Infection Control in Intensive Care Units

Chiranjay Mukhopadhyay^{1,2}

¹Department of Microbiology, Kasturba Medical College, ²Department of Infection Control and Management, Kasturba Hospital, Manipal, Karnataka, India

Abstract

Infections acquired in the hospitals, especially in the intensive care unit (ICU) settings, ranging between 15% and 20%, may further lead to complications in >40% in critically ill patients. The order of incidence may vary in different settings, but the most usual causes are ventilator-associated pneumonia, intravascular catheter-associated bloodstream infection, catheter-associated urinary tract infection, posttraumatic intra-abdominal infection, and surgical site infection. These can be prevented by adequate and appropriate application of preventive strategies, which can be implemented strictly at the bedside. The basic norms for surveillance strategies, general preventive measures such as standard and isolation precautions and monitoring of antibiotic use should be followed without fail. Specific practical measures for ICU-related infections should be in place, and the monitoring of activities should be documented regularly as “bundle-care” in view of standardizing the practice, irrespective of place or person. Adequate attention, unfortunately, has not been paid for infection control measures in India for years. It is now mandatory that the essential practices are prioritized and integrated fully into regular hospital administrative procedure as a continuous process for improving quality health care.

Keywords: Handwashing, hospital-acquired infections, infection control, surveillance

INTRODUCTION

Effective control of infection in the hospital, especially in the intensive care unit (ICU) set up, is always challenging; it not only demands adequate awareness and constant vigilance among the health-care workers (HCWs) but also needs a multidisciplinary approach to handle the management and control of infection in every patient. The WHO estimates that the rate of hospital-acquired infections (HAIs) is 7%–12% among hospitalized patients all over the world, where >1.4 million people had infection-related complications during their stay in the hospital at any time.^[1-3] The recent Centers for Disease Control report about HAI rates among National Acute Care Hospitals in USA (2014 data, published in 2016) informs us that there is a decrease in Central Line-Associated Bloodstream Infections (CLABSI) between 2008 and 2014, whereas no change was observed in overall Catheter-Associated Urinary Tract Infection between 2009 and 2014.^[4] It is also reported that there is 17% decrease in surgical site infection (SSI) related to 10 selected procedures, with special mention of 17% decrease in abdominal hysterectomy SSI, and 2% decrease in colon SSI in 6 years (2008–2014). The rate of hospital-onset *Clostridium difficile* infection has come down by 8% and hospital-associated methicillin-resistant

Staphylococcus aureus (MRSA) bacteremia by 13% between 2011 and 2014. In 2011, there were an estimated 722,000 HAIs in USA acute care hospitals, out of which, about 75,000 patients died with HAIs occurred outside the ICUs. It has been predicted that appropriate steps to control and prevent HAIs in a variety of settings, by creating awareness among individual doctors and nurses may decrease some targeted HAIs (e.g., CLABSI) by >70%.

The burden of HAIs is more in the developing countries, with highest prevalence in the ICUs. A prospective, multicentric, and cohort surveillance study of device-associated infection as conducted by International Nosocomial Infection Control Consortium (INICC) in 55 ICUs of 8 developing countries including India revealed the overall rate of 14.7% HAIs corresponding to 22.5 infections/1000 ICU days.^[5] In 2007, the INICC conducted prospective surveillance from 12 ICUs in 7 different cities showed that the overall HAI incidence rate of 4.4% (9.06 infections per 1000 ICU days), where a total of

Address for correspondence: Dr. Chiranjay Mukhopadhyay, Department of Microbiology, Kasturba Medical College, Manipal - 576 104, Karnataka, India.
E-mail: chiranjay.m@manipal.edu

Access this article online

Quick Response Code:

Website:
www.ijrconline.org

DOI:
10.4103/ijrc.ijrc_9_17

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

How to cite this article: Mukhopadhyay C. Infection control in intensive care units. Indian J Respir Care 2018;7:14-21.

10,835 patients were studied for 52,518 days.^[6] Indian data on HAI during 2004–2012 showed that the HAI rates vary from 4.36% to 83.09% with infections per 1000 patient days ranging from 6.16 to 40.66.^[7] HAIs account for major causes of disability of the patient's functional aspects, economic burden, emotional suffering, and never the least, death among the hospitalized patients.^[2,8] The crude fatality rate in the INICC survey in India and other developing countries varies between 35.2% and 44.9%.^[5] The HAIs are mostly due to multidrug-resistant (MDR) hospital environmental flora, which demands the use of higher antibiotics for a longer duration. As a consequence, there is more chance of developing higher selection pressure and further development of resistance to reserved antibiotics, leading to increased length of stay for infected patients and increased chance of mortality.^[9] Moreover, use of higher-end antibiotics such as carbapenems, colistin, tigecycline, vancomycin, linezolid, and daptomycin to combat MDR HAIs increase the health-care cost immensely due to an increased need for isolation and the use of additional laboratory and diagnostic tools.

In the European Prevalence of Infection in Intensive Care Study, increased mortality rate is independently associated with laboratory-confirmed bloodstream infection, pneumonia, and clinical sepsis.^[10,11] However, other additional predictors of mortality such as APACHE (acute physiology and chronic health evaluation)–II score >20, prolonged (>21 days) ICU stay, age >60 years, the presence of organ failure or hospital admission, and cancer as comorbidity also play a significant role. The scoring systems (most widely used APACHE II/III) are more suitable to predict mortality, rather than predicting HAIs. On the other hand, understaffing and overcrowding in ICUs, type of nutrition (for example, catheter-related bloodstream infection (CRBSI) is apparently associated with total parenteral nutrition in critically ill patients), mechanical ventilation, length of stay, and ratio of nurse to patient were found to be major independent contributors for HAIs.^[10] Cross-transmission was facilitated by understaffing and overcrowding, along with carriage of Gram-negative fecal flora, leading to outbreak.^[12–18]

MICROBIOLOGY OF INFECTIONS IN INTENSIVE CARE UNITS

As microbiology and pathophysiology of infections are common, there is a continuous shift toward more resistant strains over years, which includes MRSA, vancomycin-resistant enterococci (VRE), extended-spectrum beta-lactamases (ESBLs), carbapenems-resistant *Enterobacteriaceae* (CRE), colistin-resistant acinetobacter, and fluconazole-resistant *Candida* spp. These pathogens play a major role in HAIs, especially in ICUs, but the factors responsible for this evaluation are yet to be understood fully. However, antibiotic pressure certainly plays a major role. Selective pressure due to prolonged antibiotic exposure constitutes an independent risk factor which determines the colonization and infection status of MDR organisms (MDROs) in ICUs. It has been well-emphasized

in a study, where cephalosporin-based prophylaxis was given in 2,641 consecutive patients who had undergone heart surgery for over 5 years.^[19] Prolonged prophylaxis (>48 h), as compared to short-term prophylaxis, is not encouraged since it is not associated with decreased risk of SSI; it, on the other hand, is clearly associated with increased risk of colonization with MDROs.

CLASSIFICATION OF INTENSIVE CARE UNIT INFECTIONS

Infections in ICUs are always crucial and need to be classified for any surveillance program. A time cutoff of 48 h has generally been accepted to distinguish between community-acquired and HAIs from the practical point of view. However, it might not be always a “true” HAI if it develops after 48 h of ICU stay, since the causative microorganism may not belong to the ICU microbial ecology, rather imported by the patient as normal flora of his/her body. The “traditional” approach is challenged with the concept of “carrier state,” when genotypically similar strains grew repeatedly at any concentration from samples taken on admission and then afterward twice weekly from body sites such as throat or rectal swab taken for surveillance purpose to detect potentially pathogenic microorganisms (PPMs).^[20] On the other hand, clinical samples are collected from the superficial sites of suggestive infection and from internal organs which are normally sterile such as lower respiratory tract, blood, and bladder while diagnosing local infections or systemic infections, respectively.^[20] The HAI has been classified on the basis of carrier status and diagnostic cultures as follows:

Primary endogenous infections

This is the most frequent form of infection in the ICUs, with an incidence between 50% and 85%, that occurs usually early, during the 1st week of ICU stay.^[21–26] These may consist of both normal and abnormal PPMs and may be imported in the ICUs during admission of the patient.

Secondary endogenous infections

These usually occur after 1 week of ICU stay by aerobic MDR Gram-negative bacilli and Gram-positive cocci, especially MRSA and VRE. It accounts for one-third of all ICU infections.^[21–26] These PPMs are first colonized in the oropharynx, and subsequently, in the stomach and the intestine, which can be prevented by the topical applications of nonabsorbable antimicrobials.

Exogenous infections

These are approximately 15% of all ICU-acquired infections, which are caused by the abnormal hospital PPMs at any time during the patient's stay in the ICU.^[21–26] *Acinetobacter* infection of lower respiratory tract of the patients is the typical example, especially when the patient is on long-standing ventilator care. Surveillance samples may be negative for the microorganisms, but they readily appear in the clinical samples. These type of infections are difficult to treat, rather more feasible to control by high level of hygiene.^[23]

According to the criterion, ICU-acquired infections are only secondary endogenous and exogenous infections, whereas primary endogenous infections are usually imported by the patient while during admission.

SURVEILLANCE OF INFECTIONS IN INTENSIVE CARE UNITS

The surveillance has been recognized as the major component of infection control since late 1970s. It has been observed that there was a decrease in HAI rates on average 32% in hospitals with well-documented surveillance program in place over a 5-year period as compared with an increase of 18% in other hospitals without any such program.^[27] Epidemiological intervention following surveillance, control at the administrative level for medical devices used for critical patients as well as for the HCWs working in hospital setups, and also, control of biomedical engineering parameters are among others, the major distinct surveillance components in controlling HAIs [Table 1].^[10]

There can be total surveillance all over the hospital, which includes routine collection, tabulation, analysis, and circulation of data regarding the prevalence of HAIs in specified areas. Target-oriented surveillance usually is restricted to objectives on the priority basis as decided in the local settings, for example, control of the spread of MDR Gram-negative bacteria in developing countries, MRSA in the developed countries or reduction of the incidence of CRBSI or urinary tract infections, which are universal problem in every setting. Last but not the least, infection-specific surveillance targets toward particular types of infection-related events, for example, surveillance of outbreaks or generating antibiogram in the

microbiology laboratory while formulating antibiotic policy in the hospital [Table 2].^[10] There are a number of definite tools which are applied for infection control in ICU: Chart review, Laboratory Data, ICU Documents Review, Temperature, Antibiotics Review, Readmission, and Autopsy [Table 2]. The time required to implement these tools may vary according to the number of beds under surveillance.

In practical terms, optimal use of the resources in resource-limited settings, relentless monitoring of different infections, especially due to MDROs, to detect and control outbreaks are essential for both specific and emergency measures, which may further help design targeted programs to reduce number of HAIs.^[28]

Critical care bundle therapy

A “Bundle” is a structured way to improve patient care and outcomes by following straightforward, well-defined, checklist-based set of evidence-based practices and it is an essential part of surveillance for infection in ICUs. The bundles which are prepared as an objective, bedside practice-based approach with 3–5 elements in each have shown significant reduction in HAIs and improvement in patient outcomes. The Institute of Healthcare Improvement, USA has with the power of providing a reliable, best possible health care for patients without any chance of infection from the setting itself, only when executed with complete consistency. The bundles are derived from well-established practices. Failure of execution of bundles most often makes the treatment unreliable, at times idiosyncratic. There is a clear-cut impact of successfully implemented bundle if it is followed religiously and regularly as a continuous process. It is all or none, for example, “Yes, I completed the ENTIRE bundle” or “No, I did not complete the ENTIRE bundle.”

Table 1: Elements of surveillance applied to infection control in Intensive Care Units

Elements of surveillance	Specific items
Engineering controls	Adequate space around beds Individualised cubicles (provided optimal nurse-to-patient staffing ratio is allocated) Adequate sink/hand hygiene facilities' location Isolation rooms in each ICU Identified traffic circuits for clean and dirty equipment and/or activities
Administrative controls for medical equipment	Procedures for introduction of new materials/devices Written cleansing protocols for multiple use material Routine application of guidelines for the appropriate use of medical devices
Administrative controls for healthcare personnel	Continuous postgraduate medical education to learn new technologies and the proper use of new medical devices and procedures Maintain the presence of highly skilled HCWs by extensive training of replacement workers In-depth training on infection control procedure Recommendation for nurse/patient staffing ratio Monitoring quality of patient care using defined indicators
Administrative controls for patients	Guidelines for ICU admission Epidemiological surveillance of nosocomial infection rates and reporting Total surveillance Surveillance by objective (targeted to selected wards, infections or pathogens) Outbreak surveillance and control Computerised surveillance of lab data (targeted on resistance, device use) Guidelines for patient isolation

Table 2: Concepts and tools for surveillance of hospital acquired infections

Surveillance	Description	Sensitivity (%)	Time required h/wk/500 beds
Concepts			
Total	Routine collection, tabulations, analysis and dissemination of all information on the occurrence of Nis in a specified ward and/or hospital		
Target-oriented	Surveillance is restricted to priority-specific objectives, such as the control of the spread of MRSA or reduction of the incidence of catheter related infections		
Infection-specific	Surveillance is limited to particular types of infection such as outbreaks, or to specific laboratory data dealing with the resistance pattern of microbiological isolates		
Tools			
Chart review	Complete review of all charts, including laboratory data	74-94	36-54
Laboratory data	Identification of all patients with positive microbiological cultures	77-91	23
Ward documents review	Identification of patients at risk	75-94	14-22
Temperature	Identification of all patients with a body temperature $\geq 37.8^{\circ}\text{C}$ and receiving antibiotics	9-56	8
Antibiotics	Review of all patients receiving antibiotics	57	14
Temperature and antibiotics	Review of all patients with a body temperature $\geq 37.8^{\circ}\text{C}$ and receiving antibiotics	70	13
Readmission	Review of all patients readmitted	S	NA
Autopsy	Review of all autopsied patients	S	1

NA: Not available

Table 3: Requirements of standard precautions*

Requirement	Field of application
Hand hygiene	After direct contact with blood, body fluid, secretion, excretions and contaminated items, immediately before gloving and after gloves removed
Gloves	Between patient contacts and between dirty and clean body site contact in the same patient For anticipated contact with blood, body fluid, secretion, excretion and contaminated items For anticipated contact with mucus membranes and nonintact skin
Mask, eye protection, face shield	To protect mucous membranes of the eyes, nose and mouth during procedures and patient-care activities likely to generate episodes or sprays of blood, body fluid secretions or excretions
Gowns	To protect skin and prevent soiling of clothing during procedures and patient-care activities likely to generate splashes or spray of blood, body fluid secretions or excretions
Patient care equipment	Soiled devices, linen, or clothing should be handled to prevent skin and mucus membrane exposure and transfer of micro-organisms to the environment Reusable devices should be cleaned and reprocessed according to hospital policy
Sharp objects	Avoid recapping used needles Avoid removing used needles from disposable syringes by hand Avoid bending, breaking, or manipulating used needles by hand Place used sharp objects and needles in puncture-resistant containers

*Also available online at <http://www.cdc.gov/ncidod/hip/isolat/isolat.htm>

There is no credit for partial completion (doing few steps for once or some days).

At least, there are two bundles which need to be implemented in all ICUs at the initial stage:

Central line maintenance bundle

The following steps may help prevent CLABSI: (1) Daily review of line necessity, (2) Hand hygiene before manipulation of the intravenous (IV) system, (3) Daily inspection of the insertion site, (4) Catheter-site care, and (5) Alcohol scrub of insertion hubs for 15 s before each use.

Ventilator bundle

Ventilator-associated pneumonia is a well-encountered infection of lower respiratory tract, which may have a fatal outcome for the patients who are receiving mechanical ventilation, especially for longer duration. The ventilator bundles have following steps: (1) Elevation of the head end of the bed between 30° and 40° , (2) Mouth care with 1%–2% Chlorhexidine (6 h), (3) Subglottic aspiration 1–2 h, (4) Daily sedation vacation, (5) Daily assessment of readiness to wean, (6) Daily spontaneous breathing trial, (7) Peptic ulcer disease prophylaxis, and (8) Deep venous thrombosis prophylaxis.

Control and prevention of infections in intensive care units

Prevention plays a major role in the control of infections in ICUs, which can be implemented through various guidelines. However, the main approaches are schematized as follows: First, the potential sources of pathogens which may be responsible for transmitting infection from one patient to another, or to HCWs need to be identified and controlled, and the techniques to prevent cross-contamination such as proper cleaning, disinfection, and maintenance of various equipment or devices need to be documented and practiced; second, for selected group of patients, who need surgical antibiotic prophylaxis or empirical therapy guidelines need to be in place and strictly in use; third, appropriate strategies to restrict the use of higher antibiotics and prevent the emergence of MDROs need to be implemented and followed up at regular interval to check the effectiveness. Added to this, some more measures which are specifically targeted to curb the infections in ICUs are listed below:

Isolation practices

It has been documented that >50% patients while being admitted in ICUs have already been colonized with the potential pathogens that are responsible for infection in due course subsequently.^[10] A prospective observational study from a tertiary care center from the southern part of India showed that there were 4.28% MRSA, 18.58% ESBL *Enterobacteriaceae*, and 2.65% VRE asymptomatic carriers among 210 newly admitted adult patients;^[29] among them, 14.28% had monobacterial carrier stage. Although surgical admissions were more at risk (5.03 times; 95% CI: 1.3–19.6; $P = 0.023$) than medical, and 55.5% MRSA carriers, 61.9% ESBL *Enterobacteriaceae* carriers, and 100% VRE carriers underwent invasive procedures including surgery, IV or urinary catheterization, there was no evidence of infection due to their colonization status. However, some patients may acquire the infection from the hospital environment. Microorganisms can be transmitted by air-borne, tiny droplets or large-particle droplets, or by direct contact. Patients who are detected as colonizer or carrier of MDROs through active surveillance are isolated, either by nurse cohorting or contact isolation, so that the potential pathogens are not transmitted to other patients. The responsibility lies with the HCWs, who need to wear gown and gloves and wash their hands for all 5 moments as recommended by the WHO at the bedside as a mandatory practice to prevent transmission to other patients, especially to the patient who is designated to be on contact precautions. Airborne infection isolation rooms are set at the negative pressure (> -2.5 Pa) with >12 air exchanges per hour for airborne disease patients to prevent transmission of airborne microorganisms from the room to the adjacent rooms or corridors. Protective environment rooms housing severely neutropenic patients are set at the positive pressure ($> +2.5$ Pa) with >12 air exchanges per hour so that the airborne pathogens are not able to come from adjacent rooms, spaces, or corridors to contaminate the airspace occupied by such high-risk patients. It may further

be enforced by self-closing doors, which may help maintain the correct pressure difference.

Standard precautions

Ignaz Semmelweis, the obstetrician from Vienna >150 years ago, used chlorinated lime water as the first ever example of systemic hand disinfection while examining patients and showed a dramatic reduction of mortality related to puerperal fever. Since then, routine hand washing before and after patient contact remains the most important infection control measure.^[30,31] Transmission of exogenous *Staphylococcus* or other potential pathogens, especially in the ICUs where patient care necessitates frequent contact, by the hands of HCWs is well-documented.^[18,32–36] Higher contamination was documented with handling of the body fluid secretions, respiratory care, maintaining devices, or in any such occasions where the sequence of patient care is interrupted. Standard precautions like hand hygiene, wearing gloves, mask, protective gears, and gowns should be mandatory requirements in any hospital setting [Table 3].^[10] Appropriate hand disinfection before patient care may reduce 68 CFU of bacterial load, independent of the types of care provided and the location of the hospital.^[37] ICUs all over the world have always had a low-level compliance with hand hygiene, hardly exceeding 40%; lame excuses given are higher priority work over required hand-wash procedures, less time, inconvenient approach to hand wash facility, allergy or intolerance to hand-hygiene solutions, lack of leadership from administration, etc.

Alcohol-based hand rubs using antimicrobial agents such as chlorhexidine, instead of hand washing with alcohol and soap reduces the rate of HAIs more efficiently.^[38,39] Gloves must be used for any anticipated contact with blood or body fluids, mucous membrane, nonintact skin, secretions, and moist body substances of all patients.^[40] Gloves should be changed between contacts with the patients; in addition, gowns and masks may protect mucous membranes of the eyes, nose, and mouth from splashes or sprays of blood, body fluid secretions, and excretions during procedures and patient care activity [Table 3].^[41]

In addition to standard precautions, there were other precautions such as airborne, contact, droplet to prevent transmission of microorganisms. The droplet nuclei with <5 μm in size may remain suspended in the air for long periods and can travel long distance in patients with pulmonary tuberculosis, varicella and disseminated zoster, acute viral hemorrhagic fever, H1N1 influenza, or measles. These patients should be placed in a private room with negative air pressure.^[42] High-efficiency masks such as N-95 standard are required for HCWs or visitors, and also for the patient during transport outside the specified room.

When the infective microorganisms can be transmitted by larger particles (>5 μm in size) during coughing, sneezing and talking, or during invasive procedures such as bronchoscopy, pleural tap, endotracheal or tracheal aspiration, and suctioning, droplet precaution needs to be adopted. There

are cases with *Haemophilus influenzae* type B, meningococci, MDR pneumococci or any other MDROs in respiratory tract (e.g., MRSA, ESBLs, CRE), pharyngeal diphtheria, mycoplasma pneumonia, and some viral diseases such as Adeno, Influenza, Mumps, Parvo B-19, and Rubella, where the microorganisms may be inhaled or can be deposited on the mucous membrane of host's eyes, nose, and mouth.^[10] However, a HCW must wear a mask when he/she comes in contact within 60 cm to 1 m of any such patient.

If suitable isolation room or a private room is unavailable in any hospital, the patient for airborne or droplet precautions may be cared for in cohort with another patient infected with the same organism. However, like airborne precautions, special air handling and ventilation are not necessary in case of droplet precaution.^[10] Few PPMs such as MRSA, VRE, ESBLs, CRE, or *C. difficile* can be transmitted by direct physical contact or indirect contact with the patient's environment. It is mandatory for the HCWs that they should wear gloves and gowns and discard them properly before leaving the room. Systematic hand hygiene measures should be strictly maintained before and after the examination or procedure. Patient care devices such as stethoscopes, blood pressure cuffs, and knee hammer should be rigorously cleaned and disinfected before being used on another patient. If the patient is immunocompromised or severely neutropenic, separate isolation room facility in a private room with filtered air instilled in positive pressure should be provided. However, due to lack of proper infrastructure in overcrowded hospitals in the developing countries, even shifting the patient to the corner of the ward or ICU with strict barrier nursing practice may suffice the requirement. Patients who are readmitted to the same hospital or are transferred from other hospital are possibly carrying and transmitting MDROs. These patients should be screened on admission and be segregated in isolation if they have any infection with PPMs during readmission.

Control of antimicrobial uses

The misuse of antimicrobial agents is one of the major determinants in the evolution of MDR strains in the hospital settings. Several strategies such as optimal use of the antimicrobial agents, strict implementation of antibiotic policy, removal or restriction of higher/reserve antibiotics from routine use as empirical agents, use of antimicrobial agents in combination, and cycling of the antibiotics have been tried to curb the misuse of the antimicrobial agents and control the emergence of resistance. However, it is already established that selection of antimicrobial agents is crucial at the bedside. There is always definitive therapy for proven infections, which is determined according to the antimicrobial sensitivity report. In few selective occasions, there is prophylaxis for specific infections, which is uniformly standardized all over the world. In case of empirical therapy for suspicion of infection, which constitutes the large majority of cases, there is always a chance of misuse of antibiotics, unless there is a local antibiotic policy in place. It may be essential in a few occasions, considering

the high mortality and morbidity associated with nosocomial infection with MDROs that early empirical broad-spectrum antimicrobial coverage for critically ill patients needs to be started. However, every empirical therapy should be guided by hospital antibiotic policy, prepared on the basis of local antibiotic susceptibility data, and has to be reevaluated based on the initial culture results and clinical response of the patients after 48–72 h. In a study with patients suffering from pneumonia, either community or hospital-acquired, it is found that the mortality rate of patients receiving inadequate treatment (52%) was significantly higher than that for those receiving adequate treatment (12%).^[43] Guidelines for systematic evaluation of fever in critically ill patients to recognize nosocomial infection at the earliest along with implementation of antibiotic policy reduce cost and mortality of the patients in medical and surgical ICUs. It is essential to have a good knowledge of the total epidemiology and resistance profile of the hospital and community pathogens, and to have a multidisciplinary approach, which includes clinical microbiologists and experts in Infectious Diseases and Infection Control to solve the challenging cases.

Attitudes of health-care workers toward infection control

It has been emphasized that control of the HAIs is mainly related to teamwork and leadership. Moreover, there should be effective communication in place and guidelines to be followed to improve patient care. However, implementation is difficult in clinical practice, since most guidelines, requirements, and measures are unpopular with HCWs, who have to practice them at the bedside. It depends on the quality of a successful leader or the “Champion,” where an organized team under a leadership brings the changes through interaction and communication on daily basis. It is not as easy as it sounds and it is probably because noncompliance is connected with the yearning of human being for liberty.^[44] Noncompliance as related to several aspects of human behavior may include the false perception of an impending risk, or the underestimation of individual responsibility in the epidemiology of the institution, or passive attitudes regarding the increased complexity of the process of care, nor the least, the negative impact of the socioeconomic constraints that are responsible for understaffing.^[44]

CONCLUSION

It is estimated that more than one-third of HAIs are acquired in various ICUs, which roughly accounts for a crude incidence of 15%–40% of all hospital admissions.^[45] Although infection is not always the single most cause for mortality for patients in ICUs, it is definitely associated with increased length of stay and excessive hospital cost.^[11,43,46,47] An improved knowledge of clinical epidemiology, microbial etiology, and pathophysiology of the disease will help understand the concepts of infection control, and thereby, the right use of antibiotics. In developing countries, where rapid turnover of workforce, lack of structured ICUs, and inadequate awareness of infection control practices are predominant, prevention of HAIs in the ICUs to provide better health care is always a challenge. Infection control in an

ICU or in a hospital can never be stand-alone actions; rather it should be a part of everyday flow of work, where HCWs must be focused on it as part of their essential duty, for the patients and for themselves as well.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

- WHO. Prevention of Hospital Acquired Infections: A Practical Guide. 2nd ed. World Health Organization; 2002. Available from: http://www.who.int/csr/resources/publications/whodcscreph_200212.pdf. [Last accessed on 2017 Mar 31].
- Patel DA, Patel KB, Bhatt SK. Surveillance of hospital acquired infection in surgical wards in tertiary care centre Ahmedabad, Gujarat. *Natl J Commun Med* 2011;2:340-5.
- Saleem M, Kumar VA, Zafar IM, Arun SA, Agarwal J, Singh M, *et al*. Pattern of nosocomial infection among patients admitted in medical and surgical wards of a secondary care hospital in north India, an epidemiological evaluation. *Indian Journal of Community Health*. 2013; 24:285-90.
- CDC's National Healthcare Safety Network (NHSN). Available from: <https://www.cdc.gov/hai/surveillance/index.html#nhsn1>. [Last updated on 2016 Oct 25].
- Rosenthal VD, Maki DG, Salomao R, Moreno CA, Mehta Y, Higuera F, *et al*. Device-associated nosocomial infections in 55 Intensive Care Units of 8 developing countries. *Ann Intern Med* 2006;145:582-91.
- Mehta A, Rosenthal VD, Mehta Y, Chakravarthy M, Todi SK, Sen N, *et al*. Device-associated nosocomial infection rates in Intensive Care Units of seven Indian cities. Findings of the international nosocomial infection control consortium (INICC). *J Hosp Infect* 2007;67:168-74.
- Ramasubramanian V, Iyer V, Sewlikar S. Epidemiology of healthcare acquired infection – An Indian perspective on surgical site infection and catheter related blood stream infection. *Indian J Basic Appl Med Res* 2014;3:46-63.
- Sensitizing People about Hospital- Acquired Infections; 09 February, 2006. Available from: <http://www.thehindu.com/2006/02/09/stories/2006020912040400.htm>. [Last accessed on 2012 Mar 23].
- Ganguly NK, Arora NK, Chandy SJ, Fairuze MN, Gill JP, Gupta U, *et al*. Rationalizing antibiotic use to limit antibiotic resistance in India. *Indian J Med Res* 2011;134:281-94.
- Eggimann P, Pittet D. Infection control in the ICU. *Chest* 2001;120:2059-93.
- Vincent JL, Bihari DJ, Suter PM, Bruining HA, White J, Nicolas-Chanoine MH, *et al*. The prevalence of nosocomial infection in Intensive Care Units in Europe. Results of the European prevalence of infection in intensive care (EPIC) study. EPIC international advisory committee. *JAMA* 1995;274:639-44.
- Donchin Y, Gopher D, Olin M, Badihi Y, Biesky M, Sprung CL, *et al*. A look into the nature and causes of human errors in the Intensive Care Unit. *Crit Care Med* 1995;23:294-300.
- Giraud T, Dhainaut JF, Vaxelaire JF, Joseph T, Journois D, Bleichner G, *et al*. Iatrogenic complications in adult Intensive Care Units: A prospective two-center study. *Crit Care Med* 1993;21:40-51.
- Tarnow-Mordi WO, Hau C, Warden A, Shearer AJ. Hospital mortality in relation to staff workload: A 4-year study in an adult Intensive-Care Unit. *Lancet* 2000;356:185-9.
- Haley RW, Bregman DA. The role of understaffing and overcrowding in recurrent outbreaks of staphylococcal infection in a neonatal special-care unit. *J Infect Dis* 1982;145:875-85.
- Haley RW, Cushion NB, Tenover FC, Bannerman TL, Dryer D, Ross J, *et al*. Eradication of endemic methicillin-resistant *Staphylococcus aureus* infections from a neonatal Intensive Care Unit. *J Infect Dis* 1995;171:614-24.
- Robert J, Fridkin SK, Blumberg HM, Anderson B, White N, Ray SM, *et al*. The influence of the composition of the nursing staff on primary bloodstream infection rates in a surgical Intensive Care Unit. *Infect Control Hosp Epidemiol* 2000;21:12-7.
- Vicca AF. Nursing staff workload as a determinant of methicillin-resistant *Staphylococcus aureus* spread in an adult intensive therapy unit. *J Hosp Infect* 1999;43:109-13.
- Harbarth S, Samore MH, Lichtenberg D, Carmeli Y. Prolonged antibiotic prophylaxis after cardiovascular surgery and its effect on surgical site infections and antimicrobial resistance. *Circulation* 2000;101:2916-21.
- Sarginson RE, Taylor N, van Saene HK. Glossary of terms and definitions. *Curr Anaesth Crit Care* 2001;12:2-5.
- Murray AE, Chambers JJ, van Saene HK. Infections in patients requiring ventilation in intensive care: Application of a new classification. *Clin Microbiol Infect* 1998;4:94-9.
- Silvestri L, Monti Bragadin C, Milanese M, Gregori D, Consales C, Gullo A, *et al*. Are most ICU infections really nosocomial? A prospective observational cohort study in mechanically ventilated patients. *J Hosp Infect* 1999;42:125-33.
- Petros AJ, O'Connell M, Roberts C, Wade P, van Saene HK. Systemic antibiotics fail to clear multidrug-resistant *Klebsiella* from a pediatric ICU. *Chest* 2001;119:862-6.
- de La Cal MA, Cerdá E, García-Hierro P, Lorente L, Sánchez-Concheiro M, Díaz C, *et al*. Pneumonia in patients with severe burns: A classification according to the concept of the carrier state. *Chest* 2001;119:1160-5.
- Silvestri L, Sarginson RE, Hughes J, Milanese M, Gregori D, Van Saene HK, *et al*. Most nosocomial pneumonias are not due to nosocomial bacteria in ventilated patients. Evaluation of the accuracy of the 48 h time cut-off using carriage as the gold standard. *Anaesth Intensive Care* 2002;30:275-82.
- Sarginson RE, Taylor N, Reilly N, Baines PB, Van Saene HK. Infection in prolonged pediatric critical illness: A prospective four-year study based on knowledge of the carrier state. *Crit Care Med* 2004;32:839-47.
- Haley RW, Culver DH, White JW, Morgan WM, Emori TG, Munn VP, *et al*. The efficacy of infection surveillance and control programs in preventing nosocomial infections in US hospitals. *Am J Epidemiol* 1985;121:182-205.
- Pittet D, Safran E, Harbarth S, Borst F, Copin P, Rohner P, *et al*. Automatic alerts for methicillin-resistant *Staphylococcus aureus* surveillance and control: Role of a hospital information system. *Infect Control Hosp Epidemiol* 1996;17:496-502.
- Albert RK, Condie F. Hand-washing patterns in medical Intensive-Care Units. *N Engl J Med* 1981;304:1465-6.
- Vandana KE, Varghese G, Krishna S, Mukhopadhyay C, Kamath A, Ajith V, *et al*. Screening at admission for carrier prevalence of multidrug-resistant organisms in resource-constrained settings: A hospital-based observational study. *J Hosp Infect* 2010;76:180-1.
- Goldmann D, Larson E. Hand-washing and nosocomial infections. *N Engl J Med* 1992;327:120-2.
- Huebner J, Pier GB, Maslow JN, Muller E, Shiro H, Parent M, *et al*. Endemic nosocomial transmission of *Staphylococcus epidermidis* bacteremia isolates in a neonatal Intensive Care Unit over 10 years. *J Infect Dis* 1994;169:526-31.
- Coudron PE, Mayhall CG, Facklam RR, Spadora AC, Lamb VA, Lybrand MR, *et al*. *Streptococcus faecium* outbreak in a neonatal Intensive Care Unit. *J Clin Microbiol* 1984;20:1044-8.
- Finkelstein R, Reinhertz G, Hashman N, Merzbach D. Outbreak of *Candida tropicalis* fungemia in a neonatal Intensive Care Unit. *Infect Control Hosp Epidemiol* 1993;14:587-90.
- Chang HJ, Miller HL, Watkins N, Arduino MJ, Ashford DA, Midgley G, *et al*. An epidemic of *Malassezia pachydermatis* in an intensive care nursery associated with colonization of health care workers' pet dogs. *N Engl J Med* 1998;338:706-11.
- Goldmann DA, Leclair J, Macone A. Bacterial colonization of neonates admitted to an intensive care environment. *J Pediatr* 1978;93:288-93.
- Pittet D, Dharan S, Touveneau S, Sauvan V, Perneger TV. Bacterial contamination of the hands of hospital staff during routine patient care. *Arch Intern Med* 1999;159:821-6.
- Ehrenkranz NJ, Alfonso BC. Failure of bland soap handwash to prevent hand transfer of patient bacteria to urethral catheters. *Infect Control*

- Hosp Epidemiol 1991;12:654-62.
39. Doebbeling BN, Stanley GL, Sheetz CT, Pfaller MA, Houston AK, Annis L, *et al.* Comparative efficacy of alternative hand-washing agents in reducing nosocomial infections in Intensive Care Units. *N Engl J Med* 1992;327:88-93.
40. Patterson JE. Isolation of patients with communicable diseases. In: Mayhall G, editor. *Hospital Epidemiology and Infection Control*. Baltimore, MD: Williams & Wilkins; 1996. p. 1032-51.
41. Garner JS. Guideline for isolation precautions in hospitals. The hospital infection control practices advisory committee. *Infect Control Hosp Epidemiol* 1996;17:53-80.
42. Guidelines for preventing the transmission of *Mycobacterium tuberculosis* in health-care facilities, 1994. Centers for Disease Control and Prevention. *MMWR Recomm Rep* 1994;43:1-32.
43. Kollef MH, Sherman G, Ward S, Fraser VJ. Inadequate antimicrobial treatment of infections: A risk factor for hospital mortality among critically ill patients. *Chest* 1999;115:462-74.
44. Farr BM. Reasons for noncompliance with infection control guidelines. *Infect Control Hosp Epidemiol* 2000;21:411-6.
45. Pittet D, Harbarth S. The Intensive Care Unit. In: Bennett JV, Brachman PS, editors. *Hospital Infections*. 4th ed. Boston, MA: Little, Brown and Co.; 1998. p. 381-402.
46. Pittet D, Tarara D, Wenzel RP. Nosocomial bloodstream infection in critically ill patients. Excess length of stay, extra costs, and attributable mortality. *JAMA* 1994;271:1598-601.
47. Fagon JY, Chastre J, Vuagnat A, Trouillet JL, Novara A, Gibert C, *et al.* Nosocomial pneumonia and mortality among patients in Intensive Care Units. *JAMA* 1996;275:866-9.