

INFECTION CONTROL IN INTENSIVE CARE UNIT

Intensive Care Units (ICUs) in a hospital make approximately 10% of the total bed strength of the hospital, but prevalence of hospital-acquired infection (HAI) is highest in ICUs than in wards. As per WHO estimate, HAIs is 7–12% among hospitalized patients all over the world.^{1–3} Data from Center for Disease Control and Prevention (CDC), National Nosocomial Infection Surveillance (NNIS) and International Nosocomial Infection Control consortium (INICC), HAIs in Indian hospitals have shown a prevalence rate of 4.3–83.9% with a death rate of 35.2–52.6%.⁴

Nosocomial infections (NIs) affect 5–35% of patients admitted to ICUs. Most common causes are catheter-associated urinary tract infection, intravascular catheter-associated bloodstream infection, ventilator-associated pneumonia, posttraumatic intra-abdominal infection and surgical site infection.¹

Presence of underlying comorbidities like diabetes, renal failure, malignancies predispose ICU patients to colonization and infection with multidrug resistant organisms (MDRO). Indwelling catheters like Central venous catheters, Foley's catheters, and Endotracheal tubes bypass the natural host defence mechanisms and serve as portals of entry for pathogens.^{5,6}

Nosocomial infections can be acquired either by endogenous or exogenous sources that include colonization of the host by methicillin resistant *Staphylococcus aureus* (MRSA), vancomycin resistant Enterobacteriaceae (VRE), azole resistant *Candida* species, *Clostridium difficile*, extended spectrum B lactamase (ESBL), carbapenem resistant Enterobacteriaceae, (CRE), and colistin resistant *Acinetobacter*.⁶

Ventilator-associated pneumonia (VAP), catheter-related bloodstream infections (CRBSI), surgical site infections (SSI), urinary catheter-related infections (UCRI) account for >80% of nosocomial infections and are major causes of morbidity and mortality. It might be due to microorganisms normally present as normal flora on the body of the patients which have become opportunistic pathogens.⁷

Prolonged ICU stay (>21 days), age >60 yrs, presence of organ failure at the time of hospital admission, frequent manipulations and contact with healthcare workers (HCWs) concurrently caring for multiple patients in ICU, prolonged hospital stay prior to ICU admission, more antibiotic exposure, prolonged ventilation, and low nurse to patient ratio are the major contributors of increased NIs in ICU. Understaffing and overcrowding in ICUs increase the risk of human errors, iatrogenic complications and even death.^{6–8}



Endogenous Infection^{9,10}

- **Primary:** It is the most frequent form of infection in ICU. It occurs early during the 1st week of ICU admission. It commonly consists of normal or abnormal potentially pathogenic microorganisms (PPMs) that are imported to ICU by the patients during admission. They may be carried in through skin, oropharynx, GI tract, use of invasive devices like IV cannulas, urinary catheters, nasogastric or ET intubation.
- **Secondary:** Usually it occurs at 1 week after ICU admission, caused by aerobic MDR gram-negative bacilli and gram-positive cocci, especially MRSA, VRE.

Exogenous Infection^{9–12}

It is caused by hospital's potential pathogenic microorganisms (PPMs) during the patient's stay in the ICU and accounts for approximately 15% of ICU-acquired infections. These infections are difficult to treat but can be controlled by high level of hygiene.

- **Surgical site Infection (SSI):** Infection occurring within 30 days of an operative procedure, characterized by pain, tenderness, localized swelling, redness/heat, pus or culture positive discharges from closed incisions, discharge of culture positive fluid or pus from beneath a drain.
- **Catheter-related bloodstream infections (CRBSIs):** Bacteremia or fungemia occurring as a result of insertion of a CVP line, IV cannula or arterial line and accounts to 19% of ICU infections.
- **Urinary tract infections (UTI):** It is characterized by +ve urinary culture for bacteremia, fever, urgency/frequency, dysuria, loin pain/supra-pubic pain or tenderness in the presence or absence of a catheter. It accounts for 31% of ICU infections, 95% occurring in catheterized patients.
- **Ventilator-associated pneumonia (VAP):** New radiographic infiltrates with fever (>38 C /<35 C), leukocytosis (>10000 or < 3500/c mm), purulent sputum or isolation of pathogenic bacteria from lower respiratory tract, accounting for about 27% of ICU infections.

Role of antibiotic use plays an independent risk for colonization of infection with both resistant gram +ve cocci and gram –ve bacilli.

Use of antibiotics can be divided into three categories.^{13,14}

1. Definitive therapy for proven infection.
2. Prophylaxis for specific infection.
3. Empirical therapy for suspected infection.

The inappropriate use of antibiotics, particularly cephalosporins increases the emergence of resistant strains of microorganisms. Any empirical treatment has to be reevaluated after 48–72 hrs, depending on the results of the initial culture and sensitivity results and clinical response. Automatic stop order after 72 hrs of empirical treatment has been proposed to curb this emergence. Monthly rotation of antibiotics, called antibiotic cycling, using four different B lactams combined with four different aminoglycosides, for the empirical treatment has also found to decrease the resistant strains of microorganisms.

The endemic transmission of exogenous staphylococci and other potential pathogens by the hands of healthcare workers is well documented and is of particular concern in the ICUs, where patient care necessitates frequent contact. Direct patient contact such as respiratory care, handling of body fluid secretions and interruption in the sequence of patient care, like, healthcare workers leaving the

patient's bedside to accomplish another task like attending a phone call and returning to resume care, carries higher risk of contamination and cross infection.

Urinary tract infection (UTI) is one of the most common complications in ICU accounting for up to 40% of the hospital-acquired infections, varying from 3.1 to 6.4 catheter-associated UTI per 1000 catheter days. The risk increases when a patient has indwelling catheter for a prolonged period. Yan Liu, et al. have investigated the effect of 10% povidone iodine with silver water in preventing catheter-related UTI before catheter insertion and found that 10% povidone iodine use before catheter insertion may not be beneficial for prevention of UTI.

WHO recommendation to control the spread of multidrug resistant microorganisms, especially vancomycin resistant Enterobacteriaceae (VRE), *Pseudomonas aeruginosa*, and *Acinobacter baumannii* is to remove sinks from ICU rooms since the hospital plumbing systems have been identified as reservoir of carbapenem resistant organisms.¹⁵⁻¹⁸

Chiang et al. in their meta-analysis of data from Taiwan, South Korea, and Japan, taking into account of surveillance protocols, hospital coverage rates and National Infection Prevention and Control (IPC) policies programs from 2008 to 2015, found that a significant decrease in HAIs (>50% reduction) by following multifaceted interventions such as hand hygiene, care bundles (well-defined, checklist-based, evidence-based practices prepared as bed-side practice approach, like strict aseptic precaution to prevent device or procedure associated infections) and antibiotic stewardship programs.¹⁹

Dr Ignaz Philipp Semmelweis, a Hungarian obstetrician from Vienna showed in 1847 that hand dips with chlorinated lime water decreased the incidence of puerperal sepsis in Vienna General Hospital drastically. This idea of routine hand washing before and after patient contact remains the most important infection control measures till today. Elementary bedside hand-disinfection results in a sustained improvement with hand hygiene and reduces infection rate by 50%. Alcohol-based hand rubs using chlorhexidine reduces the rate of HAIs more efficiently. Alcohols have rapid onset of action, broad spectrum of activity and little residual activity. Iodophors have broad spectrum of activity, slow onset of action and prolonged contact with the skin, whereas chlorhexidine has narrow spectrum of activity with good residual activity but causes irritation to eye.^{1,20}

Standard Precautions for Infection Control¹

- Hand hygiene after direct contact with blood, body fluid secretions, excretions and contaminated items, immediately before gloving and after degloving, between contact with different patients and between contact with dirty and clean body parts/sites in the same patient is recommended by CDC and NNIS with a documented reduction of 68% of bacterial load both in wards and ICUs. Reasons for low level of compliance with hand hygiene in ICUs include:
 - Lack of priority over other procedure
 - Insufficient time
 - Inconvenient placement of hand-washing facilities
 - Allergy/intolerance to hand hygiene solutions
 - Lack of leadership from senior medical staff
- Wearing gloves for anticipated contact with blood, body fluids, secretions, excretions and contaminated items, non-intact skin and mucous membranes
- Mask and eye protection for personal protection during procedures and patient care activities likely to generate splashes or sprays of blood, body fluids, secretions or excretions
- Wearing gowns to protect skin and soiling of clothing during procedures and patient care activities likely to generate splashes/sprays of blood, body fluids, secretions or excretions
- Transport of soiled devices (segregation and channeling of clean and dirty equipments and linen services) should be handled carefully to avoid contamination
- *Sharp objects*: Avoid recapping used needles, removing needles from disposable syringes by hand. Avoid bending/breaking or manipulating used needles by hand. Place used needles, and sharp objects in a puncture resistant containers
- Adequate space around beds
- Adequate hand/skin hygiene facilities at alternate beds in ICUs
- Maintain 1:2 ratio of nurse: patient staffing
- Written guidelines for ICU admission
- Epidemiologic surveillance of nosocomial infections (NIs) and reporting
- Outbreak surveillance and control
- Surveillance of laboratory data
- Isolation of patients infected with microorganisms that can be transmitted by air, tiny droplets or large particulate droplets or by direct contact

If private room/isolation room is not available for patients for airborne or droplet precautions, they may be grouped with another patient infected with the same organism. Healthcare workers should discard the gloves and gowns properly before leaving the room. Hand hygiene protocols should be strictly followed before and after the examination of the patient or the procedure. Patients who are readmitted to the same hospital or transferred from other hospital should be screened on admission for carrying MDROs and should be segregated in isolation.^{1,20}

Misuse of antibiotics giving rise to the evolution of MDROs can be controlled by optional use of the antibiotic, removal or restriction of higher/reserve antibiotics from routine use as empirical agent, use of antibiotics in combination and cycling of antibiotics. Start the antibiotic agents for proven infections according to antibiotic sensitivity report. Empirical therapy should be started as per the hospital antibiotic policy (prepared on the basis of local antibiotic sensitivity data) and should be reevaluated after 48–72 hrs based on the culture report and clinical response of the patient.¹

Target-oriented surveillance restricts the spread of MDROs, MRSA and reduces the incidence of CRBSI, and UTI. Infection-specific surveillance, like surveillance of outbreak, antibiotic sensitivity test, formulating antibiotic policy in the ICU and hospital are other important components of infection control.²¹

Infections related to central line (CLABSI) can be prevented by daily review of the line, practicing hand hygiene before manipulating the line, prompt catheter-site care by scrubbing the insertion hub for 10–15 sec with alcohol before each use.

Patients on ventilator can be prevented from VAP by elevation of the head end 30–40 degrees, proper mouth care with 1–2% chlorhexidine, subglottic aspiration 2–3 hourly, daily assessment of readiness to wean by spontaneous breath trial and DVT prophylaxis.

While person-to-person touch is an important mode of transmission, bacteria can also thrive on bed rails, call buttons, telephones, door handles, mattresses, taps, bathroom fixtures and chairs and survive for long periods on these surfaces.

Decontamination of patient's rooms through cleaning and disinfection is a key method for comprehensive infection control/preventing the transmission of pathogens. Cleaning is the physical removal of foreign materials or debris on the surfaces, whereas disinfection is killing or inactivation of microorganisms that can cause infection. Manual cleaning and disinfection require disinfectants that are not only fast acting, broad spectrum, safe for humans and environment, but also compatible with the materials and medical devices. [Sodium hypochlorite solution (bleach) to inactivate spore-forming bacteria, e.g. *C. difficile*]^{22,23}

Given the limitations of standard cleaning and disinfection, several no-touch ultraviolet (UV) light systems have been developed to supplement cleaning and disinfection.²⁶

UV lights are automated disinfection systems used to kill pathogens associated with infectious disease. They work primarily through the use of lamps that produce high-intensity ultraviolet C (UV-C) light (wavelength 100–280 nm) on the electromagnetic spectrum. UV-C is germicidal. It destroys the DNA of bacteria, viruses and other microorganisms preventing them from multiplying and repairing the damaged DNA. They are used to enhance disinfection after surfaces are cleaned and disinfected manually.

Two types of UV devices are available, i.e. continuous dose of UV-C light through a mercury bulb and pulsed xenon light.^{24,25}

Mercury UV-C

It uses low pressure mercury gas bulbs which emit a strong narrow band of UV-C spectrum. Depending on the number of lamps used and the type of output produced, they are classified as standard or maximum output mercury lamps. Rooms must be vacated before beginning disinfection. Shadowed areas of the room are not disinfected. Multiple cycles from different locations in the room are recommended. They are built to stop operation if the door is opened or movement is detected in the room. They require >45 min for a single cycle.

Pulsed Xenon UV Device

It uses xenon lamps to produce flashes of germicidal light across the disinfecting area (wavelength 200–320 nm including UV-B and UV-C spectrum). Flashes are delivered in millisecond pulses. Effectiveness of UV-C light depends on the dose and intensity, distance from the object, type of surfaces and the type of microorganisms present. Rooms must be vacated and the doors closed as in mercury UV-C disinfection process. Some of these devices come with a protective curtain which can be placed between patient beds for partial disinfection of shared patient rooms. Pulsed xenon UV device takes 15–20 min for disinfecting the entire room.

Both the UV room disinfection devices are available on mobile casters and can be moved wherever disinfection is needed.

Both the devices have been found to reduce common pathogens like methicillin-resistant *Staphylococcus aureus* (MRSA), carbapenamase-producing Enterobacteriaceae (CPE), vancomycin-resistant Enterobacteriaceae (VRE), and *Clostridium difficile*.^{24,25}

Hydrogen Peroxide as Disinfectant²⁶⁻²⁹

Hydrogen peroxide (H_2O_2) has been found to have microbicidal effect on many organisms including *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Candida albicans*, etc. It is being used from many years as one of the best antimicrobial substances with a broad spectrum of action. It has been incorporated with products used for scrub, surface disinfectants, disinfection of drinking water pipes, and also dialysis equipments.

Hydrogen peroxide aerosol generator generates a finely dispersed aerosol distributing throughout the room. This is a microprocessor-controlled appliance programmed with the degree to which the relative atmospheric humidity is to be increased and the duration of exposure. When a relative atmospheric humidity is set, enough aerosol is generated until the corresponding difference in the relative atmospheric humidity is recorded for the room and is maintained throughout the exposure time. If the relative atmospheric humidity drops by >2%, the aerosol generator automatically switches on to produce aerosol until the desired atmospheric humidity is restored. The set atmospheric humidity varies between 30% and 53%. Once the exposure time had expired, the room will be opened to atmospheric air. The room must be sealed during aerosol generation.

Pure H_2O_2 was not used since this is very unstable. Sanosil SO 10" which contains 5% H_2O_2 + 0.01% silver, and Sanosil 15" with 7.5% H_2O_2 + 0.0075% silver were used during the trial.

With the use of Sanosil 15", almost all the test organisms were completely eradicated with variable results against *S. aureus*. With better distribution of the aerosol within the room, it would be possible to achieve widespread disinfection of all the surfaces including the fittings within the room.

Routine cleaning of the room should be performed after the patients are discharged or shifted out before H_2O_2 disinfection is started. Aerosolization should not be performed in an occupied room.

If hydrogen peroxide is used as vapor disinfectant, ICU room's floor should be cleaned three times a day with wet mop and once in a day using a quaternary ammonium compound (sodium hypochlorite solution). Hydrogen peroxide concentration inside the room should be continuously monitored. After a contact time of 30 min, H_2O_2 should be converted to H_2O + O_2 vapors by the catalyzer. The room should be opened when the inside H_2O_2 concentration is <1 ppm, the safe permissible limit.

If H₂O₂ + paracetic acid (aHPP) aerosolization is used, terminal cleaning of the room is performed as usual, all the monitor screens are covered and the aHPP machine is placed in a corner of the room and switched on and immediately leave the room and locked. 7% H₂O₂ solution along with 0.25% paracetic acid and 30% acetic acid is used as aerosols. H₂O₂, paracetic acid and acetic acid are corrosive and caustic and are toxic to human beings at doses higher than 1 ppm, >0.17 ppm and >10 ppm, respectively.

The effectiveness of H₂O₂ spray with no mechanical wiping or cleaning for disinfection of soft surfaces is tested recently by Jennifer Cadnum BS et al. and found that H₂O₂ applied as sprays (1.4%) resulted with significant reduction in VRE, MRSA, with a 1 min contact time and have concluded that H₂O₂ was effective (1.4%) for disinfection of soft surfaces when applied as a spray.

Of late, textiles with an ability to kill bacteria after a few hours of contact time are being tried. Some studies have shown reduction in the burden of VRE by using silver curtains, and MRSA with use of quaternary ammonium impregnated scrubs by healthcare workers.

Fully automated monitoring systems capable of monitoring healthcare worker's hand hygiene as they enter and exit patient areas are being tried. But were found to be of low quality and carry certain amount of risk.

Infection control in ICU can never be a stand-alone action, it should be a part of everyday flow of work.

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