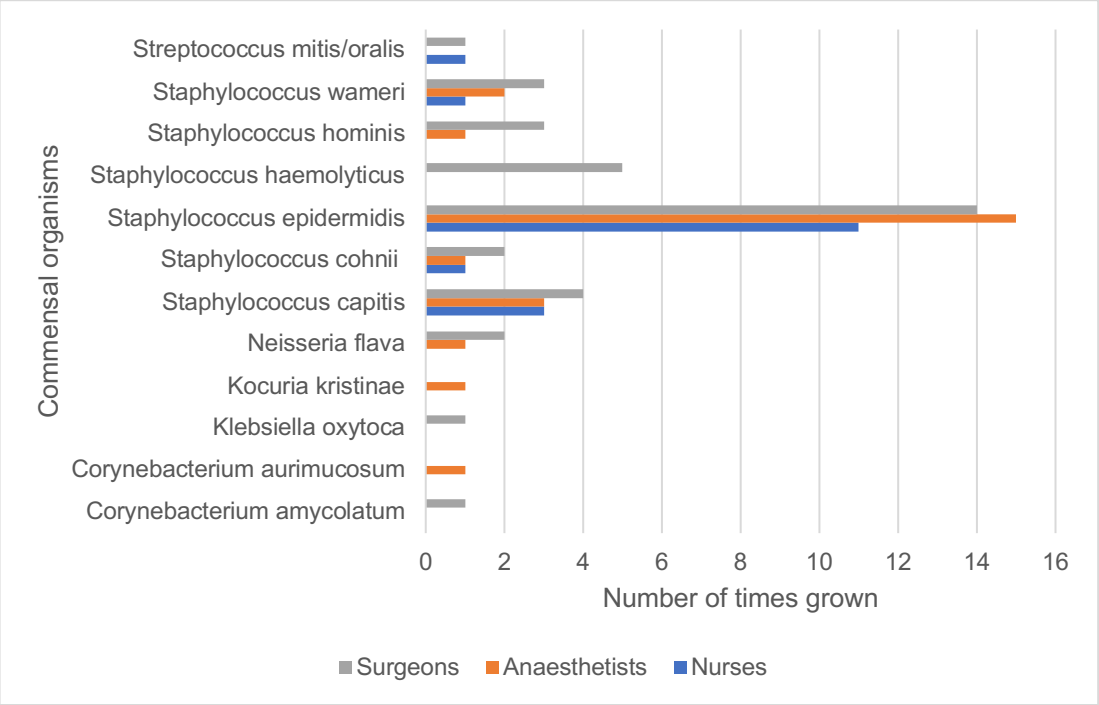

Figure 2 Commensal growth among each group

The level of contamination of microorganisms on the hands between the three groups was compared as shown in Table 4. No significant differences were found.

Table 4 Comparison of the level of contamination among the groups

Professional designation	Level of contamination			p-value
	1+	2+	3+	
Combined growth				
Anaesthetist	27	23	2	
Nurse	23	18	8	
Surgeon	30	30	3	p=0.180
Commensal growth				
Anaesthetist	14	11	0	
Nurse	10	5	3	
Surgeon	17	17	2	p=0.226
Pathological growth				
Anaesthetist	13	12	2	
Nurse	13	13	5	
Surgeon	13	13	1	p=0.673

The number of microorganisms on the hands of each group was compared. There was a significant difference in the growth of commensals between the groups (p=0.019). A significant difference was present between nurses and surgeons (p=0.0028) and anaesthetists and surgeons (p=0.0351). The surgeons had the

highest number of commensal microorganisms on their hands. There was no significant difference in the growth of pathological microorganisms (p=0.499) and combined microorganisms (p=0.927).

Discussion

This study emphasises a significant level of microorganism contamination on the hands of HCPs; all the hands of the participants were contaminated, with 76% of the hands growing two or more microorganisms. A study in Wales by Al-Allak et al (27) found 100% of HCPs' hands were contaminated. Hand contamination ranged from 62.3 – 100% in studies conducted in various hospital settings in developed and developing countries (19, 23, 28-33). It is of concern that in our study, all participants were about to commence with the surgical list for that day and have already been in contact with the operating theatre environment.

Commensal microorganisms were cultured in 82% of participants. Twelve commensal microorganisms were cultured with the most predominant being *Staphylococcus epidermis* 54.7%, *Staphylococcus capitis* 13.3% and *Staphylococcus warneri* 8.0%. *Staphylococcus epidermidis* may promote sepsis by its ability to form biofilms on indwelling medical devices and produce toxins (34). *Staphylococcus capitis* can be considered a pathogen in neonates and a drug-resistant form has emerged as a cause of sepsis in neonatal intensive care units (35). *Staphylococcus warneri* may manifest as an insidious infection or cause protracted infection of various prostheses and endovascular catheters (36). The microorganisms grown in our study are in keeping with commensal strains (37). Commensal microorganisms may cause infection if they enter a sterile body cavity (38), may permanently colonise the hands of HCPs and are often associated with HAIs (39).

Pathological microorganisms were cultured in 80% of participants. Twenty-seven pathological organisms were grown with the most predominant being *Bacillus cereus* 32%, *Micrococcus luteus* 28%, *Staphylococcus aureus* 12% and *Acinetobacter iwoffii* 5.3%. *Bacillus cereus* can cause localised infection, bacteraemia and be associated with haematogenous spread (40). In haematological patients' *Bacillus cereus* has the ability to invade the central nervous system (40). *Micrococcus luteus* has been implicated in HAI in

immunocompromised patients (41). *Staphylococcus aureus* has the propensity to develop resistance to antimicrobial agents and is one of the most lethal bloodstream pathogens (42). *Acinetobacter iwoffii* can cause HAIs in patients with chronic illnesses and increases the length of hospitalisation and mortality (43).

Thirty-nine microorganisms were cultured in total. The microorganism count was more than other studies; Rocha et al (44) grew 11 microorganisms, Wong et al (19) grew 20 microorganisms, Sureshkumar et al (32) grew 12 microorganisms and Larson (45) grew 14 microorganisms. Possible reasons for microorganism growth could be ineffective hand hygiene, damaged skin and the local healthcare microbial environment (1, 44-46).

There was no significant difference between the level of growth of microorganisms on the hands of anaesthetists, nurses and surgeons. No differences were noted between professional designations in prior studies indicating that this does not influence the microbial environment of hands (18, 23, 47). When comparing the number of microorganisms present on the hands of HCPs, there was no significant difference for combined and pathological growth. The surgeons' hands had a higher number of commensal microorganisms present when compared to anaesthetists and nurses. The surgeons are possibly exposed to a different microbial environment by performing work in wards prior to arriving in theatre.

From the three studies assessing hand hygiene of anaesthetists, only two gave total growth values that ranged from 66 – 71% (48, 49). Anaesthetists in this study had a 100% growth rate from their hands while growing more microorganisms. The 100% growth rate from the hands of nurses was higher than the growth rates identified in two studies ranging from 5.1 – 77.5% (45,50). The growth from this study was in keeping with studies assessing damaged skin and poor nail hygiene (45,50). There were no specific studies identified that assessed hand hygiene of only surgeons in the OT environment.

The population was skewed with regard to sex as 52 females and 23 males participated in the study. However, there was no statistically significant difference between the sexes. No study was identified which showed differences with microorganisms between males and females. The analysis was done due to

females possibly having longer nails, nail polish and more rings when compared to males. This was not further analysed as this was not an objective of the study.

Results from this study indicate the need for adequate hand hygiene practice. A simple hand hygiene model, such as the “My Five Moments of Hand Hygiene” has had low compliance in healthcare settings (51, 52). Altering poor hand hygiene practice requires a multidimensional model targeting knowledge, attitude and clinical skills (53). Elective hand hygiene is difficult to correct and will be challenging to adjust to an implemented guideline (54). Barriers to hand hygiene, which are similar in our healthcare setting, are high workloads, too few personnel, unfavourable materials and structures and high infection risk activities (53). Limitations of this study included a contextual analysis of microorganisms present. Funding of the study was a limitation since a semi-quantitative analysis was done however a single microbiological assessment of hands can provide a good assessment of the potential transmission .

Conclusion

It was concerning that 100% of the hands of HCPs who were about to commence with the surgical list had microbial growth. These HCPs could have already been in contact with patients and equipment in the theatre environment. Microorganisms cultured on hands are a source of cross-transmission which may result in HAIs. Institutions require the implementation of a multidimensional model to amend guidelines, implement guidelines and increase awareness and availability of hand hygiene materials.

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

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Section 4: Proposal

Microbial contamination of hands of healthcare providers in the operating theatre of a central hospital

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4.1 Introduction

Sepsis is a serious and often fatal clinical syndrome that is characterised by organ dysfunction (1). Sepsis is associated with increased morbidity and mortality and accounted for 23.7 billion dollars in healthcare expenditures in the United States of America in 2013 (2). The epidemiology of sepsis in the developing world is not well described. The increased risk of sepsis in the developing world includes poverty and overcrowding, inadequate basic healthcare, inadequate hygiene and public health programmes and a high prevalence of HIV infection (3). Globally there are 31 million cases of sepsis annually and it accounts for six million deaths (4). The incidence of sepsis is increasing dramatically due to the ageing population despite the advantages of modern medicine including vaccines, antibiotics and intensive care (5). There is a 5 – 16 fold increase in the risk of nosocomial infections in studies conducted in developing countries (3).

Sepsis can be divided into three subsets: community acquired, healthcare associated and hospital acquired. Healthcare associated infections (HAI) appear in a patient under medical care that was not present at the time of admission (6). The incidence of HAI in high income countries ranges from 3.5 – 12% while in middle to low income countries the range is from 5.7 – 19.1% (7). Patients who develop a HAI remain in hospital two and a half times longer, with hospital costs nearly three times higher, and incur further medical costs after discharge from hospital when compared to uninfected patients (8). The most frequent types of HAI include central line associated blood stream infections, catheter associated urinary tract infections, surgical site infections and ventilator associated pneumonias (6). The risk factors for developing a HAI include poor hygienic conditions of the healthcare setting, increased patient susceptibility and poor knowledge of adequate infection control policies (9). Poor infection control policies, such as inadequate hand hygiene, increase the risk of transmission to patients (9).

In the operating theatre (OT) much effort is invested in maintaining sterility of the operating field, but less attention is paid to potential HAI sources through patient contact by non-scrubbed healthcare providers (HCP) (10). The microorganisms present on the hands of HCPs serves as a reservoir for potential contamination. In the OT contamination of the hands of the HCPs can independently increase the

risk of patients being contaminated (11). Loftus et al (12) conducted a study between March 2009 and February 2010 where the phenotypes of *Staphylococcus aureus* isolated from HCPs' hands were linked phenotypically to patients' 30-day postoperative cultures. Pathogenic organisms cultured from the hands of HCPs include coagulase-negative *Staphylococci, Acinetobacter baumannii, Klebsiella pneumoniae, Proteus mirabilis, Enterobacter cloacae, Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli* and methicillin-resistant *Staphylococcus aureus* (13). Microorganisms can pass directly from contaminated surfaces to the hands of HCPs and serve as a microbial reservoir until patient contact occurs (14,15). The infective dose for many pathogens appears to be very low and a slight contamination of the environment is sufficient to cause onset of infection (16).

Ineffective hand hygiene is being practiced globally (5-10). The duration of microorganism survival on hands differs with various microorganisms, some able to survive for more than an hour (16). Inadequate hand hygiene often leads to survival of these microorganisms leading to an increased risk of cross-transmission (16).

4.2 Problem statement

Contamination of HCPs' hands serve as a reservoir for vertical bacterial transmission thereby increasing the risk of HAI (11). Hand contamination has been linked, phenotypically, to the causative microorganisms of 30-day postoperative infections (12). Hand contamination has increased sequelae beyond intraoperative risk of transmission (17). Directly observed behaviour of hand hygiene has shown a low compliance to institutional developed protocols (10,18,19).

A single microbiological assessment of hands can provide a good assessment of the potential dynamic transmission (20). One South African study has been identified which focused on two organisms and reduction levels after handwashing (21). Limited South African studies have been identified, either nationally or at Chris Hani Baragwanath Academic Hospital (CHBAH), to identify and quantify the microbiological contamination of the hands of HCPs in OT.

4.3 Aim and objectives

4.3.1 Aim

The aim of this study is to identify and quantify the microbial growth on the hands of HCPs in the OTs of CHBAH.

4.3.2 Objectives

The primary objective of the study is to describe the identity and quantify the microorganisms present on the hands of HCPs prior to the commencement of the surgical list in the morning.

The secondary objective is to compare the quantity of microorganisms amongst surgeons, anaesthetists and nurses.

4.4 Research assumptions

Healthcare provider: is any individual, institution, or agency that provides health services to healthcare consumers, which in this study will be anaesthetists, surgeons and nurses (22).

Anaesthetist: is any qualified doctor working in the Department of Anaesthesiology including interns, medical officers, registrars and consultants**.**

Surgeon: is any qualified doctor working in the Department of Surgery or surgical subspecialties including interns, medical officers, registrars and consultants.

Nurse: is any professional nurse, enrolled nurse or auxiliary nurse who work in the OT of CHBAH.

Contamination: in this study contamination refers to any microorganism growth on the hands of HCPs.

Level of contamination: for this study a standard semi-quantitative criterion will be used with assigned scores given to microorganisms. 1+ = rare, 2+ = few, 3+= moderate, 4+= many (23).

4.5 Demarcation of study field

The study will be conducted in the theatre complex of CHBAH affiliated to the Department of Anaesthesiology at the University of the Witwatersrand. CHBAH is a 2888 bed hospital comprising 25 OTs and performs approximately 65 000 cases annually.

4.6 Ethical considerations

Approval to conduct the study will be obtained from the Human Research Ethics Committee (Medical) and the Graduate Studies Committee of the University of the Witwatersrand. Permission to conduct the study at CHBAH will be obtained from the Chairman of the Medical Advisory Committee prior to commencement of the study (Appendix 1). A letter approving the study has been signed by the Head of Department of Anaesthesiology at CHBAH (Appendix 2).

The focus of this study is on the microbial contamination of the hands of the HCPs. HCPs in the OT, prior to the commencement of the surgical list in the morning, will be approached and invited to participate in this study with the study being explained. Should they agree to participate they will then be given an information sheet (Appendix 3) and will be asked to sign written consent (Appendix 4) prior to the specimens being taken.

HCPs will be assigned a study number and this will be used on the data collection sheet. Their study number and microbiological result will be stored in a database should the participant want to know their result. However, in the event of an infectious organism being grown, the participants will be informed of their result.

Data will be stored securely in a password protected database for six years after the completion of the study.

The study will be conducted in accordance with the Declaration of Helsinki (24) and Good Clinical Research Practice and Good Laboratory Practice (25).

4.7 Research methodology

4.7.1 Research design

A prospective, contextual and descriptive study design will be followed in this study.

In a prospective study the data about a presumed cause is first collected and then the effective outcome is measured. These studies usually yield better quality evidence than retrospective studies (26). This study is prospective as the samples will be collected over a period of time until the sample size is realised.

Contextual research influences the implementation of an intervention and thus the outcomes of the study. These include social and environmental setting and individual variables that can influence the intervention and study outcomes (27). The study will be conducted contextually in the OTs of CHBAH.

A descriptive study is designed to gain more information about characteristics within a particular field. It provides an accurate portrayal or account of characteristics of a particular group, individual or situation (28). This study is descriptive as it provides information on the contamination of the hands of HCPs

4.7.2 Study population

The study population will consist of HCPs working in the OTs of CHBAH.

4.7.3 Study sample

Sample method

A convenience sampling method will be used in this study. Convenience sampling consists of entering readily available subjects into the study until the sample size is realised (26).

Sample size

Due to financial constraints 75 samples will be collected for this study to allow an equal number of participants in each of the three groups. A sample size of 75 participants at an expected contamination rate of 80% in all HCPs, with an

average of 65% contamination in literature will give a power of 84% at a significance level of 5% (29-35).

Inclusion and exclusion criteria

The inclusion criterion is all HCPs who consent to participate in the study and the exclusion criterion is HCPs who previously enrolled in the study.

4.7.4 Data collection

In consultation with a microbiologist, a low budget yet high volume process will be used. Agar plates will be used to take specimens for the study. Simple and cheap tests can be applied to large sample sizes, which increases the power to detect differences (26). This form of semi-quantitative analysis is cheaper, requires minimal microbiological analysis and logistical support (27). Data will be collected on isolated days over a one-month period to prevent HCPs changing practices of hand washing during the study period.

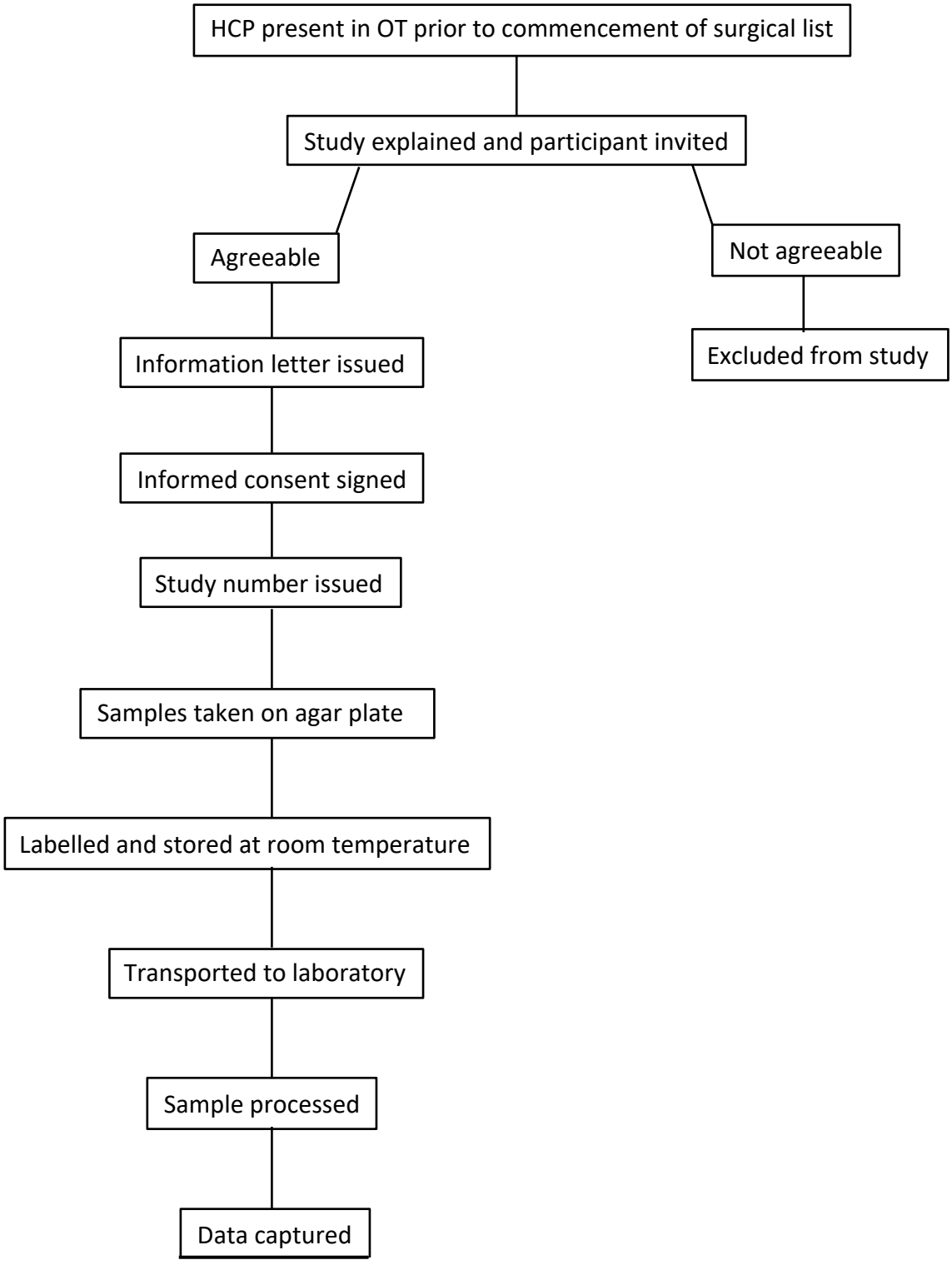
Data collection process

The data will be collected in the OTs at CHBAH. Any HCP present in the OT at the time of data collection will be invited to participate. There will be three groups consisting of anaesthetists, surgeons and nurses with 25 samples being taken from each group.

Agar plating will be done in the morning prior to the commencement of the surgical list. The dominant hand will be used. The collection process will consist of a HCP pressing their fingertips followed by the base of their hand into the agar plate for five seconds each (28, 36-37). The agar plate will then be closed and labelled. Each agar plate will be entered as a separate sample.

The data collection process is summarised in Figure 1.

Figure 1: Data collection process



Sample taking

Samples will be collected by a single researcher. The agar plate will be placed on a clean level surface, then opened and the specimen will be collected. The agar plate will then be closed and labelled.

Sample labelling

A standard request form will be used to enter each specimen's differentiating information**.** The samples will be processed by Vermaak and Partners Pathologists which will be referred to as the study laboratory. The following information will be entered on the laboratory request form:

A standard request form will be used to enter each specimen's differentiating information**.** The samples will be processed by Vermaak and Partners Pathologists which will be referred to as the study laboratory. The following information will be entered on the laboratory request form:

Patient surname: Research

Patient first name: Dr K Pegu

Patient hospital number: This will be the unique study number for each specimen collected e.g. a1/01/01

The first letter will refer to the group that the sample is taken from with "a" referring to an anaesthetist, "s" referring to a surgeon and "n" referring to a nurse. The number following will refer to the chronological order of the specimen taken from that group and will be from 1 – 25.

The second and third number, 01/01, will refer to the date and the month that the sample is taken.

The following standard data will be entered on the request form:

- Hospital/Clinic: CHBAH
- Ward: Theatre
- Diagnosis/Reason for request: Research
- Date taken: dd/mm/yyyy
- Time: hh:mm
- Taken by: Dr K Pegu
- Specimen: Hand swab for microscopy and culture.

Sample storage and transport

The collected samples will require delivery to the study laboratory at Unitas Hospital in Centurion. In the interim, samples collected will be stored at room temperature and then be delivered to the study laboratory at the earliest possible time on the same day by the researcher.

Sample processing

The culture and isolation of bacteria will be performed by trained laboratory personnel using standard microbiological techniques. Samples will be incubated for 48 hours aerobically and the colonies examined, tallied and detailed.

4.8 Data capturing

Data will be captured on an electronic data collection sheet (Appendix 5). The following information will be recorded:

- study number
- sex
- date collected
- laboratory reference number
- bacterial growth
- organisms isolated
- level of contamination

4.8.1 Data analysis

A Microsoft Excel electronic spreadsheet will be used to capture the data. Data will be analysed with descriptive and inferential statistics. GraphPad InStat, will be used for statistical analysis**.** Categorical variables will be described using frequencies and percentages. Comparisons between level of contamination and group (anaesthetist, surgeon, nurse) will be done using 3 x 3 contingency tables, chi square or Fisher's exact test. A p-value of <0.05 will be considered statistically significant.

4.9 Significance of the study

There have been several studies worldwide that have shown that the hands of HCPs are contaminated with a variety of microorganisms, some of which may be pathogenic microbes that could result in morbidity and mortality of patients (14,15, 17, 28). The contamination of hands can increase HAIs thus adding to the financial strain of the healthcare system in the developed and especially in the developing world (28).

By sampling the hands of HCPs contamination can be assessed by isolating organisms and then quantifying the number of CFUs. The study will allow for the description of pathogenic organisms. Identifying and quantifying the contamination of microbes on hands could potentially result in further hand hygiene studies and decrease the transmission of microbes to patients.

4.10 Validity and reliability of the study

Validity indicates whether the conclusions of the study are justified based on the design and interpretation (38). Reliability represents the consistency of the measure achieved (38).

The validity and reliability of this study will be maintained by:

- all sample collections, labelling, storage and transportation being performed by a single researcher using a standardised method
- data entry will be checked
- a single accredited study laboratory will analyse the specimens
- qualified laboratory personnel will process the samples using standard protocols and laboratory equipment
- data analysis will be done in consultation with a biostatistician.

4.11 Potential limitations

Limitations are described as the weakness in a study or the uncontrolled variables (26).

This study will be conducted contextually at CHBAH. The results of this study may not be generalisable to other hospitals as hand hygiene techniques as well as the organisms cultured may be different.

Differentiating between transient and resident flora would require molecular typing of all bacterial strains recovered from the hands of HCPs, the related patient and device contacts. Such a study would require considerable resources which is beyond the scope of this M Med.

Limitation of the funding available restricts the sample size and extent of microorganisms assessed.

The specimen collection will be done over a one month period on isolated days to prevent HCPs from altering their behaviour.

4.12 Project outline

4.12.1 Time frame

Activity	May 2018	Jun 2018	July 2018	Aug 2018	Sept 2018	Oct 2018	Nov 2018	Dec 2018	Jan 2019	Feb 2019
Proposal preparation										
Literature review										
Proposal submission										
Ethics approval										
Postgraduate approval										
Data collection										
Data analysis										
Draft article										
Submission										

4.12.2 Budget

The Department of Anaesthesiology will bear the cost of printing and paper for the proposal, ethics and Graduate Studies Committee application. An application for funding has been submitted to the Jan Pretorius Research Fund but was rejected.

The Department of Anaesthesiology will fund the cost for the cultures. A quote from the study laboratory has been attached (Appendix 6).

Expense	**Price per unit**	**Quantity**	**Cost**
Cultures	R212	75	R15 900
Paper and printing	R1 per copy Proposal 23 pages x 10 copies Ethics 10 pages x 25 copies Post grad application form 1 page x 6 copies Completed research report 100 pages x 4 copies	 230 250 6 400	 R886
Binding	R150	4	R600
Total			**R17 386**

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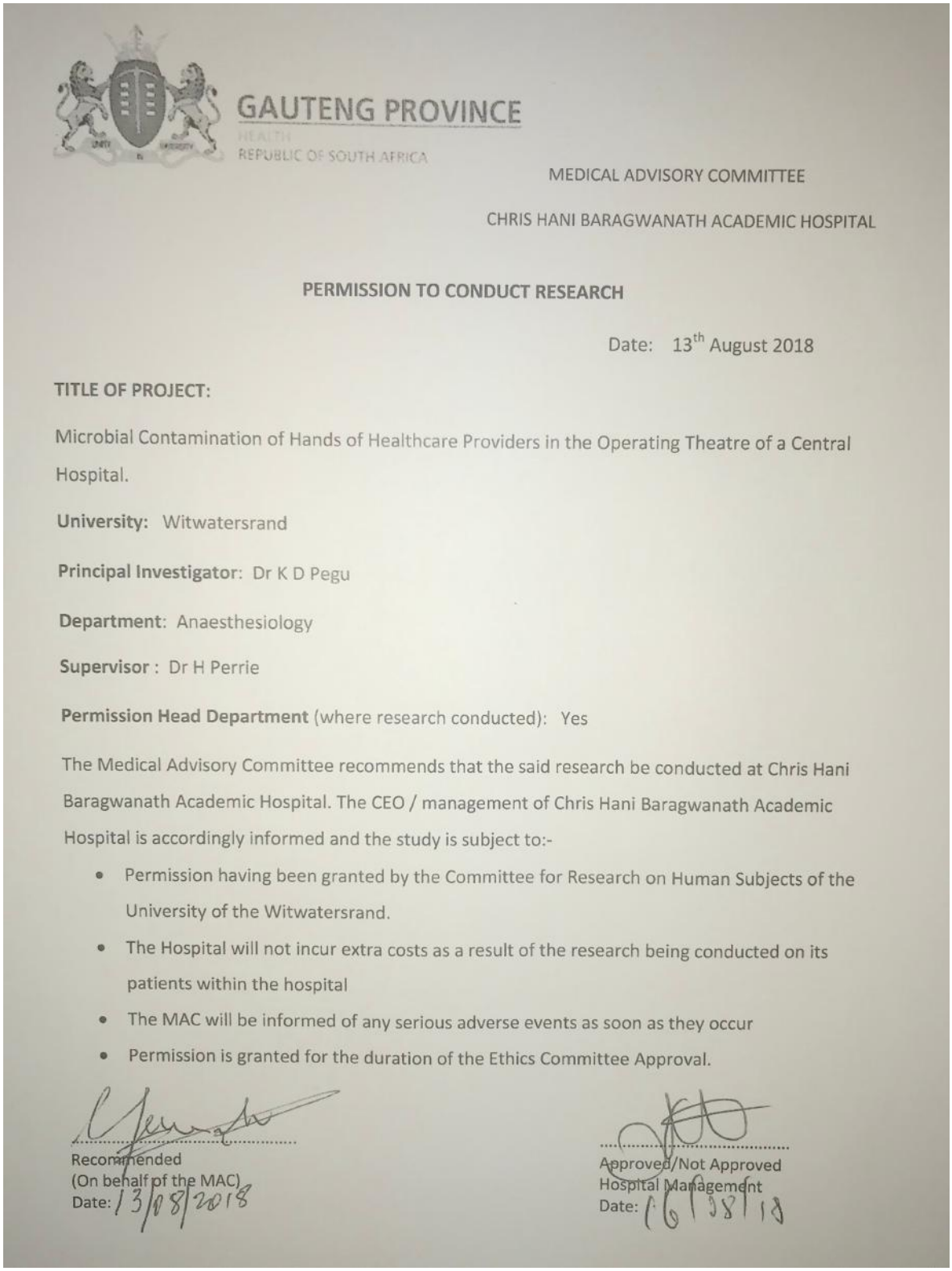
4.14 Appendices

Appendix 1: Permission to conduct research



GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

MEDICAL ADVISORY COMMITTEE

CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL

PERMISSION TO CONDUCT RESEARCH

Date: 13th August 2018

TITLE OF PROJECT:

Microbial Contamination of Hands of Healthcare Providers in the Operating Theatre of a Central Hospital.

University: Witwatersrand

Principal Investigator: Dr K D Pegu

Department: Anaesthesiology

Supervisor : Dr H Perrie

Permission Head Department (where research conducted): Yes

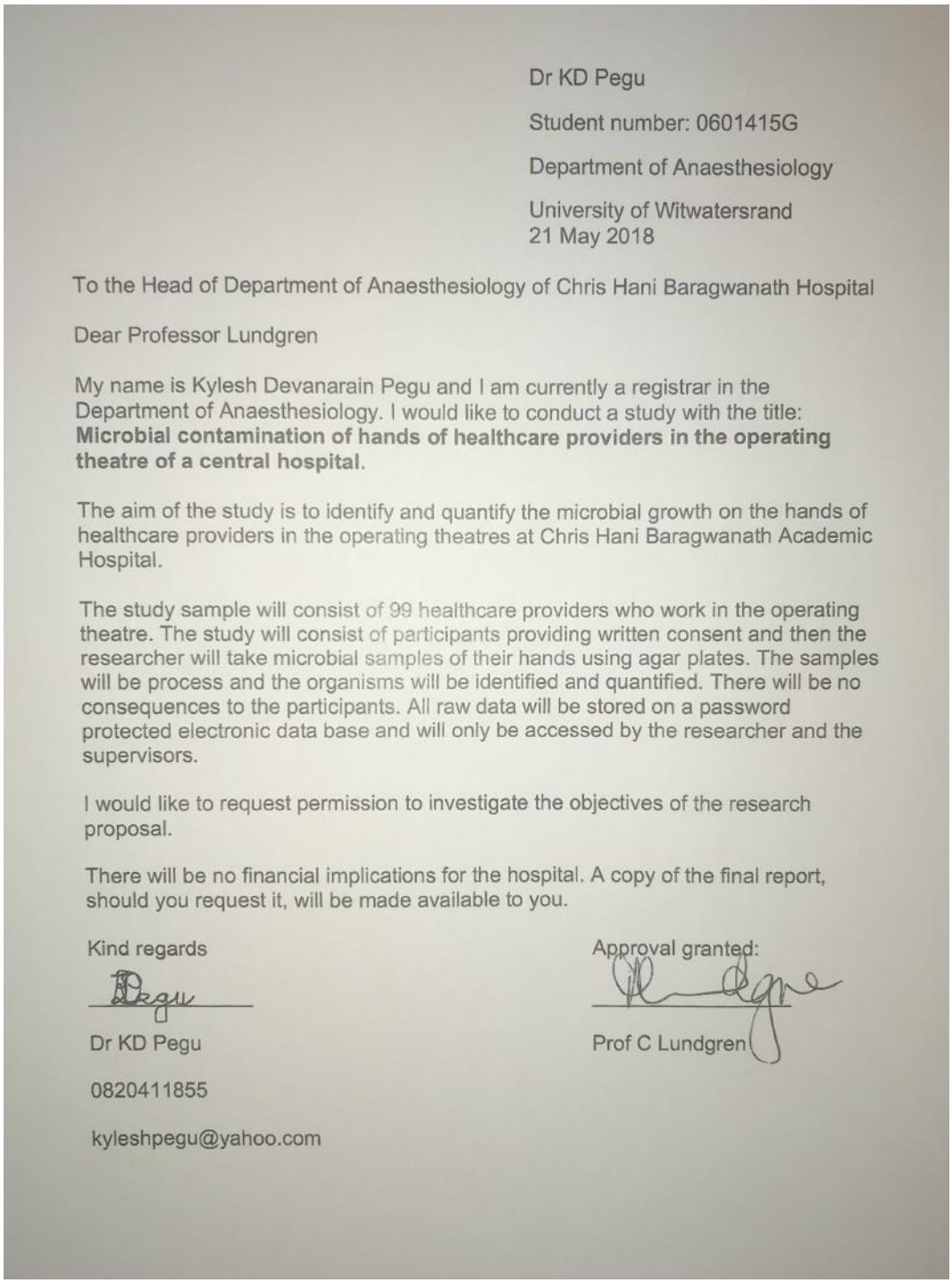
The Medical Advisory Committee recommends that the said research be conducted at Chris Hani Baragwanath Academic Hospital. The CEO / management of Chris Hani Baragwanath Academic Hospital is accordingly informed and the study is subject to:-

- 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: 13/08/2018

Approved/Not Approved
Hospital Management
Date: 16/08/18

Appendix 2: Permission from Head of Department of Anaesthesiology



Dr KD Pegu

Student number: 0601415G

Department of Anaesthesiology

University of Witwatersrand
21 May 2018

To the Head of Department of Anaesthesiology of Chris Hani Baragwanath Hospital

Dear Professor Lundgren

My name is Kylesh Devanarain Pegu and I am currently a registrar in the Department of Anaesthesiology. I would like to conduct a study with the title: **Microbial contamination of hands of healthcare providers in the operating theatre of a central hospital**.

The aim of the study is to identify and quantify the microbial growth on the hands of healthcare providers in the operating theatres at Chris Hani Baragwanath Academic Hospital.

The study sample will consist of 99 healthcare providers who work in the operating theatre. The study will consist of participants providing written consent and then the researcher will take microbial samples of their hands using agar plates. The samples will be process and the organisms will be identified and quantified. There will be no consequences to the participants. All raw data will be stored on a password protected electronic data base and will only be accessed by the researcher and the supervisors.

I would like to request permission to investigate the objectives of the research proposal.

There will be no financial implications for the hospital. A copy of the final report, should you request it, will be made available to you.

Kind regards

Dr KD Pegu

0820411855

kyleshpegu@yahoo.com

Approval granted:

Prof C Lundgren

Appendix 3: Information letter

Dear colleague

Hello, my name is Kylesh Pegu and I am an anaesthetic registrar who is employed by the Department of Anaesthesiology.

I would like to invite you to participate in my research study which is part of my MMed degree. My study is titled: Microbial contamination of hands of healthcare providers in the operating theatre of a central hospital. The aim of the study is to identify and quantify the microbial contamination of the hands of healthcare providers who work in the operating theatre of Chris Hani Baragwanath Academic Hospital.

The study is safe with no risk to the participant. The study will only take a few minutes of your time and I will ask you to first press the fingertips of your dominant hand followed by pressing the heel of your hand on the agar plate for another five seconds.

If you agree to take part in the study, I will ask you to sign a consent form. By signing the consent form, you will give me permission to include you in the study. Consent is entirely voluntary. You can withdraw from the study without any consequences. The microbiological results will also have no consequences for you. You are welcome to ask any questions or provide any feedback.

The study has been approved by the Human Research Ethics Committee and the Graduate Studies Committee at Witwatersrand. Furthermore, permission has been obtained from the hospital management.

Each participant will be assigned a study reference number that will be stored electronically. Should you require access to your results please contact the researcher as participant names with the microbiological result will be stored separately. The results that are published will contain no identifying data.

This will help to create a safer working environment for the patients and staff.

If you have any questions or concerns following this study, you may contact the following persons:

Dr Kylesh Pegu (Researcher): 0820411855

Chairman of Human Rights EC: 011 717 1234

Thank you for taking the time to read this information letter.

_____ ____/____/2019

Kylesh Pegu Date

Appendix 4: Informed consent

I ..... (name) understand the content of the information letter and had the opportunity to ask questions which have been answered to my satisfaction. I understand that taking part in this study is voluntary.

I hereby give consent to take part in the study. The study is titled: Microbial contamination of hands of healthcare providers in the operating theatre of a central hospital. The Principal Investigator is Dr Kylesh Pegu.

.....

(Participant)

.....

(Date)

Appendix 5: Data collection sheet

Sample Information	
Study number	
Sex	
Date collected	
Laboratory reference number	
Microbiological Information	
Bacterial growth	Yes/No
Organism isolated	
Level of contamination	

Appendix 6: Quote from study laboratory

Quote

vermaak and partners

Quote ID	: 101873
Client Name	: Dr Kylesh Pegu
Client ID Number	: 20170920
Client Contact Number	: 20411855
Fund	: PRIVATE PATIENT

Microbiology
Lifestyle Management Park,
Unit 1, Lyttleton
Tel: (012) 644-0891
Fax: (012) 644-0857
Emergency Tel: (071) 687-8857
Pr 0520000047368

Test	Billing Code	Price
Phenotypic Abridged Manual ID	3923	R 71.70
Gram Stain	3867	R 111.20
Bacterial Aerobic Culture *	3893	R 143.20
Total		R 326.10
Total discount		R 114.10
Total after discount		R 212.00

** Test may incur additional charges.*

Payments within 30 days of service date qualify for a discount of 35%.

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): admin@vpath.co.za

Issued By Kleinhans, Vicky (VK) Ms on 2017/09/20 14:40
Skyline 2017/09/20 14:39

Page 1 of 1

Section 5: Annexures

5.1 Ethics approval

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

R14/49 Drs KD Pegu & M Fourtounas & Prof J Scribante

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M180603

NAME: (Principal Investigator)	Drs KD Pegu & M Fourtounas & Prof J Scribante
DEPARTMENT:	School of Clinical Medicine Department of Anaesthesiology Chris Hani Baragwanath Academic Hospital
PROJECT TITLE:	Microbial contamination of the hands of healthcare providers in the operating theatre of a central hospital
DATE CONSIDERED:	29/06/2018
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Ms H Perrie
APPROVED BY:	Professor CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	30/08/2018

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary on 3rd floor, Phillip V Tobias Building, Parktown, University of the Witwatersrand, Johannesburg.
I/We fully understand the conditions under which I am/we are authorised to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated from the research protocol as approved, I/we undertake to resubmit to the Committee. **I agree to submit a yearly progress report**. When a funder requires annual re-certification, the application date will be one year after the date of the meeting when the study was initially reviewed. In this case, the study was initially reviewed in **June** and will therefore reports and re-certification will be due early in the month of **June** each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature _____ Date _____

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

5.2 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

28 August 2018
Person No: 0601415G
PAG

Mr KD Pegu
41 Nicola Crescent
Glenmore
4001
South Africa

Dear Mr Pegu

Master of Medicine: Approval of Title

We have pleasure in advising that your proposal entitled *Microbial contamination of hands of healthcare providers in the operating theatre of a central hospital* 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

5.3 Turnitin report

0601415g:turnitin2.docx

ORIGINALITY REPORT

15%	9%	8%	12%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	journals.lww.com Internet Source	1%
2	Submitted to University of Witwatersrand Student Paper	1%
3	www.wageningenacademic.com Internet Source	1%
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6	Submitted to Napier University Student Paper	1%
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8	Submitted to Central Queensland University Student Paper	1%
9	content.karger.com Internet Source	<1%

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

FACULTY OF HEALTH SCIENCES

25th October, 2019

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

Dear Madam,

Re: M Med: Microbial contamination of hands of healthcare providers in the operating theatre of a central hospital

Dr Kylesh Pegu, student number: 06014115G, has submitted his research report to Turnitin which revealed a similarity index of 15%. 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,

H Perrie

Helen Perrie
Supervisor