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An Outbreak of Ventilator Associated Pneumonia Caused by Carbapenem Resistant *Acinetobacter baumannii* in an Intensive Care Unit: Lessons Learned for Better Infection Prevention Practices

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A B S T R A C T

Background: *Acinetobacter baumannii* is a known opportunistic pathogen that act as a source of life threatening healthcare associated infections (HAIs) and outbreaks. The aim of the study was to describe the events, management and the control of ventilator associated pneumonia (VAP) outbreak that occurred in intensive care unit (ICU) of a tertiary care hospital caused by carbapenem resistant *A.baumannii* (CRAB). Methods: Total five case patients admitted in intensive care unit presented with ventilator-associated pneumonia. Respiratory secretions from patients were processed for microbiological culture. The isolates recovered were identified by using gram stain morphology and the Vitek2 compact system (bioMerieux, France). Hypothesis made and investigation of an outbreak was carried out. Discussion with ancillary staff and environmental surveillance done. Infection control practices were evaluated and appropriate measures taken. Results: Index case presented with ventilator-associated pneumonia caused by CRABat the time of admission. Thereafter, five patients developed ventilator-associated pneumonia. Carbapenem resistant *A.baumannii* isolated in clinically significant cultures. All patients managed with strict contact precautions until discharge. Of the environmental samples, one sample obtained from the monitor screen beside the bed of an index case yielded growth of carbapenem resistant *A.baumannii*. Other non-critical surfaces showed contamination with mixed bacterial flora. The main reason of outbreak was breach in cleaning and disinfection protocols. Corrective and preventive measures taken accordingly. Conclusions: An integrated approach of epidemiological and microbiological data along with strict infection control measures were crucial to cut down the outbreak. The distinguishing characteristics of this outbreak was introduction of automated disinfectant dilutor pumps and positive impact of educational sessions conducted for HCWs.

Introduction

Acinetobacter baumannii is an opportunistic gram-negative coccobacillus that has become a major threat to public health worldwide. The vast majority of *A. baumannii* isolates arise in medical institutions. Therefore, hospitalized patients are at a greater risk of *Acinetobacter* infections, especially those on a mechanical ventilation, with a prolonged hospital stay, having open wounds and those with

invasive devices, such as central venous catheters or urinary catheters. (Wisplinghoff *et al.,* 2000; Howard *et al.,* 2012)

The colonisation and transmission of *A. baumannii* favoured by its remarkable resistance to disinfectants and its capacity to develop tolerance to antibacterial agents rapidly.

In addition, its ability to survive under a wide range of environmental conditions and to persist for extended periods on surfaces makes it a frequent cause of outbreaks and an endemic, healthcare associated pathogen. (Wendt *et al.,* 1997)

Recently, Multidrug-resistant (MDR) *A. baumannii* strains are prevalent worldwide, with the highest percentage of carbapenem resistance of over 90%. (Ma *et al.,* 2021) As per the definition, the multidrug-resistant CRAB has documented resistance to three or more classes of antibiotics and show non-susceptibility to atleast one carbapenem. (Magiorakos *et al.,* 2012)

This carbapenem resistant *Acinetobacter baumannii* (CRAB) has being recognised as a perilous nosocomial pathogen affecting critically ill patients. (Munoz-Price and Weinstein, 2008) In 2017, the World Health Organization (WHO) listed carbapenem-resistant *A. baumannii* as a critical priority towards which, new antibiotics are urgently needed for treatment.(Tacconelli *et al.,* 2018) Many outbreaks in ICUs caused by CRAB have been reported during last decade. (Kohlenberg *et al.,* 2009; Ayraud-Thevenot *et al.,* 2012; Molter *et al.,* 2016) Although it is a low virulence pathogen, but well known for its substantial morbidity and mortality. (Falagas *et al.,* 2006)

The outbreaks caused CRAB are always difficult to control and requires active patient screening and strict isolation strategies along with environmental cleaning (Peleg *et al.,* 2008). Hence, present study describe the occurrence, management and control of VAP outbreak caused by CRAB occurred in ICU of tertiary care hospital located in Northern Mumbai.

Materials and Methods

Hospital setting

The outbreak occurred in the month of November 2018 at 250 bedded tertiary care hospital located in Northern Mumbai. The hospital has National Accreditation Board for Hospitals & Healthcare Providers (NABH) accreditation with robust hospital infection control committee. The well-organized infection control team manages the standardisation and implementation of infection control polices.

The facility has12-beddedmedical ICU located at second floor of hospital. As per the infection control policy of ICU, curtains separate the patient areas and nursing ratio was maintained one nurse to two patients. Chlorhexidine (0.5% w/v) with 70% v/v isopropyl alcohol based hand rubs are available at entry and exit points. Single-use nonsterile gloves with alcohol based hand rub are available next to each patient's bed. For hand washing, chlorhexidine (2% w/v) based soap solution is available at hand wash sinks. Environmental cleaning was performed principally with 1% ppm sodium hypochlorite solution.

Standard protocols of insertion and maintenance bundles for prevention of HAIs were followed. All procedures like central line insertion, endotracheal intubation and catheterization are done with all aseptic precautions and properly documented.

For monitoring the prevalence of multidrug resistant pathogens, patients are screened on admission for selected multi drug resistant bacteria. Considering the epidemiology of regional area, nasal, axillary and groin swabs are collected to rule out colonisation of methicillin resistant *Staphylococcus aureus*. Swabs for MDR gram-negative organisms and candida spp. are collected as and when required or as per the patients risk factors. For prescribing higher antibiotics, reserved drug form is used. Antibiotics are dispatched by in-house pharmacy to ICU after approval from infection control team. Daily rounds conducted by infection control nurse to

monitor compliance to infection control policies. Continuous education of staff, as well as hand hygiene monitoring, compliance, and feedback are routinely implemented.

Identification and investigation of the outbreak

In ICUs, infection control nurse continuously carried out an active surveillance of HAIs and Multidrug Resistant Organisms (MDROs). The baseline CRAB prevalence in ICU was 7.4% (number of CRAB isolates/total number of isolates tested). The unusual increase in CRAB cases was identified through patient based active surveillance. All required data related to date and site of CRAB isolation and outcome were noted. The case patient was defined as a patient with an HAI caused by CRAB isolate identified in a clinically significant culture. According to the CDC criteria, HAI was considered significant if they appeared after 48hr of hospital admission and not present at the time of admission. (VAP, 2014) However, colonization was defined as acquisition of this pathogen during hospitalization but without any evidence of clinical disease. Therefore, the detection of CRAB at admission or the acquisition of this pathogen during hospitalization without any clinical evidence was considered CRAB colonisation.

Although the entire outbreak investigation and interventions were considered an infection control response to an outbreak in intensive care unit. Still institutional review board approval was obtained for retrospective evaluation of entire event and journaling.

Environmental surveillance

Bacteriological surveillance conducted to know the extent of environmental contamination and source of the outbreak. Environmental samples were collected using sterile disposable swabs (Himedia Laboratories Pvt Ltd, Mumbai) and plating done on nutrient agar and blood agar media (Biosmart, Mumbai). The samples were collected from all critical and non-critical surfaces like medical equipment, door handles, monitors, surfaces of tables, medical instruments, bedside trolley, stethoscopes and from the hands of randomly selected healthcare workers of ICU. Samples were also collected from surroundings of asymptomatic cases. Water samples were collected for screening from different sources in ICU to check for possible contamination.

Microbiological procedure

Respiratory secretions from only symptomatic patients were processed for microbiological culture. All clinical samples received in microbiology laboratory were processed as per standard microbiological procedures (Tille, Patricia, 2014). Respiratory specimens were plated on Blood agar, MacConkey agar and Chocolate agar (BioSmart, Mumbai). Gram stain prepared and screening done for appropriateness of specimens to rule out salivary contamination. All plates were incubated at 37°C for 48hrs. Screening for significant growth was done at 24 hrs and 48 hrs of incubation. Preliminary identification done by typical gram stain morphology. Confirmed identification and antibiotic susceptibility testing of *Acinetobacter* spp. was done using the Vitek2 compact system. The results were interpreted according to the clinical and laboratory standards institute criteria. (CLSI, 2018)

Outbreak management

Once the outbreak was confirmed, infection control measures were intensified. Infected patients were cohorted. Strict contact precautions were implemented. The protocols of environmental cleaning and disinfection were reviewed and modified. Furthermore, meetings conducted with all HCWs to discuss regarding any potential breach in standard infection control practices. All information given by HCWs were noted and trainings given.

Results and Discussion

During the month of November 2018, 6 patients hospitalized in the ICU developed ventilator

associated pneumonia. Clinical characteristics of all infected patients were noted. All patients had undergone mechanical ventilation, venous catheter and indwelling urinary catheter. Piperacillin-Tazobactam had been prescribed for all patients as per the hospital antibiotic policy. *A.baumannii* isolated from clinically significant cultures. It was observed that all isolates were having similar antimicrobial susceptibility pattern.

All strains showed resistance to beta lactam/beta lactamase inhibitors, aminoglycosides, extended spectrum cephalosporins, fluoroquinolones and trimethoprim-sulfamethoxazole. In addition, all strains were resistant to carbapenems.

For all isolates, minimum inhibitory concentrations to carbapenems ranged between 8 and 16 ug/ml as per the CLSI criteria. Whereas they were susceptible to colistin with MIC of 0.5mg/ml.

The first isolated patient was a 55yr old female transferred from other healthcare facility. The patient had ventilator-associated pneumonia at the time of admission and identified as caused by CRAB. Soon after confirmation, contact precautions were implemented until discharge. Subsequently, five more patients developed VAP within one week. One patients died due to multiple risk factors.

Environmental surveillance showed heavy bacterial colonisation of non-critical surfaces (31%) followed by hands (21%) of HCWs and critical surfaces (10%).(Figure No.1-2) Of the non-critical surfaces, one sample obtained from the monitor screen beside the bed of an index case yielded growth of carbapenem resistant *A.baumannii*. Amongst other organisms isolated were gram positive bacilli (6%), gram positive cocci (3%) followed by gram negative coccobacilli (2%) and gram negative bacilli (2%) (Figure No.3).

The chronological distribution of the cases were reconstructed considering several factors like hospitalization of patients, medical procedures performed, diagnostic investigations and positions of beds in ICU. All four patients had no clinical evidence of infection at the time of admission. The arrangement of beds and spread of pathogen was studied using ICU layout and it was observed that CRAB had spread to only certain areas of ICUs. The sequence of cases indicates the pattern and flow of CRAB isolate (Figure No.4).

Upon discussion with housekeeping staff of ICU, it was noted that dilution method of disinfectant and cleaning protocol of non-critical surface was not appropriate. After root cause analysis, few corrective and preventive actions were adopted.

Corrective measures

Emphasis given on hand hygiene practices

All HCWs were instructed to follow five moments of hand hygiene. They were encouraged to use hand rubs and perform seven steps of hand hygiene. Compliance to hand hygiene was checked and on the spot feedback given on daily basis.

Appropriate use of personal protective equipment (PPE)

PPE were made mandatory while performing procedures to any patients in ICU. Staff members were instructed to protect themselves and prevent soiling of clothing while performing procedures.

Contact precautions

While handling patients, contact precautions to be followed strictly to interrupt the transmission of pathogen. Use of disposable patient-care items were encouraged to minimize cross-contamination with multiple-resistant microorganisms.

Cohorting the patients

Due to space constraint, all patients with VAP caused by CRAB were cohorted to one side of the ICU with allocated dedicated staff & materials to prevent cross contamination.

Cleaning and disinfection

All high-touch surfaces in patient-care areas (e.g., doorknobs, bed rails, light switches, carts, bedside commodes, or faucet handles) were cleaned with Ethyl alcohol or isopropyl alcohol in concentrations of 60%–90% (v/v). Instruction given to disinfect them more frequently.

One bed, one bowl technique

Thorough cleaning and disinfection of environmental surfaces and keeping visibly clean on a regular basis and clean up spills promptly.

Proper procedures for effective use of mops, cloths, and solutions

1. Prepare cleaning solutions daily or as needed, and replace with fresh solution frequently. 2. Change the mop head at the beginning of the day, or after cleaning up large spills of blood or other body substances. 3. Clean mops and cloths after use and allow to dry before reuse. 4. Discard any remaining solution and dry out the containers properly.

Meetings with HCWs

Periodic meetings with HCWs were conducted to check the compliance to protocol and to raise awareness about outbreak. Special attention were given to educating housekeeping staff for cleaning and disinfection procedures.

Instructions to visitors

Leaflet prepared for visitors that mentioned the basic steps to be followed while visiting the patient. It highlights about the importance of hand hygiene to minimize the spread of body substance contamination (e.g., respiratory secretions or fecal matter) to surfaces.

Terminal cleaning

Patients were shifted to surgical ICU and medical ICU was closed down for cleaning. All air conditioning ducts were cleaned and fumigation done. ICU was reopened after post fumigation swabs recovered negative result.

Preventive measures

Replacement of disinfectant

Sodium hypochlorite solution was replaced with quaternary ammonium compound (QACs). This low level disinfectant has good stability and toxicology, surface activity and compatibility with cleaner formulation ingredients.

Automation of dilution procedure

Automated dilutor pumps were installed for preparing disinfectant solution. So, freshly prepared solution was available as and when required along with consistent efficacy of solution.

Modification of environmental cleaning and disinfectant protocol

Cleaning protocols were changed as per the instructions given for use of new disinfectant. Housekeeping staff were encouraged to clean high touch surfaces and non-critical surfaces frequently.

Dedicated nurse for ventilated patients

One dedicated nurse would be allotted to patients with mechanical ventilation.

Awareness programs

Trainings and awareness programs were conducted to update the knowledge of HCWs on regular basis.

The present study reported the incidence and management of an outbreak in ICU caused by carbapenemase resistant *Acinetobacter baumannii* at a tertiary care hospital. The strength of the present outbreak investigation lie in the small number of patients affected, introduction of automated disinfectant dilutor pumps, infection control

measures and regular staff training programs that were task oriented and continuously reinforced.

As it is known, that hand hygiene is the most basic part of infection prevention and control.

World Health Organization (WHO) recommends five moments of hand hygiene during patient care and use of personal protective equipment as a universal practices for infection prevention. The compliance to hand hygiene practices and PPE protocols were noted by ICN routinely. During outbreak investigation, it was observed that majority of HCWs did not follow 5th moment of hand hygiene i.e after touching the patient surroundings. In one study by Enoch *et al.,* (2008) reported health care worker hand samples as a source of outbreak. Similarly, Gottesman *et al.,* (2021) noted that healthcare workers' hands can serve as vehicles for transmission from contaminated surfaces either to patients or from a colonized patient to other patients. Hence, emphasis was given on using hand rubs especially available at patient's bedside. Staff members were instructed to use PPE while performing procedures to protect themselves and prevent soiling of clothing.

For any outbreak management, isolation of patients or cohorting of colonized/infected patients in designated area is essential to curtail transmission. (Bianco *et al.*, 2016) However, due to unavailability of space, patients were cohorted on one side of ICU with dedicated staff & materials to prevent cross contamination.

As per the local hospital policy, the nurse to patient ratio in ICU was 1:2. The ratio recommended by Indian Nursing Council (INC) was 1:1. (Sharma and Rani, 2020) Bala *et al.,* (2010) also highlighted the required nurse-patient ratio of 1:1 in different ICUs. Furthermore, NABH recommended 1:1 for ventilated patients and 1:2 for non-ventilated patients. These recommendations are in line with international norms. Hence, it was decided that dedicated nurse would be allotted for ventilated patients in ICUs.

Hospital environment acts as a reservoir for many potential pathogens and there is documented evidence that environmental cleaning reduces the rates of healthcare associated infections. (Dancer, 2009) Environmental surveillance showed heavy bacterial colonisation of non-critical surfaces (31%) followed by hands (21%) of HCWs and critical surfaces (10%). The various bacterial flora isolated during monitoring provided a hint as to the kind or strength of disinfection needed in the intensive care unit. It was observed in present outbreak that cleaning of high touch surfaces and non-critical surfaces were done with 1% sodium hypochlorite.

The diluted solution was stored in an open container and thus susceptible to evaporation. The efficacy of solution start degrading once it is prepared in morning. Same solution is used throughout day for cleaning all high touch surfaces and non-critical surfaces. Dilution of disinfectant and cleaning protocol of one bowl for 3 beds could be one of the factor responsible for outbreak. Furthermore, the observation also highlights the need of proper cleaning protocol for non-critical surfaces.

Considering the advantages of quartenary ammonium compound, it was introduced for cleaning and disinfection in ICUs. Quaternary ammonium compounds are low-level disinfectants, as defined by the US Centers for Disease Control and Prevention. They are effective against most vegetative bacteria and enveloped viruses, and some fungi. The conditions necessary to attain disinfection depend on concentration and contact time. (Johansson Ingegärd and Somasundaran , 2007) Hence, cleaning protocol revised along with implementation of one bed, one bowl technique. Manian *et al.,* (2011) reported that *A. baumannii* persist on unexpected surfaces despite a stringent disinfection and immersion in a disinfectant solution could be necessary. However, in present outbreak, immersion was not followed but proper procedures for effective use of mops, cloths, and solutions were introduced. ICU was closed temporarily and terminal cleaning was done to completely eradicate the pathogen.

Fig.1 Bacterial colonization observed in ICU during environmental surveillance

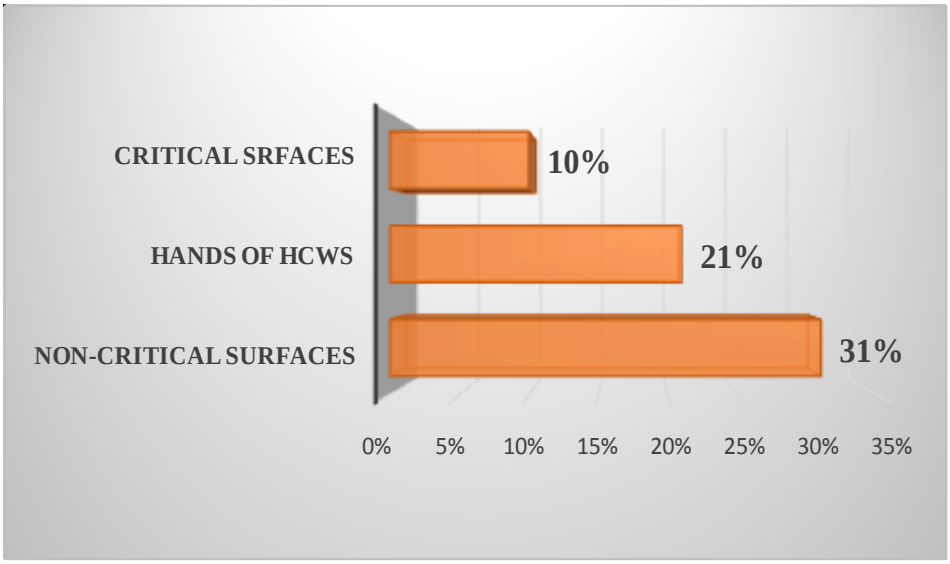


Fig.2 Percentage of bacterial colonization of non-critical surfaces in ICU

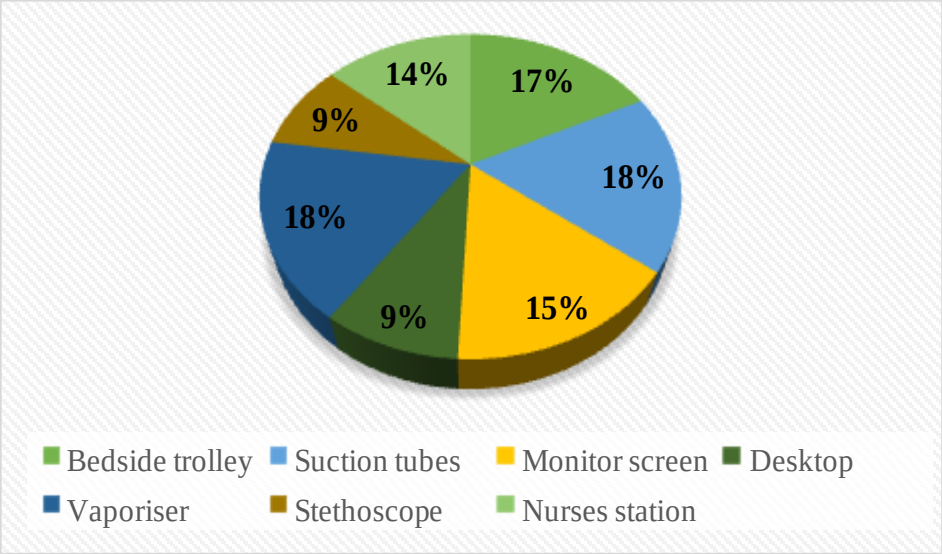
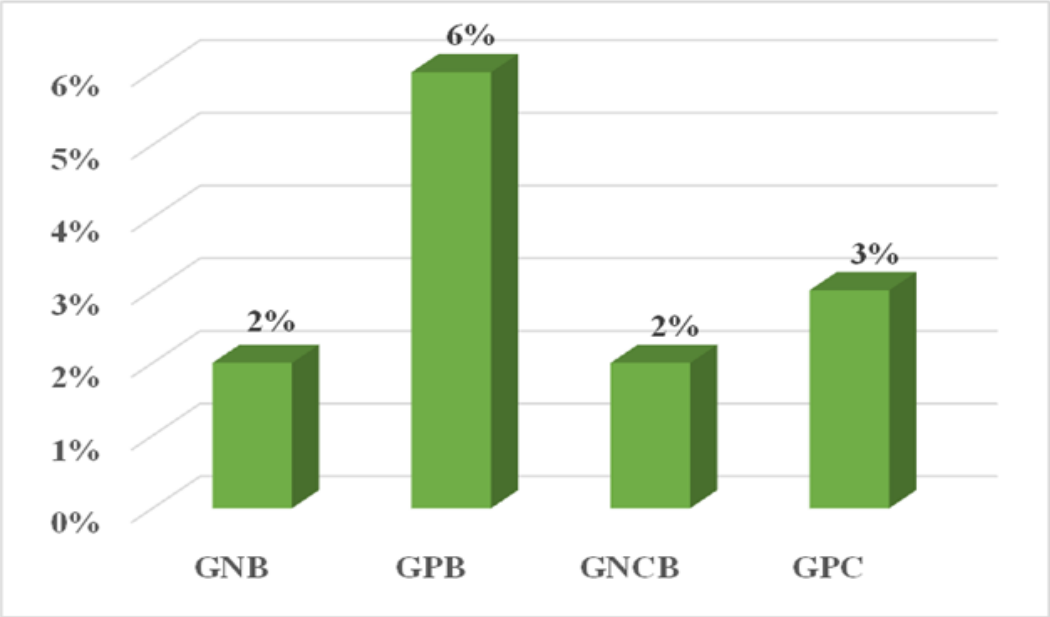
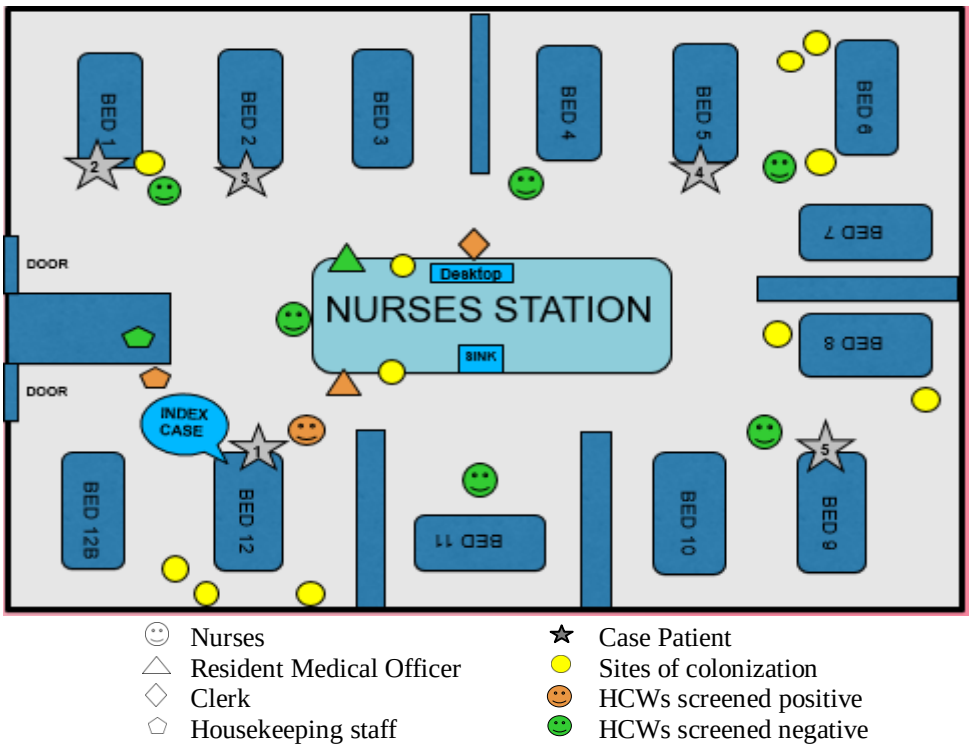


Fig.3 Percentage of different organisms isolated during environmental surveillance



(GNB: Gram Negative Bacilli, GPB: Gram Positive Bacilli, GNCB: Gram Negative Coccobacilli, GPC: Gram Positive Cocci)

Fig.4 Chronology of cases and transmission of CRAB in ICU



Study done by Ayraud *et al.*, (2012) stated that temporary closure of the ICU might be required in some situations where environmental contamination was key to the dissemination of CRAB.

Furthermore, Gottesman *et al.,* (2021) concluded that along with terminal cleaning, environmental sampling is essential to make sure no reservoir has been left. Hence, environmental samples were collected after terminal cleaning and tested.

In present outbreak, multiple meetings were conducted to identify the flaws in infection prevention practices. Special attention were given to educating housekeeping staff for cleaning and disinfection procedures. Interventions taken in the ICU also had a behavioural impact outside the ICU that caused the decline in CRAB prevalence. Awareness sessions were conducted for all staff outside the ICU. Study by Bianco *et al.,* (2016) also observed that periodic meetings with all nursing and ancillary staff to provide information and training helped to halt the outbreak.

To prevent contamination of ICU from visitors, they were allowed in ICU for fixed hours once a day.Infection prevention protocols were prepared and leaflet distributed to visitors that mentioned the basic steps to be followed while visiting the patient.

It mainly highlights about the importance of hand hygiene and clothing. Similarly, Clavel *et al.,* (2022) focussed on additional and targeted strategies to better engage patients and their families in patient safety, in the important area of infection prevention.

Digital solutions for streamlining workflows in the practice of medicine in general and infection control more specifically, have gained recognition in recent years. (Martischang *et al.,* 2020) In present outbreak, it was reported that housekeeping staff were not diluting the disinfectant as per the instructions. Installing the automated dilutor pumps assured that solution used for cleaning is prepared as and when required and correctly diluted. Hence, maintaining the efficacy consistently throughout the day and improved standards in cleaning and disinfection. In addition, to understand the significance of automation, further evidence based studies required.

In other reported outbreaks, *A. baumannii* was grown from sink and water tap (Hong *et al.,* 2012), patient environment. (Thom *et al.,* 2011; Jamal *et al.,* 2009; Choi *et al.,* 2010) The isolates from patients and environmental source showed a very similar antimicrobial susceptibility pattern. This suggested that the index patient admitted from other healthcare facility had carried that strain and transmitted to other patients and in the environment. It is important to identify the source by determining microbial genetic relatedness. However, in present outbreak, strains were compared based on their pattern of susceptibility to antibiotics only. Hence, molecular typing should be done to understand the common clone that caused the outbreak. On the contrary, Senok *et al.,* (2015) reported the presence of multiple environmental clones that was suggestive of environmental source dissemination via healthcare workers within the ICU. Besides bacterial pathogens, there is a need to cover viruses and fungi too in environmental surveillance.

Early involvement of management, patient segregation, environment surveillance, increased infection control measures and clinical vigilance controlled this outbreak. Enoch *et al.,* (2008) also reported a multidisciplinary approach to control outbreak control. Tsiatsiou *et al.,* (2015) reported that active surveillance and enhanced infection control measures effectively contained spread of CRAB clone in the neonatal intensive care unit.

The present outbreak investigation has few limitations. First, molecular typing of isolates were not done to check the genotype. An accurate and reliable typing method required for outbreak investigation. Sampling was done for checking bacterial contamination only.

Second, due to small numbers of infected patients, association between exposure to certain risk factors could not be detected. Third, incidence of CRAB cases outside the ICU were not traced during outbreak, this may led to underestimation of CRAB prevalence in the hospital.

The incidence of CRAB outbreak in ICU stresses the importance of strict adherence to infection control practices and education of staff for behavioural modification. By automating certain steps in infection prevention can streamline workflow and thereby save time and human resources.

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