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Original article

Silent threats on surfaces and equipment in the newborn unit of Kenyatta National Hospital in Kenya

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ABSTRACT

Background: Contaminated hospital surfaces and equipment can serve as reservoirs for potentially pathogenic bacteria. They can contribute to persistent and silent transmission of infections. This study aimed to investigate the bacterial contamination and antimicrobial susceptibility patterns of potentially pathogenic bacteria isolated from surfaces and equipment in the newborn unit (NBU) of Kenyatta National Hospital (KNH). **Methods:** We conducted a cross-sectional study by sampling surfaces and equipment at NBU of KNH. A total of 580 swabs were collected from cots, incubators, radiant warmers, weighing scales, suction machines, oxygen masks, desk surfaces, door handles, keyboards, PC mouse, sinks, and taps. Culture of the swabs and isolation, identification and antimicrobial susceptibility testing of the isolates were performed using standard microbiological methods. **Results:** Growth was observed in 273 (54%) of the 580 swabs. Coagulase-negative staphylococcus (CoNS) were the most common contaminants, 137/273 (50.2%). *Klebsiella pneumoniae* (119/273, 43.6%), *Escherichia coli* (16/273, 5.9%), and *Pseudomonas aeruginosa (P. aeruginosa)* (1/273, 0.4%) were also isolated. The highest proportion of contaminants were found in cots (55/273, 20%), radiant warmers (51/273, 19%), oxygen masks (46/273, 17%), and desk surfaces (29/273, 11%). Antimicrobial resistance to penicillin, clindamycin, and vancomycin was observed in several isolates. **Conclusion:** Significant proportions of antibiotic-resistant contaminants were isolated from the NBU's surfaces and equipment. The hospital should implement strict infection control measures and regularize monitoring and surveillance of hospital surfaces and equipment for potential antibiotic-resistant pathogens to prevent their persistence and silent transmission.

Introduction

Nosocomial infections are a major cause of severe morbidity and mortality in hospitalized newborn infants [1,2]. They adversely affect preterm or term infants in intensive care units. Approximately 70% of hospital-acquired infections manifest as bacteremia and neonatal sepsis [2,3]. Almost a third of neonates in the newborn unit (NBU) at Kenyatta National Hospital (KNH) get neonatal sepsis [4]. Meningitis and pneumonia also commonly occur among neonates [5], independently affecting about one in every 10 neonates [3].

Nearly 50% of under-five deaths globally occur among neonates [6]. The neonatal mortality rate in developing countries is almost seven times

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that in developed countries, which is only 3 per 1000 live births. In Kenya, the neonatal mortality rate is 22 deaths per 1000 births [4]. The leading causes of neonatal mortality are preterm birth complications, intrapartum-related events, and severe infections. Hospital-acquired severe infections are implicated in more than a quarter of neonatal deaths globally [5]. In Kenya, neonates who get nosocomial infections die at a disproportionately high rate [5].

The commonly implicated bacteria in neonatal infections include coagulase-negative *staphylococci* (CoNS), *Staphylococcus aureus*, *Escherichia coli (E. coli)*, *P. aeruginosa*, and *Klebsiella pneumoniae (K. Pneumoniae)* [1,6]. Among the common sources of these pathogens are inanimate sources such as contaminated equipment and surfaces, which have been directly linked to increased incidence of neonatal infections in the neonatal intensive care unit (NICU) [7-10]. Invasive procedures in NICU such as insertion of nasogastric feeding tubes, intubation or catheterization, can create opportunities for bacteria to adhere and form biofilms that can serve as a source of infection for the neonates [1, 3, 11-15]. Other medical equipment that can be a source of infections among neonates include oxygen masks, endotracheal tubes, intravenous cannulas, and suction catheters [14]. In addition, asymptomatic parents and healthcare professionals may also introduce infectious agents to the neonates through contact with contaminated fomites [1, 13, 14].

Enterobacteriaceae and *Staphylococcus* spp. are common in equipment that get into direct contact with infant skin or mucus membranes [11, 15, 16, 24]. Medical equipment such as catheter, ventilators, and endoscopes are commonly colonized with multi-drug oranisms such as methicilin-resitant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococcus (VRE), and extended spectrum betalactams (ESBLs). On the other hand, *Pseudomonas aeruginosa* and coagulase negative *Staphylococcus* (CoNS) often colonize non-medical equipment including door handles, sink faucets, and computer keyboards [9,14,17].

Treatment of neonatal infections is complicated by antimicrobial resistance of the pathogens. It is estimated that nearly 50% of the pathogens that cause severe neonatal bacterial infections are resistant to the WHO-recommended first- and second-line antibiotics [18]. Thus, other alternative antibiotics such as carbapenems are used [19,20]. Recently, unpublished data from Kenya's largest referral hospital reported eleven neonatal deaths following infection with a drug-resistant *Klebsiella* spp. In addition, 55% of neonates at the Kilifi hospital in Kenya were identified as having ESBL *Enterobacterales* carriage during hospitalization [21]. Methicillin-resistant *Staphylococcus aureus* (MRSA) and *Klebsiella* spp. resistant to ceftriaxone, cefotaxime, and gentamicin were also implicated in a study of neonatal sepsis at Moi Teaching and Referral Hospital (MTRH) in Kenya [2].

To the best of our knowledge, potential sources of pathogens causing nosocomial infections in the NBU, which often lead to neonatal sepsis, have not been investigated. The identification of the potential sources and of the causative agents is essential when selecting and implementing multifaceted infection prevention and control strategies.

The aim of this study was to investigate the bacterial contamination profile of surfaces and equipment in the newborn unit and assess resistance of key pathogens isolated at Kenyatta National Hospital.

Methods

Study design

A cross-section study design was used.

Study site

The study was conducted at the Newborn Unit (NBU) of Kenyatta National Hospital (KNH) whose admission rate is about 250 neonates per month. The rooms within the NBU are grouped into an admission room, NICU 1 and 2; nurseries B1, B2, B3, and D; an isolation room for babies referred from other hospitals and those with confirmed culture positive. The equipment in the NBU include incubators, cots, mechanical ventilators, radiant warmers, suction machines, continuous positive airway pressure (CPAP) machines, and oxygen pots spread across the various rooms. The NBU also has a nurse station with tables, chairs, computers, a sink, and a tap. Milk preparation, utility, and equipment cleaning rooms each with a table, chairs, a sink, and a tap are also in the NBU.

Sample collection

Sampling was conducted between February and March 2021 while adhering to the principles for environmental sampling by the Center for Disease Prevention and Control (CDC) [22]. The surfaces

and equipment in the NBU were categorized into medical and non-medical items. The medical items sampled included suction machines, oxygen masks, incubators, infant weighing scales, radiant warmers, and baby cots. The non-medical items included taps, sinks, door handles, PC keyboards, PC mouses, and desk surfaces. Surfaces and equipment that were not in used or touched during the study period were excluded from sampling. Swabbing was performed using sterile cotton swabs dipped in normal saline (0.9% w/v). It was systematically done after routine disinfection once daily between 7 am and 10 am for all items until the required sample size was obtained. The swabs were labeled as per their specific identification codes, location, and date of sample collection **(Table 1).** The samples were then transported to the University of Nairobi's Department of Medical Microbiology & Immunology Laboratory within two hours of collection for microbiological analysis.

Microbial culture and identification

The swabs were inoculated on MacConkey agar (BD, New Jersey) and blood agar (BD, New Jersey) and incubated at 37 °C for 24 hours. The culture plates were investigated for bacterial growth and identified as per the standard microbiological procedures.

Antimicrobial susceptibility testing

Isolated CoNS, *Staphylococcus aureus, E. coli, Klebsiella pneumoniae,* and *Pseudomonas aeruginosa* were tested for antibiotic susceptibility using the Kirby-Bauer disk diffusion method. Results interpretation were based on 2020 Clinical and Laboratory Standards Institute (CLSIM100) guidelines [23].

Meropenem (10 µg), imipenem (10 µg), vancomycin (30 µg), clindamycin (2 µg), and penicillin (1IU) antibiotics were tested against gram-positive bacteria. Gentamicin (30 µg), cefotaxime (30 µg), ceftazidime (30 µg), amikacin (30 µg), ceftriaxone (30 µg), clindamycin (2 µg), imipenem (10 µg), and meropenem (10 µg) were tested against Gram-negative bacteria. *P. aeruginosa* ATCC27853 and *E. coli* ATCC25922 were used in the identification and antimicrobial susceptibility testing as control strains [23].

Data management and analysis

Data generated were entered into microsoft Excel and analyzed using Statistical Package for Social Sciences (SPSS) software version 21.0. Univariate analysis was done to obtain frequency distributions and proportions of contaminants and antimicrobial susceptibility patterns. In bivariate analysis, a Chi-square test was used to assess the presence of significant associations between bacteria spp. isolated from surfaces and equipment in different NBU locations.

Ethical consideration

This proposal was approved by Kenyatta National Hospital and the University of Nairobi (KNH-UON) Ethics and Research Committee (P539/09/2020). Permission to conduct the study was sought from the head of the KNH pediatric and child health department. A waiver for the informed consent was obtained as the study was not dealing with human subjects.

Table 1. Items swabbed from each room within NBU of KNH.

Medical equipment	**Codes /location**	**Non-medical equipment**	**Code /location**
Incubator	Incubator 001NICU1	Sink	Sink001nurseryB2
Baby cot	Baby cot 001nurseryB1	Tap	Tap001nurseryB3
Oxygen mask	Oxygen mask 001NICU2	Door handle	Door hand l001NICU2
Radiant warmer	Radiant warmer 001NICU1	PC keyboard	PC keyboard 001nursestation
Suction machine	Suction machine 001admission room	PC mouse	PC mouse 001sursestation
Weighing scale	Weighing scale 001nurseyB2		

Results

A total of 508 swabs were collected from both medical and non-medical equipment and the number of postitive cultures is summarized in **table (2)**. A total of 273/508 (54%) samples showed bacterial growth on culture with high contamination rates observed in medical equipment 178/308 (59%).

Among the bacteria isolated, CoNS were the most abundant comprising 137/273 (50.2%) of the positive bacterial cultures, followed by *Klebsiella pneumoniae* 119/273 (43.6%) and *E. coli* 16/273 (5.9%). Positive bacterial cultures were mostly isolated from surfaces of medical equipment (178/273, 65%) than non-medical equipment (95/273, 35%). However, the difference was not statistically significant (p = 0.241). Most of the positive bacterial cultures were from baby cots, radiant warmers, and oxygen masks.

The majority of the positive bacterial cultures were from NICU1 and NICU2 as compared to other newborn unit locations/rooms **(Table 3).** The differences in proportions of positive cltures between the NICUs and other NBU units were statistically significant (p< 0.05). Of positive cultures, 22% and 24% were *K. pneumoniae* and CoNS, respectively.

Baby cots in NICU1 and Nursery B3 were the most contaminated. Radiant warmers in NICU2 were the most contaminated. Other most cotaminated equipment include oxygen masks in NICU 2 and incubators in Nursery B1. Non-medical equipment most contaminated with bacteria included desk surfaces in the nurse station, door handles in NICU 2, admission room, and waiting area **(Table 4).**

CoNS and *K. pneumoniae* were the predominant bacteria isolated from different equipment **(Table 5).** However, there was no significant difference in isolation of CoNS and *K. pneumoniae* from the equipment (p = 0.865).

The antimicrobial testing results showed that CoNS were highly susceptible to meropenem (96%), amikacin (77%), and imipenem (93%). Resistance was recorded for vancomycin (45%), ceftazidime (48%), penicillin (97%), and clindamycin (46%). *K. pneumoniae* isolates showed high resistance to clindamycin (87%) but high susceptibility to meropenem (90%), imipenem (97%), amikacin (68%), and ceftazidime (67%). Although *E. coli* and *P. aeruginosa* cultures were less than 30; the recommended CLSI threshold, we reported the antimicrobial susceptibility testing (AST) results. Both were highly susceptible to meropenem (94-100%), amikacin (69-100%), and imipenem (94-100%) but they were resistant to clindamycin (100%). Cultures of swabs obtained from the different NBU environmental surfaces and equipment were highly susceptible to meropenem, amikacin, and imipenem (70-100%) but resistant to clindamycin, penicillin, and vancomycin (45-100%).

Table 2. Distribution of positive bacterial cultures in items sampled in the NBU.

Items sampled	**No. of swabs collected (n = 508)**	**No. of postive bacterial cultures n (%)**
Medical equipmets (n = 178)		
Cot	96	55 (57)
Incubator	40	16 (40)
Radiant warmer	88	51 (58)
Weighing scale	6	4 (67)
Suction machine	10	6 (60)
Oxygen mask	68	46 (68)
Non-medical equipmets (n = 95)		
Desk surface	57	29 (51)
Door handle	44	17 (39)
Keyboard	10	5 (50)
PC mouse	11	4 (36)
Sink	41	24 (59)
Tap	37	16 (43)

Table 3. Bacteria isolated from different locations/rooms in the NBU.

Site	No. of positive cultures				
		CoNS n = 137 (%)	***K. pneumoniae* n = 119 (%)**	***E. coli* n = 16 (%)**	***P. aeruginosa* n = 1 (%)**
NICU 2	60	33 (24)	24 (20)	3 (19)	0 (0)
NICU 1	48	17 (12)	26 (22)	5 (31)	0 (0)
Nursery B3	42	33 (24)	9 (7)	0 (0)	0 (0)
Nursery B1	32	15 (11)	13 (11)	4 (25)	0 (0)
Nursery B2	26	15 (11)	9 (8)	2 (13)	0 (0)
Admission room	22	7 (5)	13 (11)	2 (13)	0 (0)
Isolation room	21	5 (4)	15 (13)	0 (0)	1 (100)
Nurse station	19	11 (8)	8 (7)	0 (0)	0 (0)
Writing area	3	1 (1)	2 (2)	0 (0)	(0)

Table 4. Number of positive cultures obtained from items sampled from different locations in NBU.

Items Sampled	NBU Sites								
	Admission room n (%)	Isolation Room n (%)	NICU n (%)		Nursing station n (%)	Nursery B n (%)			Waiting area n (%)
			1	2		1	2	3	
Cot	0 (0.0)	5 (9.1)	17 (30.9)	6 (10.9)	0 (0.0)	6 (10.9)	6 (10.9)	15 (27.3)	0 (0.0)
Radiant warmer	5 (9.8)	3 (5.9)	11 (21.6)	25 (49.0)	0 (0.0)	4 (7.8)	0 (0.0)	3 (5.9)	0 (0.0)
Oxygen mask	7 (15.2)	0 (0.0)	7 (15.2)	16 (34.8)	0 (0.0)	2 (4.3)	4 (8.7)	10 (21.7)	0 (0.0)
Incubator	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	9 (56.3)	6 (37.5)	1 (6.3)	0 (0.0)
Suction machine	0 (0.0)	1 (16.7)	1 (16.7)	2 (33.3)	0 (0.0)	2 (33.3)	0 (0.0)	0 (0.0)	0 (0.0)
Weighing scale	2 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (25.0)	0 (0.0)	1 (25.0)	0 (0.0)
Desk surface	3 (10.3)	4 (13.8)	4 (13.8)	3 (10.3)	8 (27.6)	1 (3.4)	4 (13.8)	2 (5.9)	0 (0.0)
Sink	1 (4.2)	4 (16.7)	3 (12.5)	3 (12.5)	1 (4.2)	5 (20.8)	2 (8.3)	5 (20.8)	0 (0.0)
Door handle	3 (17.6)	1 (5.9)	2 (11.8)	3 (17.6)	0 (0.0)	1 (5.9)	2 (11.8)	2 (11.8)	3 (17.6)
Tap	1 (6.3)	3 (18.8)	3 (18.8)	2 (12.5)	1 (6.3)	1 (6.3)	2 (12.5)	3 (1.8.8)	0 (0.0)
Key board	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	5 (100)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
PC mouse	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	4 (100)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

Table 5. The proportions of bacteria isolated from the items sampled.

Equipment	Bacteria			
	CoNS n (%)	***E. coli* n (%)**	***K. pneumoniae* n (%)**	***P. aeruginosa* n (%)**
Baby cot (n=55)	28 (50.9)	3 (5.5)	24 (43.6)	0 (0.0)
Radiant warmer (n=51)	26 (51.0)	4 (7.8)	21 (41.2)	0 (0.0)
Oxygen mask (n=46)	27 (58.7)	2 (4.3)	17 (37.0)	0 (0.0)
Incubator (n=16)	8 (50.0)	1 (5.9)	7 43.8)	0 (0.0)
Suction machine (n=6)	4 (66.7)	1 (16.7)	1 (16.7)	0 (0.0)
Weighing scale (n=4)	2 (50.0)	1 (25.0)	1 (25.0)	0 (0.0)
Desk surface(n=29)	15 (51.7)	2 (6.9)	12 (41.4)	0 (0.0)
Sink (n=24)	12 (50.0)	0 (0.0)	11 (45.8)	1 (4.2)
Door handle (n=17)	5 (29.4)	1 (5.9)	11 (64.7)	0 (0.0)
Tap (n=16)	6 (37.5)	1 (6.3)	9 (56.3)	0 (0.0)
PC.Keyboard(n=5)	3 (60.0)	0 (0.0)	2 (40.0)	0 (0.0)
PC mouse(n=4)	1 (25.0)	0 (0.0)	3 (75.0)	0 (0.0)

Abbreviation; n = number of colonies [24].

Discussion

Overall, the surfaces and equipment in NBU were contaminated with antibiotic-resistant pathogenic bacteria. The 54% positivity rate of contamination mirrors previously published studies in NICU settings where 52.8% to 74.6% contamination rates have been reported [9, 20]. The high bacterial contamination rate observed may be attributed to overcrowded units considering neonates in this setting share incubators, baby cots, and radiant warmers [25]. Poor compliance to infection control practices when working in the unit could be increasing the risk of contamination. For instance, occasional disinfection of surfaces and equipment within the unit may facilitate microbial colonization, growth, and survival consequently increasing the risk of infections in a susceptible neonate [9]. Healthcare workers, parents, and visitors could be a source of infection to the NBU/NICU environment because of interactions that might facilitate the spread and transmission of infections [20].

Coagulase-negative Staphylococcus (CoNS), *K. pneumoniae* and *E. coli* were the main contaminants isolated in the current study. Previous studies have isolated similar patterns of bacteria from NBU surfaces and equipment [22, 23]. Studies in Namibia and Egypt showed that CoNS accounted for the predominant group of bacteria isolated from NBU in both inanimate and environmental surfaces [20,22]. The abundance of CoNS could be due to the fact that they are normal flora in hands and skin, which get into contact with the equipment and surfaces to cause the contamination if they are disinfected [20]. Although *Staphylococci aureus* is sporadically involved in causing nosocomial infections, it was not isolated in the current study [26].

Variations in levels of contamination were observed across the swabbed items. Baby cots, desk surfaces, oxygen masks, and radiant warmers showed high levels of bacterial contamination as reported in previous studies [9,17]. Ambient humidity and temperature levels of some items like radiant warmers are ideal for the survival of pathogenic bacteria.27 The most touched items are usually the commonly contaminated as observed in the current study [28].

Meropenem, imipenem, amikacin, and ceftazidime were effective against most bacteria. Resistance was noted against penicillin, vancomycin, and clindamycin. A previous study in Nigeria found all isolates to be susceptible to meropenem [11]. Another study in Egypt reported sensitivity to imipenem and resistance against cefotaxime in all isolates [29]. In a research in Namibia, resistance to penicillin and cephalosporins was common [20]. Selective pressure secondary to

frequent use of the antibiotics could explain the observed resistance patterns [30].

Although vancomycin is rarely used to treat CoNS-related diseases, resistance against it was observed. A broth dilution test that will give minimum inhibitory concentration is needed to confirm the finding [23]. Since findings of the current study are only based on disk diffusion method, they should be cautiously interpreted.

This study has revealed the bacteria that could be commonly contaminating NBU surfaces and equipment at KNH. The resistance patterns of some pathogenic bacteria are also described even though the method used limits the precision of the findings. Future studies should use the more conclusive minimum inhibitory concentration-based tests for antibiotic resistance testing. Besides, since the newborn environment could be contaminated with other potential pathogens including parasites, fungi, and viruses, more comprehensive studies are needed.

Disclosure of potential conflict of interest

The authors declare no conflict of interest.

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Author Contributions

Conceptualization, A.C., W.M. and A.M.; methodology, A.C.; formal analysis, A.C.; investigation, A.C.; resources, A.C.; data curation, A.C and W.M.; writing—original draft preparation, A.C. and D.K..; writing—review and editing, A.C, W.M, A.M and D.K; visualization, A.C. and D.K.; supervision, A.M. and W.M; project administration, A.C.; funding acquisition, A.C. All authors have read and agreed to the published version of the manuscript.

Data availability statement

The data supporting the reported results can be found by emailing A.C. at adut80@yahoo.com.

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