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Common hydrotherapy practices and the prevalence of burn wound bacterial colonisation at the University Teaching Hospital in Lusaka, Zambia[☆]

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ABSTRACT

Background: In many parts of the world, hydrotherapy plays an important role in the management of patients with wounds including burns. Different centers practice hydrotherapy differently. At the University Teaching Hospital in Lusaka, Zambia, burn patients use a common bathtub for cleaning their wounds which theoretically increases the risk of cross-infection, an important source of morbidity and mortality. There is currently no evidence that hydrotherapy as practiced at our institution leads to cross infection among patients with burns.

Objective: The objective was to determine if our hydrotherapy practice and water plays a role in cross-infection and what organisms cause this infection.

Methods: This was a prospective analytical study. Patients meeting the selection criteria were recruited. Swabs from the burn wounds were collected on admission (day 0), day 4 and day 7. Weekly swabs of the bathtub were also collected, after the tub had been cleaned and declared ready for the next patient. Weekly water samples were also collected. Selected results, for *Staphylococcus aureus* and *Klebsiella pneumoniae*, were subjected to further analysis and PCR. Results were analyzed using statistics software, SPSS version 23.

Results: In this study, there were 96 participants of which 51 (53.1%) were males and 45 (46.9%) were females. Age distribution ranged from 5 months to 91 years. The modal age range was 1 to 2 years. The modal burn percentage was 6%–10%, followed by 11%–15%. Hot water was the cause of burns in 65.6%. *S. aureus* and *K. pneumoniae* were the most common organisms isolated. Others were enteric organisms. In terms of readily available antibiotics, there was

Abbreviations: CTX-M, cefotaximase; ESBL, Extended Spectrum Beta Lactamases; MIC, minimum inhibitory concentration; MRSA, Methicillin resistant *Staphylococcus aureus*; PCR, Polymerase Chain Reaction; PVL, panton valentine leukocidin; SHV, sulfhydryl variable; SPA, *Staphylococcus aureus* Protein A; TBSA, Total Body Surface Area; TEM, temoneira.

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more sensitivity to Amikacin and Chloramphenicol than Ciprofloxacin (our commonly used antibiotic). The bathtub also had *S. aureus* and *K. pneumoniae*, besides enteric organisms. Sixty five point four percent (65.4%) of the *Klebsiella* were ESBL (Extended Spectrum Beta Lactamase) producers. The tub had samples that were both ESBL producers as well as widely resistant *Klebsiella* by other means. No growth was obtained from the water samples. Seventy-two point nine percent (72.9%) of the patients were discharged, 19.8% died, while 7.3% left against medical advice.

Conclusion: Hydrotherapy as currently practiced at the University Teaching Hospital does contribute significantly to cross-infection among burn patients with widely resistant organisms. The main ones are *S. aureus* and *K. pneumoniae*. Switching care to a shower mechanism might help eliminate this problem as the study demonstrates that no bacteria were found in the water samples.

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1. Introduction

Formerly called hydropathy, hydrotherapy is a part of medicine, in particular of occupational therapy and physiotherapy, that involves the use of water for pain relief and treatment [1]. This treatment utilizes the physical properties of water, especially temperature and pressure [1]. Historically, various forms of hydrotherapy have been recorded in ancient Egyptian, Persian, Greek and Roman civilisations [1].

In today's practice of medicine, hydrotherapy plays an important role in the management of surgical patients, especially burn patients. Hydrotherapy in burns typically involves the washing of patients in a tank, shower or agitating bath [2]. Hydrotherapy is said to promote healing by softening and removing the dead tissue and enabling new healthy tissues to form [3]. In addition, hydrotherapy reduces bacterial load, cleans the surface of the wound and removes debris and helps prevent loss of fluid through the skin thus preventing dehydration [2,3]. Hydrotherapy provides a moist environment for wound healing. It also removes pus and may minimize scar tissue formation [3]. A study by Langschmidt [4] demonstrated that 96% of respondents in the UK routinely

use hydrotherapy in burns, compared to 83.1% from Canadian and American burn centers. In this same study, hydrotherapy is said to assist in the gradual debridement of the burn wound until a healthy bed of granulation tissue is evident, at which point skin grafting can be performed.

Studies have also reported increased risk of hospital acquired cross-infection with the use of hydrotherapy [2,4]. At the University Teaching Hospital in Lusaka, Zambia, burn patients use the same bathing tub for cleaning their wounds (see Figs. 1 and 2). This breaches patient isolation and increases risk of cross-infection. It has been observed that many burn patients develop infection during their hospital stay leading to increased morbidity and mortality.

Cross infection is considered to be of particular concern in burn units. Several studies have attributed outbreaks in burn centers to contaminated hydrotherapy equipment [5–7]. Another study cited tap water as a significant route of transmission in hospital [4]. It suggested that infections and colonization could be significantly reduced by placement of filters onto the water taps. Although studies have concluded that precise route by which patients become colonized remains unclear, modern technologies have identified the role of contaminated hydrotherapy equipment in strain



Figs. 1 and 2 – Hydrotherapy as practiced at the University Teaching Hospital, Lusaka – Zambia. The bathtub is disinfected between uses.

transmission [4]. Similar results were obtained in a study by Reuter et al. that 36%–42% of healthcare associated cases of *Pseudomonas aeruginosa* were due to contaminated water from the tap [8].

Considering the magnitude of the problem, and the way hydrotherapy is practiced at our institution, this study was undertaken to investigate the extent to which hydrotherapy contributed to burn wound colonization and infection. To further characterize the organisms responsible for colonization and infection and determine if they came from the tap water or the hydrotherapy equipment, we characterized the organisms using molecular method, PCR (Polymerase Chain Reaction) and antibiotic sensitivities.

2. Materials and methods

2.1. Study design

This was a prospective analytical study (explained in detail under procedure). The study was conducted in winter (April to September 2015) in the Department of Surgery at the University Teaching Hospital, Lusaka. Patients were recruited upon their first presentation to the hospital in the surgical admission wards. Follow up was done on an in-patient basis in the surgical wards. The target population was all burns patients that satisfied the inclusion criteria.

Inclusion criteria:

- Patients of any age who presented to the hospital with burns and eventually ended up being admitted to the burn unit.
- Children with burns greater than or equal to 10% TBSA (Total Body Surface Area).
- Adults with burns greater than or equal to 15% TBSA.
- Patients with burns to special areas (e.g. face, perineum, hands, feet, joints).
- Patients giving informed consent i.e. either the patient consenting or consent obtained from patient's legal guardian.

Exclusion criteria:

- Admitted for a short duration of less than four days (i.e. those admitted just to be taught how to clean the wounds).
- Any patients not meeting the above inclusion criteria.

2.2. Procedure

Patients that presented with burns meeting the inclusion criteria were recruited. A history was obtained, followed by clinical examination to determine percentage TBSA and the location of the burn wounds. Data was collected using a data collection sheet. Enrollment was then determined by the inclusion/exclusion criteria. After proper patient (or parent) counseling, all patients (or parents) were required to sign a written informed consent. Swabs of the burns wounds were collected in the surgical admission wards, to mark day 0 swabs. Follow up swabs were collected on day 4 and day 7 from the patients' respective burn wounds to mark day 4 and day 7 swabs. Weekly swabs of the hydrotherapy equipment (the bathtubs in this case) and tap water were obtained. Swabs from the tubs were collected after the tubs had been cleaned and disinfected with hypochlorite solution (3.5% sodium hypochlorite, sold under commercial name of Jik), and thus were declared ready for use by the next patient. Selected samples of culture results, for *Staphylococcus aureus* and *K. pneumoniae*, were subjected to PCR, to determine possible similarities to cultures from the hydrotherapy equipment. Results were analysed using SPSS version 23.

Collection, storage and processing of samples for microscopy, culture and sensitivity (m/c/s), and for PCR was done according to the Standard Operating Procedures for Hospital Laboratories Level III, of the Ministry of Health, Republic of Zambia.

3. Results

This study enrolled 96 patients, all of them fulfilling the inclusion criteria. Of the 96 participants, 53.1% (n=51) were males while 46.9% (n=45) were females. Thus the ratio of male to female participants was nearly 1:1. The age distribution of the participants ranged from 5 months to 91 years. Thirty-seven of the participants (38.5%) were 2 years old or below. Almost all patients presented to hospital the same day they sustained the burns. Also, no form of first-aid was given before arriving at the hospital, except in very few cases where rehydration was started at the local clinic.

The organisms analyzed in this section were *S. aureus*, *K. pneumoniae* and *P. aeruginosa*. *Staphylococcus* and *Klebsiella* happened to be the most common organisms that were isolated from the burn wounds and the bathtubs. The enteric

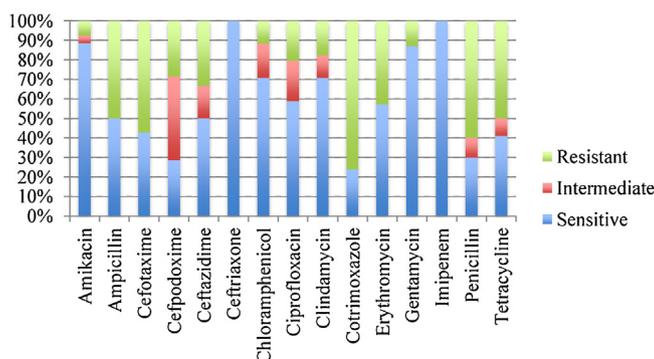


Fig. 3 – Day 0 sensitivity pattern for *Staphylococcus aureus*.

organisms are not included in this section as they are considered to have been due to faecal contamination of the wounds and the bathtubs. The following are the enteric organisms that have not been included in the analysis: *Citrobacter diversus*, *Citrobacter freundii*, *Enterobacter aerogenes*, *Enterobacter agglomerans*, *Enterobacter cloacae*, *Escherichia coli* and *Serratia marcescens*.

3.1. Day 0 (admission day) results

The prevalence of culture positive swabs was 88.5%. No growth was obtained from the water samples.

3.1.1. Fig. 3 — *S. aureus*

Sensitivity pattern of the *S. aureus* that was isolated on admission day.

A similar pattern was observed for *K. pneumoniae*, but there was more sensitivity to most of the antibiotics.

3.2. Day 4 results

The prevalence of culture positive swabs on day 4 was 98.9%. Again, no growth was obtained from the water samples. However, cultures were now positive for *P. aeruginosa*.

3.2.1. *K. pneumoniae*

The figure below (Fig. 4) shows the sensitivity pattern of the *K. pneumoniae* that was isolated from patients on day 4.

Of note is that there was increasing resistance to the antibiotics. This similar pattern was observed for *S. aureus*. The *Pseudomonas* isolated on day 4 also had some significant resistance to the available antibiotics.

3.3. Day 7 results

The prevalence of culture positive swabs on day 7 was 97.50%. Like before, no growth was obtained from the water samples (Fig. 4).

3.3.1. *K. pneumoniae*

The figure below (Fig. 5) shows the sensitivity pattern of the *K. pneumoniae* that was isolated from patients on day 7 of their admission to hospital.

It was noted that with the progression of days on the burns unit, the organisms became more resistant towards the

antibiotics. This was the case with *Staphylococcus* and *Pseudomonas*.

3.4. Bathtub results

As was the case with cultures from the patients, the most common organisms were *S. aureus*, *K. pneumoniae* and the enteric organisms. All these organisms isolated were more resistant to antibiotics than the ones that were isolated from the patients. Organisms cultured from the bathtubs were more resistant than those from patients' wounds.

3.5. Molecular work on *S. aureus* and *K. pneumoniae*

This was done to detect the genes that were responsible for the resistance in the *S. aureus* and *K. pneumoniae*. For *Staphylococcus aureus*, testing was done for MRSA, and PVL and SPA genes. For *Klebsiella pneumoniae*, testing was done for TEM, SHV and CTX genes. These genes were selected based on previous prevailing microbiology results (Figs. 6 and 7).

4. Discussion

Several organisms were isolated from the patients and the bathtubs. A similarity was noted between those from the patients and those from the bathtubs. Also, there were quite a number of organisms isolated from both patients and bathtubs that were thought to be due to wound or tub contamination. These were the enteric organisms. The enteric organisms that were isolated from both the patients and bathtubs are: *C. diversus*, *C. freundii*, *E. aerogenes*, *E. agglomerans*, *E. cloacae*, *E. coli* and *S. marcescens*. The other organisms isolated that were not enteric in origin were *S. aureus*, *K. pneumoniae* and *P. aeruginosa*. The idea that enteric organisms were contaminants is the main reason why only the other three were analysed in detail. The other reason was due to resource limitation.

This study was conducted in the winter season, April to September 2015. During the winter season, the turnover rate of patients in the burn ward is quite high. This is because the incidences of burns tend to go up. More than 50% of the participants were under 5 years old. This was in agreement with what has been observed in the department. It is also in line with what was reported in a systematic review done by

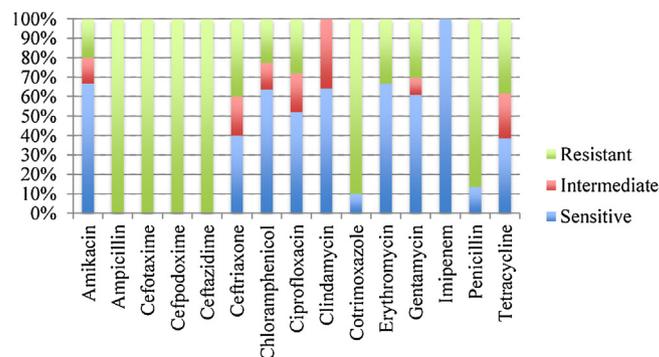


Fig. 4 – Day 4 sensitivity pattern for *Klebsiella pneumoniae*.

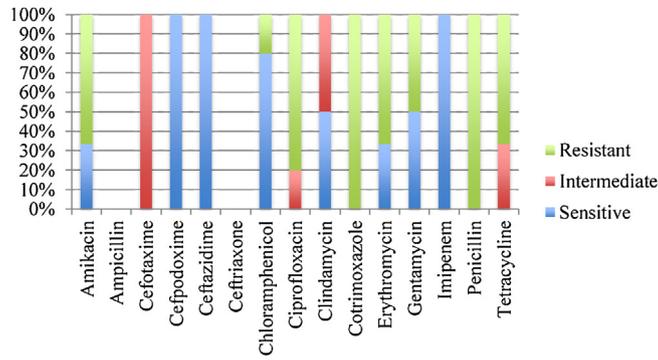


Fig. 5 – Day 7 sensitivity pattern for *Klebsiella pneumoniae*.

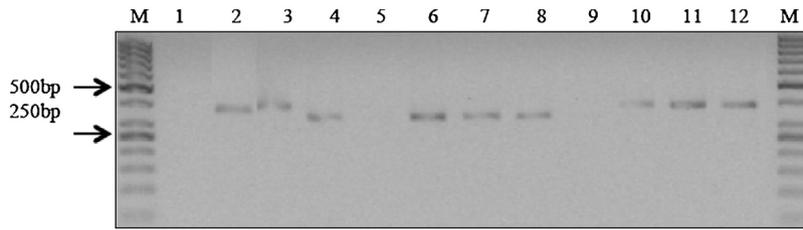


Fig. 6 – Spa typing gel picture of controls and selected samples. M: 50bp marker; Lane 1: Negative control; Lane 2: Positive control; Lane 3-12: Selected samples.

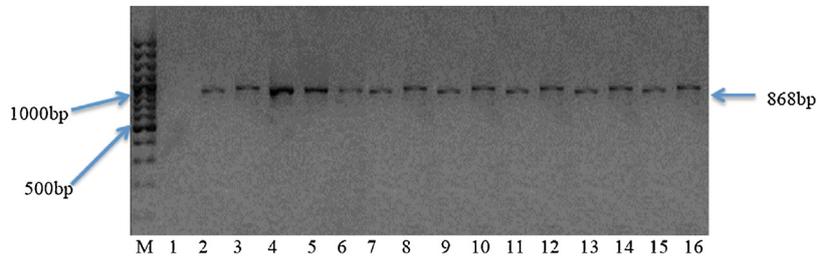


Fig. 7 – PCR detection of *Bla_{SHV}* ESBL genes. Lane M: 100bp DNA Marker; Lane 1: Negative control; Lane 2: ATCC Positive control, Lanes 3 to 16: Isolates Positive for *Bla_{SHV}* gene.

Zou [9]. In trying to keep warm, children as well as adults, want to stay near a source of heat. Sometimes a brazier or heater is left on while people have fallen asleep. Bathing water is also warm to hot. As such, accidents from fires and scalds are very likely to happen during the cold season. Due to the high turnover, patients were usually discharged early from the burns wards to create space for others. As such, not all of them had their day 7 swabs taken. The main criteria for discharge was a clean wound (clinically), absence of fever, and caretakers that had learned how to take care of the wound. The observation made in this study was that the wounds that appeared clean clinically actually harbored *K. pneumoniae* (some of which were ESBL producers) and *S. aureus* (some of which was MRSA, PVL or SPA genes positive).

Most of the swabs collected from patients yielded positive results. On day 0 (admission day), 88.5% of the swabs were positive. The prevalence of culture positive swabs on days 4 and 7 were 98.9% and 97.5%, respectively. Another observation that was made on analyzing the three organisms isolated from the patients was that their resistance to antibiotics tended to increase as the patient stayed longer in hospital i.e.

Staphylococcus isolated on day 4 was more sensitive to most antibiotics compared to the *Staphylococcus* that was isolated on day 7 of admission. This was equally true for *Klebsiella* and *Pseudomonas*. This observation agrees with Rafla and Tredget [7]. In their review, they state that the patient is initially infected with gram-positive organisms, which are rapidly replaced by antibiotic-susceptible gram-negative organisms. The antibiotic-susceptible gram-negative organisms are then later replaced by those that are antibiotic-resistant. The source of the organisms could be from poorly decontaminated equipment. Relating the above statements to our study, we could notice that the bacteria isolated on admission was more sensitive than the one isolated on day 4 or day 7. It indicates that the more resistant bacteria must have replaced the antibiotic-susceptible ones. The bathtubs had organisms that were more resistant to antibiotics. It is highly likely that this could have been the main source of the antibiotic-resistant organisms. However, in this study, there was no yeast that was isolated. In our environment, the commonly used antibiotic was Ciprofloxacin, both oral and parenteral. Others were the cephalosporins and penicillins.

Table 1 – Frequency of *Staphylococcus aureus* isolated.

<i>Staphylococcus aureus</i>		
<i>Staphylococcus</i>	No. of isolates	Frequency (%)
MRSA	26	30.6
PVLgene	10	11.8
SPA gene	30	35.3
Others	19	22.3
Total	85	100

Table 2 – Frequency of *Klebsiella pneumoniae* isolates with genes encoding ESBL production.

<i>Klebsiella pneumoniae</i>		
Bla gene	No. of isolates	Frequency (%)
Bla _{TEM}	4	23.5
Bla _{SHV}	5	29.4
Bla _{TEM} and; Bla _{SHV}	8	47.1
Total	17	100

The *Klebsiella* that was isolated, both from the patients and bathtubs, was tested further for the presence of ESBL genes (Table 2). Sixty-five point four percent (65.4%) tested positive for the ESBL genes. Among those with ESBL genes, 29.4% had the SHV gene only while 23.5% had the TEM gene only. The majority of them (47.1%) had both SHV and TEM genes. There was no CTX gene that was detected. There was none of the three genes detected in 34.6% of the *Klebsiella*. Yet a good number of them showed wide resistance against most of the antibiotics tested. This implied that they could have had other genes besides the SHV, TEM and CTX that were responsible for their resistance.

The presence of ESBL producers in our burns unit with such a high prevalence of culture-positive swabs is of very serious concern. Rupp and Fey discuss this in their review on ESBL enterobacteriaceae [9]. Our study yielded a number of enteric bacteria, both from the patients as well as the tubs. Enteric organisms are known to exchange resistance genes. This is a very high possibility in our burn unit. Frequently, a single strain or a genetically related group of strains expand clinically in an institution. Endemic strains have been shown to persist in certain units for years. The current recommendation is that any organism found to produce an ESBL be regarded as resistant to all extended spectrum beta-lactam antibacterials regardless of the in vitro minimum inhibitory concentration (MIC) results [9]. This now puts us in a serious dilemma due to the limited choice of antibiotics we have as readily available. Most of our patients are prescribed Ciprofloxacin (a fluoroquinolone), but as can be seen in the above figures, it is not as effective as other antibiotics. Mark and Paul [10] showed that treatment with fluoroquinolones is a risk factor for isolation of ESBL-producing *Klebsiella* species in hospitalized patients. An important aspect that has not been considered is the impact that these organisms are having on the community out there. This is because (as pointed out earlier) some of the patients were discharged early, yet their wounds had positive swabs for ESBLs and had not been grafted.

S. aureus was the other organism isolated from both the patients and bathtubs. MRSA accounted for 30.6% of the *Staphylococcus*. PCR was also done to detect the presence of PVL (Panton-Valentine Leukocidin) and SPA (*S. aureus* Protein A) genes (Table 1). It was noted that 11.8% had the PVL gene, 35.3% had the SPA gene and 5.9% had both PVL and SPA genes. The PVL gene is a potent cytotoxin with important virulence in *S. aureus* [11]. It is said to cause tissue necrosis, selectively disrupts leukocyte membranes thus leading to enhanced virulence [11]. PVL-carrying *S. aureus* strains have been known to cause serious skin and soft tissue infections and life threatening invasive diseases such as necrotizing fasciitis, purpura fulminans and necrotising haemorrhagic pneumonia (of which upto 75% of cases is lethal) [11]. Our departmental records indicate that pneumonia was a cause of death in 18.5% of the deaths in burns patients in 2012. The above explanation gives an insight of the pathogenesis.

This research did not yield any growth from the water cultures. The significance is that if the bathtubs were replaced with alternative treatments such as showers, there would likely be a significant reduction in cross contamination and bacterial wound colonization and infection. A proposed format of such a shower is a simple one, but able to accommodate both ambulant and bed-ridden patients. A shower trolley or stretcher draped with sterilized, disposable plastic sheets can be used to reduce the risk of contamination that can cause infection [3]. Those that are able to sit can be showered while they are seated in a chair [3]. Though simple, it definitely would go a long way in reducing the morbidities and mortalities in the burns patients. It would also improve their quality of life.

5. Conclusion

Hydrotherapy as practiced at the University Teaching Hospital in Lusaka, Zambia does contribute significantly to burn wound bacterial colonization and later infection leading to sepsis in burns patients. The main hydrotherapy equipment (in this case the bathtubs) does act as a reservoir of organisms and a place at which cross infection between patients may take place. A number of resistant organisms are present in these bathtubs. The main ones are *S. aureus* and *K. pneumoniae*. The organisms exchange resistant genes in the bathtubs hence posing a challenge to treatment of infection in burns patients. The decontamination that is done to the bathtubs cannot stop this from happening, as has been shown in this research.

Conflict of interests

There was no conflict of interests.

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