

Contamination patterns of the neonatal equipment, major microorganisms, and effectiveness of disinfection procedures including refurbished UV C lights at the University Teaching Hospital of Butare (CHUB)

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Abstract



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A contaminated environment plays a significant role in transmitting hospital-acquired infections (HAIs) but regular chemical disinfection is the backbone for tackling this chain of transmission and the combination of both UV lights may increase the effectiveness of cleaning. This study assessed the effectiveness of chemical disinfection, with and without additional UV light exposure, in reducing bacterial contamination in a Neonatal unit. Therefore, interventions consisted of usual chemical disinfection with and without a 2-hour exposure to Ultraviolet light from refurbished UV lamps. Researchers swabbed high-touch surfaces and equipment before and after disinfection to identify bacterial presence. They found that 36.4% of the sampled sites showed bacterial growth, with the nursing trolley being the most contaminated. The most common bacteria isolated was *Klebsiella pneumoniae* (50%), which, along with other bacteria, displayed high resistance to commonly used antibiotics like Amoxicillin + Clavulanic acid and Cefuroxime. Only Meropenem and Amikacin remained effective. The study concludes that despite chemical disinfection, bacterial contamination remains significant, and conventional UV light alone did not completely eradicate bacteria, highlighting the need for more effective disinfection strategies.

Keywords: Neonatology Service, University Teaching Hospital of Butare (CHUB), hospital-acquired infections (HAIs), disinfection

1. BACKGROUND

Healthcare-associated infections constitute an important public threat owing to their increasing incidence and associated mortality¹. A contaminated environment plays a significant role in transmitting hospital-acquired infections (HAIs). Infections may be transmitted manually by the healthcare providers, and caretakers or acquired through direct contact of the patient with contaminated areas. Regular chemical disinfection is the backbone for tackling this chain of transmission with a special focus on high-touch surface areas. However, this may fail in some circumstances and infections may still occur despite a relatively appropriate disinfection².

Although experts agree that careful cleaning and disinfection of environmental surfaces are essential to effective infection prevention programs, traditional manual cleaning and disinfection practices in hospitals are often suboptimal. Failure to follow the manufacturer's recommendations for disinfectant use and the lack of antimicrobial activity of some disinfectants against healthcare-associated pathogens may affect the efficacy of disinfection practices³.

Also, there are still ways for transmission of infection from patients to patients; from patients to healthcare providers, and *vice versa*. The transmission can also happen from the environment to patients through inappropriately sterilized or disinfected devices. Therefore, care providers; laboratory staff and caretakers should be equipped and regularly updated with sufficient knowledge pertaining to the available techniques for prevention of that spread of pathogens⁴.

Different chemical products are available for disinfection but quaternary ammonium-based products are more effective than alcohol-based products for example and standardized protocols coupled with regular cleaning and training healthcare professionals may substantially decrease HAIs⁵. Chemical disinfection coupled with ultraviolet light exposure may decrease further the rates of hospital-acquired infections and the effectiveness of this technique may be as high as 95-99% in the elimination of hospital pathogens from touch points exposed to UV-C⁶. A portable UV light exposure on short term is also effective in eliminating infective pathogens as far as pre-cleaning with chemical products and effective removal of bacterial biofilm on surface have been operated⁷.

Hospital-acquired infections with high rates of antimicrobial drug resistance are a major concern in Rwandan hospitals⁶.

In Paediatrics, the incidence of HAIs has been estimated at more 12% at University Teaching Hospital of Butare, CHUB⁸. The question that one can ask is whether any single efficient disinfection method can be used or combined methods may outweigh a single disinfection method. We conducted this study to evaluate the relative effectiveness of disinfection by refurbished UV-C light on pathogens' clearance through exposure of potentially contaminated surface areas and neonatal apparatus in comparison with usual chemical disinfection or a combination of both methods.

2. PATIENTS AND METHODS

2.1. Study design and procedures

This was a pre and post-intervention evaluation study during which we have evaluated the efficacy in clearance of pathogens from high-touch surface areas, high-touch objects and equipment in Neonatal unit of Paediatric Department at CHUB. Interventions consisted in usual chemical disinfection with and without a 2-hours long exposure to UV light from 3 refurbished lamps collected from Microbiology laboratory for tuberculosis. Samples were taken prior to any disinfection process to identify the presence of bacterial contamination or colonization on the same day as the intervention.

This was done on scheduled days for routine disinfection within the Neonatal Unit and different equipment, high-touch objects and surface areas or tables generally used in the unit on daily basis for patient care were gathered together in a room around a tripod light made of 3 UV C tube lamps distant by 120 degrees to make a 360° lighting zone. The exposure of those high-touch objects, surface and equipment lasted for 2 hours and all objects were at a range of 0-100cm of radius from the light source.

After the initial sampling, the sites of sample collection were marked and the usual cleaning protocol using N-3-aminopropyl-N-dodecylpropane-1,3-diamine dedecyldimethylammonium chloride (SURFANIOS), all objects and equipment were kept in the same place as prior to the disinfection. Once the chemical disinfection achieved and room ready to be re-opened for use the second sampling was done then an exposure to UV C light was performed for 2 hours while objects and equipment remains in the same places around the light from a radius of 50 cm, 100cm, 150cm from the centre where the tripod light stands.

Immediately after the first chemical disinfection, sampling for bacterial detection was operated on the same surface, objects and equipment as exactly it has been done before the disinfection. Similarly, the same sampling was operated after 2 hours of UV C light exposure.

2.2. Microbiological sampling and culture

Sampling was operated by swabbing on surface of the specified points on the object, equipment or surface by using sterile cotton swabs and specimens were immediately dipped into 5 ml of sterile Brain Heart Infusion (BHI) broth for 8-12 hours of incubation at 36°C. If there is any turbid look in BHI broth, Gram staining was performed to identify the type of the bacteria in the sample.

Samples without turbid reaction were incubated again for additional 12 hours and a Gram staining procedure was performed after that period. In case there is no bacteria growth identified by the Gram staining, the samples were reported as sterile sample or without bacteria growth.

Samples with the presence of bacteria on Gram staining were inoculated on Mac Conkey solid media if they are Gram-negative or on Blood agar media for those exhibiting growth of Gram-positive bacteria. For each individual culture-positive sample, antimicrobial drug sensitivity test (Antibiogram) was done with disk diffusion method (Kirby-Bauer method) on samples with significant bacteria growth by using CLSI guidelines⁹.

We used biochemical reactions including Catalase, Coagulase test, Oxidase test, and API 20 E for further identification of the bacteria¹⁰.

To differentiate tubes with materials collected before disinfection from those after disinfection and UVC light exposure, tubes were respectively labeled as A, B and C respectively prior to sample collection.

On the next scheduled disinfection, surface areas, equipment and objects were exposed to UV C light after initial sampling for 2 hours. Another sampling was made, and then we proceeded with chemical disinfection as described above. A post-chemical disinfection was also made. All samples underwent laboratory analysis as described above.

2.3. Statistical analysis

The overall number of sites per samples was equal and the bacterial growth rates were expressed in numbers over the total number of sampled sites before disinfection, after the initial disinfection and the second accordingly.

Number and types samples with microorganisms' growth were compared between periods of disinfection time (before, after chemical and after UV light) by using descriptive statistics.

Tables and figures were used to show the proportions of positive sites at each collection time (disinfection period) using Excel software.

2.4. Ethical clearance

Chemical disinfection and UV C light exposure were operated when all rooms of Neonatal Unit were closed for scheduled disinfection. No patients, caretakers or healthcare professionals were allowed to enter into the room during the disinfection. The Nurse in charge of switching on/off the UV C lights was wearing the UV ray ban/sun glasses before entering in the room for that purpose and did stayed over 60 seconds in the room. All rooms and windows were tightly closed and curtains used during the disinfection.

The Ethical Committee of CHUB approved the study and informed consent was waived, as the research did not involve any animal or human being.

3. RESULTS

Samples for bacteriological analyses were collected from 44 unique surface points on 15 different equipment used in Neonatology for patient care before cleaning and chemical disinfection with SURFANIOS and the same 44 surface points were sampled after the chemical disinfection.

3.1. Efficacy of chemical disinfection with Sulfanios

All samples were cultured and results read for identification of bacterial species that may have grown. From the 44 site points sampled prior to cleaning and disinfection, 16 (36.4%) have shown bacterial growths (Table 1).

Table 1. Bacterial growth before and after chemical disinfection

Items	N	Before disinfection		After chemical disinfection	
		Bacterial growth	No growth	Bacterial growth	No growth
Nursing trolley	6	4	2	0	6
Incubator	7	2	5	0	7
Cupboard	3	2	1	0	3
Fridge	1	0	1	0	1
Weighing scale	2	1	1	0	2
Alcohol dispenser	1	0	1	0	1
O2 flowmeter	3	0	3	0	3
KMC Chair	4	1	3	0	4
Cribs	5	2	3	0	5
Table	3	2	1	0	3
Phototherapy	5	0	5	0	5
Dust bin	1	0	1	0	1
Syringe pump	1	0	1	0	1
Patient's monitor	1	1	0	0	1
CPAP machine	1	1	0	0	1
TOTAL	44	16	28	0	44

O2:Oxygen; KMC: Kangaroo Mother Care; CPAP: Continuous Positive Airway Pressure

The nursing trolley, the cupboard and workstation stable exhibited the highest rates of bacterial contamination and growth with respectively 4 out of 6 samples, 2 out of 3 and 2 out of 3 samples turning positive.

After the chemical disinfection, no single bacterial growth was observed (Table 1)

3.2. Commonly isolated bacteria species on surface areas in Neonatology

The most commonly isolated bacteria were *Klebsiella pneumonia* isolated in 8 of the 16 growths (50%; Table 2).

3.3. Efficacy of refurbished UV C lights

On a second sampling prior to the cleaning and disinfection, 10 samples out of 44 (22.7%) also showed bacterial growth.

Treatment with conventional UV light did not completely eradicate the bacterial contamination except in once case on KMC chair (Table 3).

Table 2: Bacteria species isolate after culture before any disinfection

Isolate	Number
<i>Klebsiella pneumonia</i>	8
<i>E. coli</i>	4
<i>Acinetobacter species</i>	3
<i>Klebsiella oxytoca</i>	1
Total	16

Table 3. Bacterial growth before and after chemical disinfection

Items	N	Before cleaning		After exposure to UV C light	
		Growth	No growth	Growth	No growth
Nursing trolley	6	3	3	3	3
Incubator	7	0	7	0	7
Cupboard	3	0	3	0	3
Fridge	1	1	0	1	0
Weighing scale	2	1	1	1	1
Alcohol dispenser	1	0	1	0	1
Oxygen flowmeter	3	0	3	0	3
KMC chair	4	3	1	2	2
Crib	5	1	4	1	4
Table	3	0	3	0	3
Phototherapy	5	0	5	0	5
Dust bin	1	0	1	0	1
Syringe pump	1	1	0	1	0
Patient's monitor	1	0	1	0	1
CPAP machine	1	0	1	0	1
TOTAL	44	10	34	9	35

On this sampling, *K. pneumoniae* was again the mostly isolated representing 50% of all isolates (Table 4).

Table 4: Bacteria species isolate after culture before any disinfection

Isolate	Number
1. <i>Klebsiella pneumonia</i>	5
2. <i>E.coli</i>	2
3. <i>Serratia mercenses</i>	1
4. <i>Pseudomonas aeruginosa</i>	2
Total	10

3.4. Sensitivity of isolated microorganisms to antimicrobial drug

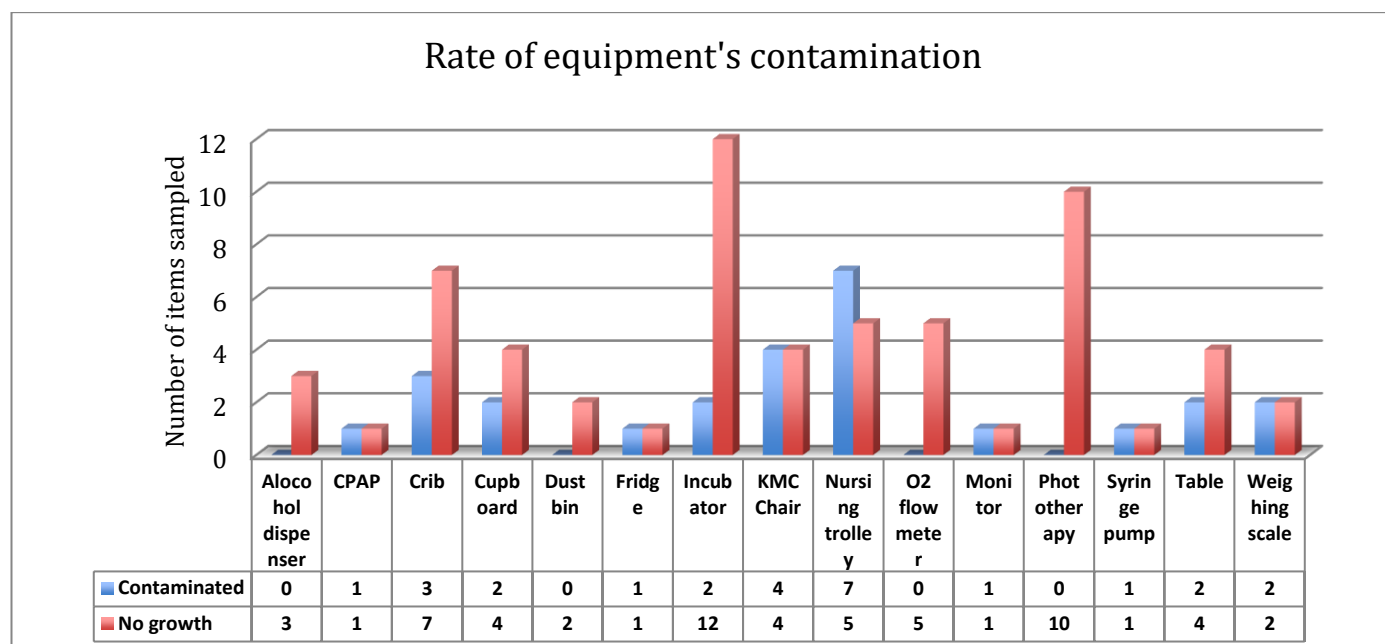


Figure 1: Rates of bacterial growth per type of surface area sampled

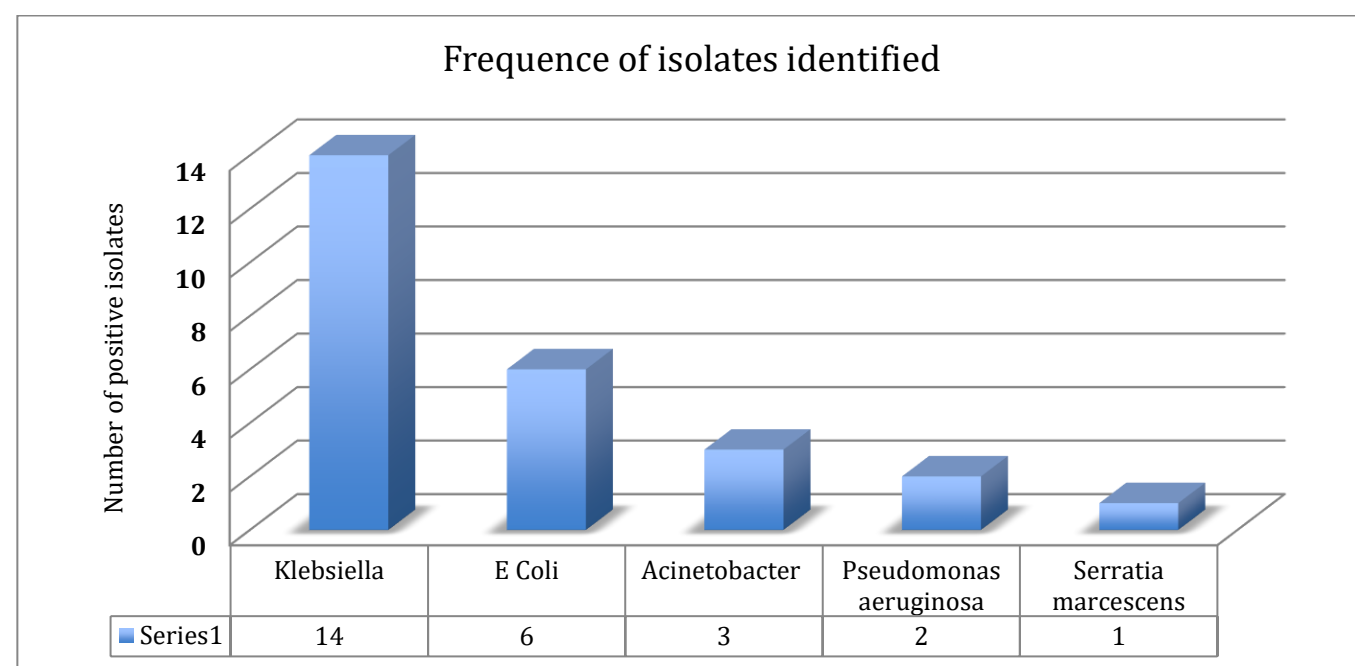


Figure 2: Frequency of isolates identified on both batches of samples taken

In total, 88 samples were collected in 2 batches and of them, 26 (29.5%) samples were cultured and turned positive. The most frequently isolated bacteria were *Klebsiella species* (n=14, 54 %) and *Escherichia coli* (n=6, 23%).

Table 5. Sensitivity of isolated bacteria to tested antibiotics

Antibiotic Microorganism	CXT	AM+CL	CIP	ME	GEN	CEF	LE	AMK
<i>K pneumonia</i>	12R/13 92% R	14R/14 100%R	4R/13 31%R	S	12R/12 100%R	12R/12 100%R	12R/12 100%R	S
<i>E Coli</i>	3R/3 100%R	5R/6 83%R	2R/6 33%R	S	5R/6 83%R	5/6R 83%R	5R/6 83%R	S
<i>Serratia Mercenses</i>	S	S	S	S	S	S	S	S
<i>Acinetobacter spp</i>	1R/2 50%R	1R/2 50%R	1R/3 34%R	S	2R/3 66%R	2R/3 66%R	2R/3 66%R	S
<i>Pseudomonas species</i>	2R/2 50%	-	2R/2 50%	S	2R/2 50%	2R/2 50%	2R/2 50%	S

CXT: Cefotaxime, AM+CL: Amoxicilline Clavulanic acid, CIP:Ciprofloxacin, ME:Meropenem, GEN:Gentamycin, SXT:Sulfamethaxazole trimetoprim, CEF:Cefuroxime, LE:Levofloxacin, AMK:Amikacin

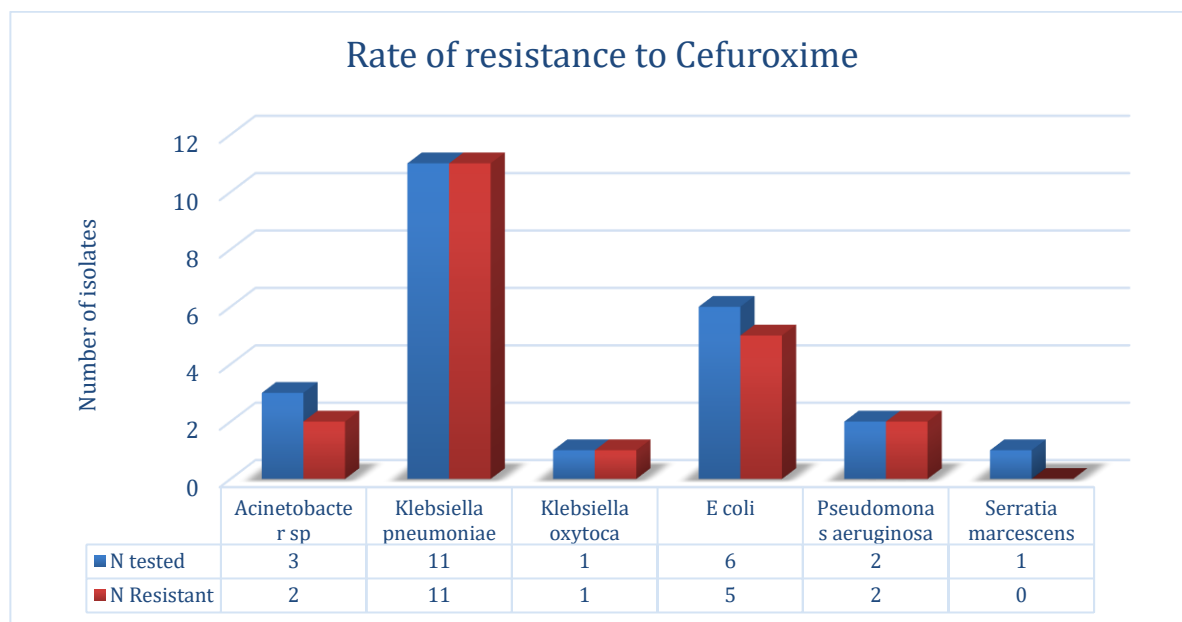


Figure 3.1: Sensitivity of isolated bacteria to Cefuroxime

Klebsiella species, *Acinetobacter* species were 100% resistant to Cefuroxime and 83.3% of *Escherichia coli* were resistant to this antibiotic.

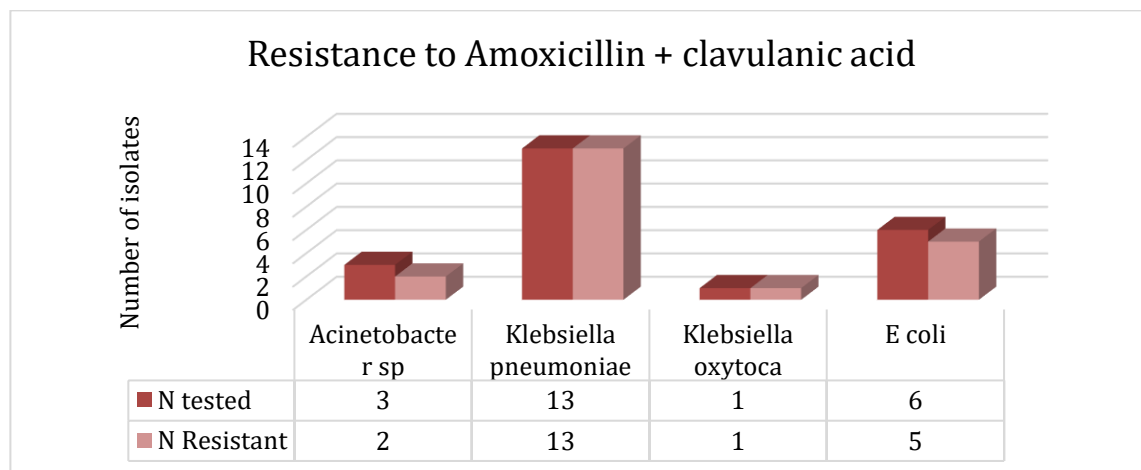


Figure 3.2: Sensitivity of isolated bacteria to Amoxicillin+Clavulanic acid

Klebsiella species was 100% resistant to Amoxicillin +clavulanic acid also and *E. coli* behaved similarly as for Cefuroxime

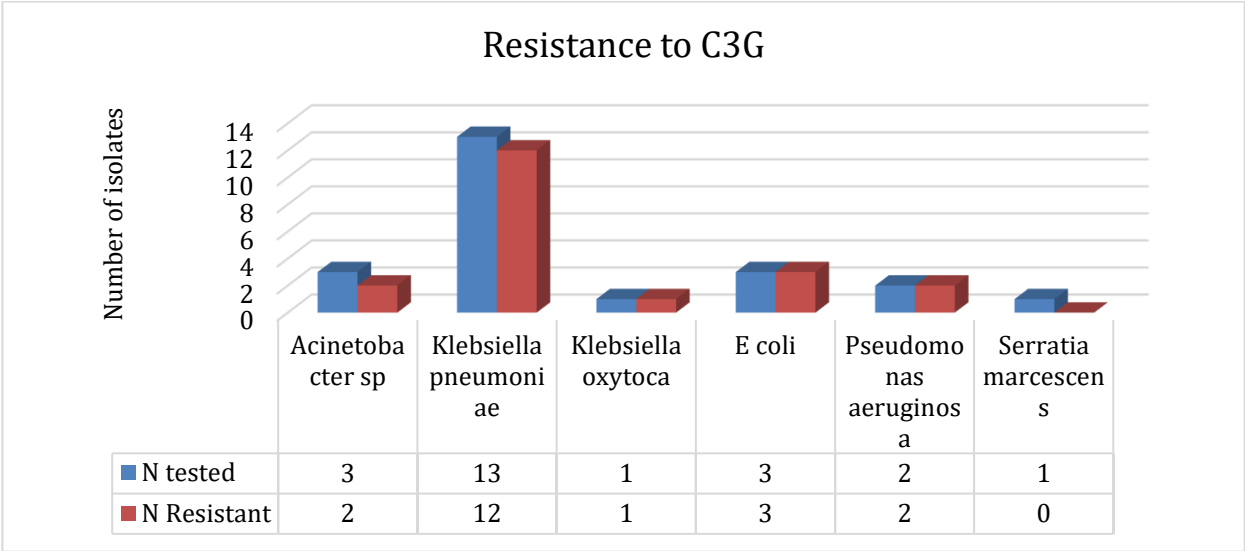


Figure 3.3: Sensitivity of isolated bacteria to third generation Cephalosporins (Cefotaxime and Ceftriaxone)

All isolated strains of *E. coli* and *Pseudomonas aeruginosa* were resistant to the third-generation cephalosporin while this rate of resistant was of 94% for *Klebsiella* species

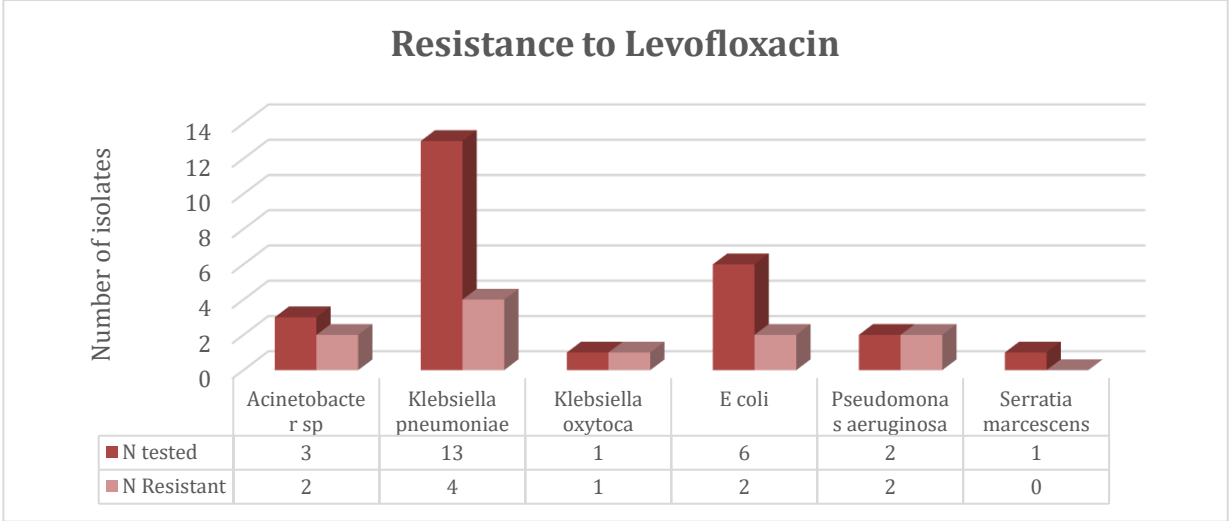
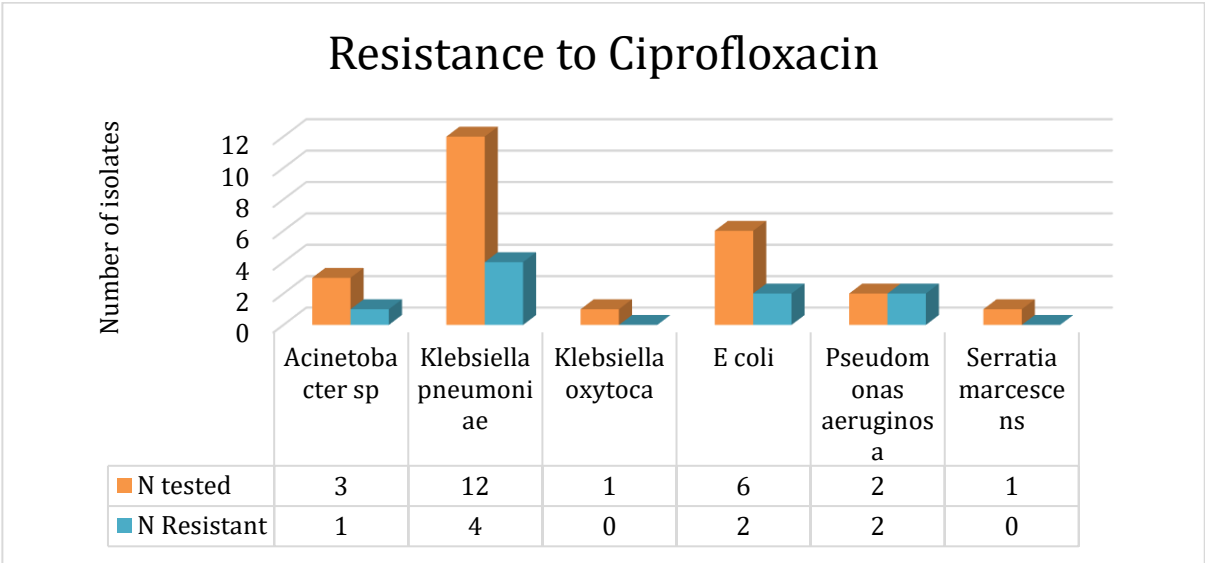


Figure 3.4: Sensitivity of isolated bacteria to Levofloxacin

All strains of *Pseudomonas aeruginosa* were resistant to Levofloxacin and Ciprofloxacin (Figures 3.4 and 3.5). Strains of *E. coli* exhibited rates of resistant of 66.7% and 33.3% for Levofloxacin and Ciprofloxacin respectively.



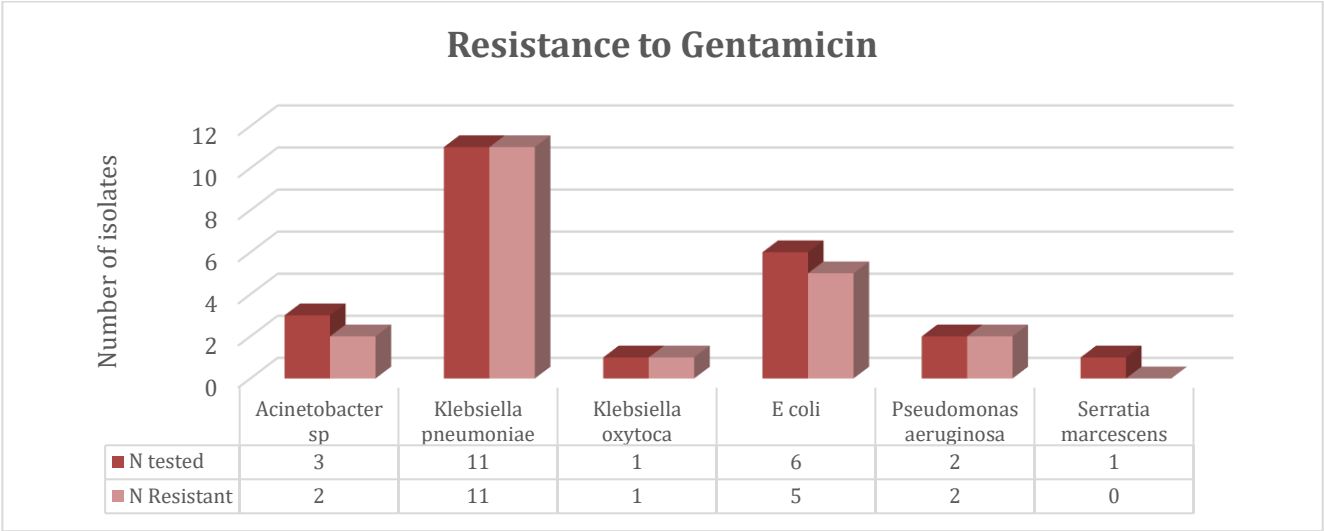


Figure 3.6: Sensitivity of isolated bacteria to Gentamycin

All strains of *Klebsiella* species and *Pseudomonas aeruginosa* were resistant to gentamicin whereas 83.3% of *E coli* strains resisted to this antibiotic.

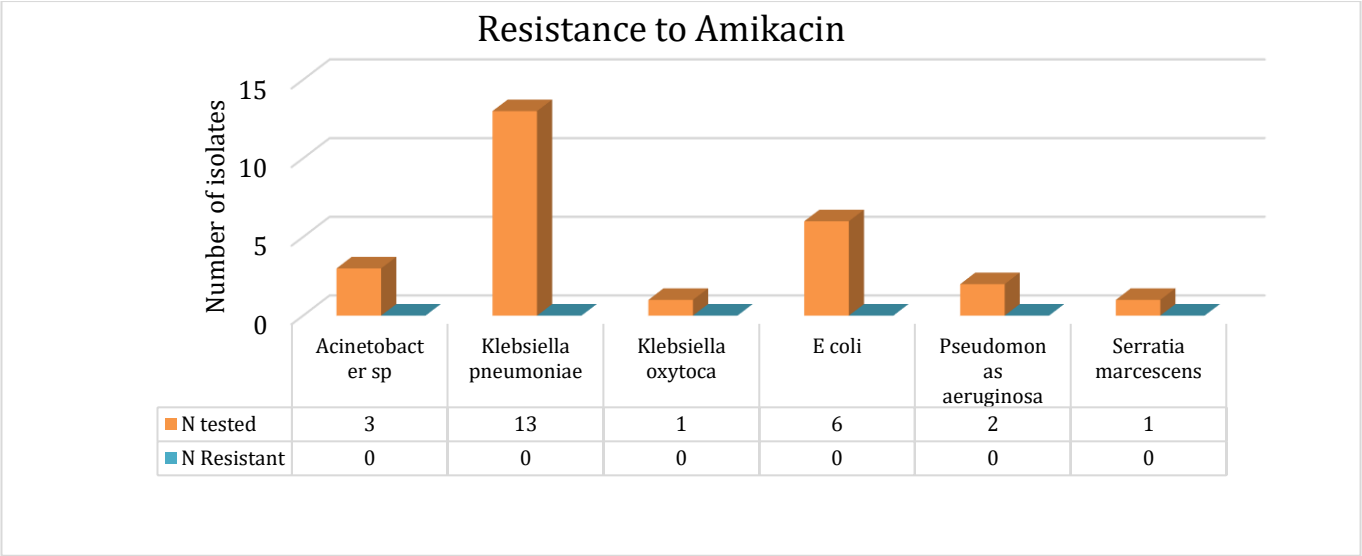


Figure 3.7: Sensitivity of isolated bacteria to Amikacin

No single strain among those isolated in this study has shown a resistance to Amikacin and Meropenem (Figures 3.7 and 3.8).

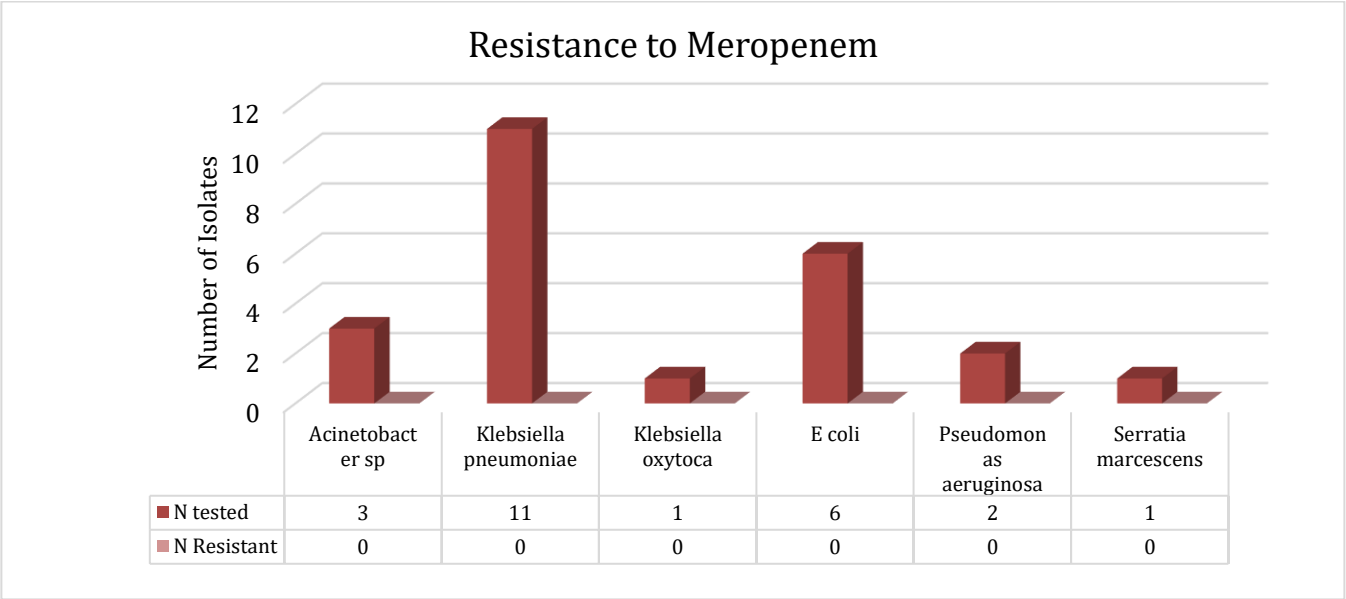


Figure 3.8: Sensitivity of isolated bacteria to Meropenem

4. DISCUSSION

In this study, we found that high touch surface areas disinfection with N-(3-aminopropyl)-N-dodecylpropane-1,3-diamine didecyldimethylammonium chloride (Surfanios) was effective whereas the used of refurbished UV C lights showed a very low disinfection activity. This study also confirmed a concern of contaminated working surface areas in Neonatology that may be source of nosocomial infections. In fact, most isolated microorganisms were resistant bacteria commonly isolated in hospital-acquired infections.

Similarly to our findings, there is a study conducted on the use of UV-C disinfection robot in the routine cleaning process that has concluded that a single standard disinfection UV-C irradiation cycle is not sufficient to inactivate pathogens with augmented environmental resilience, but can only result in a reduction in bacteria concentration on surface area exposed¹¹.

The use of UV light in our study may have resulted into limited efficacy for different reasons. It can either be linked with a lack of monitoring of intensity of light emitted. In fact, to be effective, the light should not only be kept clean to release irradiation but also lamps need to be substituted when the UV irradiation decreases below the standard level. Therefore, when one opts for using this disinfection, the irradiation intensity should be routinely monitored to guarantee enough irradiation dosage¹². During our study, we didn't dispose of tools to measure the intensity of light emitted but in order to confirm the efficacy of UV C lights, further similar studies with well-maintained lamps and monitored light intensity are needed.

Our study found also that high touch hospital equipment in Neonatology was contaminated by multidrug resistant microorganisms. The mostly contaminated were the nursing trolley with positive samples totaling 66,6% of all samples collected on this equipment. A relatively similar study assessing the contamination of hospital surfaces with bacterial pathogens during the COVID-19 pandemic has shown that 31% of hospital room surface was contaminated by bacteria¹³. This is a testimony of relatively poor hand hygiene and cleaning of highly touched equipment in the hospital. This may contribute to hospital-acquired infections among patients and also healthcare providers themselves. As many as 36.4% of equipment surface areas sampled were contaminated by different bacterial pathogens. This is a common finding as many countries have also shown this burden. The incidence of hospital environment contamination was found at different rates in different countries across the globe including African countries. It was estimated at 32.9% in Ghana¹⁴, 57% in Iran¹⁵, 46.7% in Nigeria¹⁶ and 39.6% in Ethiopia¹⁷ and could go up to 70% in burn unit in a hospital in Morocco¹⁸. Ours seem a bit lower but the difference may be explained by the compliance rates to hand hygiene or methodologies and services concerned by sampling for those studies.

Results of bacteriological analyses showed that, in the Neonatal Unit, sampled surface areas were carrying *Klebsiella pneumoniae* (54%), *E. coli* (23%), and *Acinetobacter ssp* when *Klebsiella pneumoniae* and *Pseudomonas species* before chemical disinfection. All the species were exhibiting a 100 % resistance to Cefuroxime. Our findings concur with results from the study on contamination of hospital surfaces in Italy that has also shown *Klebsiella pneumoniae* as the most isolated species (40.1%), while *Acinetobacter baumannii* was the species that showed the highest frequency of multidrug isolates (83.3%)¹⁹. This reflects exactly the current nosocomial flora in Rwandan tertiary hospitals¹⁹.

With those findings, treatment of hospital-acquired infections may only rely on Meropenem and Amikacin taken as a single

molecule or combined when indications dictate it but there is a need for action to protect those molecules and revert that trend of contamination of working surface in the hospital. Therefore, healthcare workers' hands are the most common vehicle for the transmission of healthcare-associated pathogens from patient to patient and within the healthcare environment, strict compliance with hand hygiene, its regular monitoring is among the key solutions to this burden²⁰.

CONCLUSION

Contamination of equipment and high touch surface areas and objects in Neonatology at CHUB is relatively as high as 30% of surface points sampled. The role of contamination by staff hands may be important.

Majority of isolated microorganisms are enterobacteriaceae with *Klebsiella pneumoniae* and *E coli* taking the lead. Those isolates are highly resistant to commonly used and available antibiotics to the extent that only Meropenem and Amikacin are the sole antibiotics clinicians can rely on when managing neonates with suspected or confirmed nosocomial infections.

However, an appropriate disinfection with available chemicals mainly Surfanios or similar products are effective and should be encouraged at every discharge or switch of equipment prior to admit or use the equipment on another patient, respectively. The utility of UV C light was not proven but needs to be explored with industrial UV C lights made for the purpose and whose intensity of light emitted is calibrated accordingly.

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