26 Principles of Infection Prevention and Control in ICU

Sandeep Sahu, Mekhala Paul, and Arindam Chatterjee

26.1 Introduction

Prevention of infection in ICU setting is very difficult and needs multidisciplinary approach to monitor and control it. Even after increasing awareness among healthcare workers (HCWs), WHO-estimated worldwide hospital-acquired infection rate is 7–12% (Mukhopadhyay 2018). The major infections of concern are central line associated blood-stream infection (CLABSI), ventilator-associated pneumonia (VAP), catheter-associated urinary tract infection (CAUTI), clostridium-difficile induced colitis, surgical site infection (SSI) or infected decubitus ulcer, etc. increasing resistant micro-organisms due to prolonged unnecessary use of broad-spectrum antibiotics without dose adjustment, lack of following the protocols of isolation and hand hygiene with general preventive measures, failure to maintain surveillance strategies are major factors for failure to control infections in ICU. Here we will discuss all the preventive measures one by one.

26.2 General Measures

26.2.1 Hand Hygiene (WHO’s -5 Moments of Hand Hygiene) (The WHO Guidelines on Hand Hygiene in Health Care 2009)

Two moments before touching a patient to protect the patient from harmful germs carried on hand of HCWs and patient’s own germs

1. Before touching a patient
2. Before aseptic procedures
Three moments after touching a patient to protect oneself and health care environment from harmful patient’s germs

1. After touching a patient
2. After body fluid exposure
3. After touching the patient’s surrounding

Hand-wash protocol (The WHO Guidelines on Hand Hygiene in Health Care 2009)

1. If hand is visibly dirty with blood or body fluid—after wetting all surfaces of hands and fingers with plain water and applying soap, hand should be scrubbed for at least 15 s. Then hands should be thoroughly dried using disposable towel.
2. If hand is not visibly dirty—hands should be rubbed with solution containing 0.5% chlorhexidine (CHD) and 70% w/v ethanol. This combination covers gram-positive, gram-negative bacteria, virus, fungi, and mycobacteria. CHD also has residual activity.
3. Before hand washing for any aseptic procedure, all hand jewelries should be removed (Table 26.1).

26.2.2 Other Protective Measures: (Mehta et al. 2014)

Patient-care equipment: Used patient-care equipment like laryngoscope, bougie, stylet, bronchoscope, etc. soiled with body fluids and secretions should be handled carefully to prevent spread of infection to other patients, HCWs, and environment and should not be reused without proper cleaning and sterilization. Single-use items including sharps should be discarded strictly.

26.3 Modes of Infection Transmission and Prevention

Micro-organisms can be transmitted by airborne, tiny droplets or large droplets, and by direct contact.

• Transmission through direct contact—transmission in ICU mainly occurs by contaminated hands of HCWs. Hands are directly contaminated either from patients’ infected body area or from inanimate objects around patient (Table 26.2).

26.3.1 Airborne and Droplet Transmission

Airborne transmission: Droplet nuclei with <5 μm in size remain suspended in the air for long periods and can travel long distance. (Mukhopadhyay 2018; Guidelines n.d.)
Droplet transmission: Infective micro-organisms are transmitted in the form of large particles (>5 μm in size) during coughing, sneezing, and talking or during invasive procedures such as bronchoscopy, pleural tap, endotracheal intubation, tracheal suctioning, etc. (Mukhopadhyay 2018; Guidelines n.d.) (Table 26.3).

Modes of transmission for waterborne infections include (Guidelines n.d.):

1. Direct contact (e.g. hydrotherapy).
2. Ingestion of contaminated water (e.g. consumption of contaminated iced water).
3. Indirect contact transmission (improperly processed medical device).
4. Inhalation of aerosols dispersed from water sources or respiratory therapy equipment.
5. Aspiration of contaminated water (Table 26.4).

| Table 26.1 showing indication of gloves, gown, and other protective barriers for protection from infection |
|---|---|---|
| **Sterile** | **unsterile** | **Comments** |
| Gloves | Should be worn- • When performing sterile procedure (e.g. central line, arterial line, Foley’s catheter, etc.) • Should be removed- As soon as gloves are damaged • Before answering telephone or recording patient notes, etc. | Clean, unsterile gloves should be worn- • For touching blood, body fluids, contaminated items and any infectious materials | • Gloves should be changed between touching two patients and even in same patient while moving from contaminated to clean body area • Gloves should be removed as soon as possible after care of a patient • Hand hygiene should be practiced strictly after removal of gloves |
| Gown | Require only for aseptic procedure | Clean, non-sterile gown is safe for any procedure other than aseptic one, especially to prevent soiling of clothes and skin rom blood, body fluids, secretions, and excretions | **Soiled** gown should be removed as soon as possible to prevent the spread of infection |
| Mask, face-shield | | Face-shield should be worn to prevent eyes and nasal mucosa from the exposure of blood, other body fluids, secretions, and excretions when there is chance of splashing. Masks should be worn always in ICU to prevent spread of respiratory infection |
Table 26.2 showing micro-organisms spread through contact transmission and its prevention (Russotto et al. 2015; Bhattacharya 2006)

| Vehicle of contact transmission | Micro-organisms                              | Prevention method                                                                 |
|---------------------------------|----------------------------------------------|-----------------------------------------------------------------------------------|
| HCWs' hand                      | *Gram-positive bacteria*                     | Private room preferred, cohorting allowed if necessary                           |
| Bedrails                        | Methicillin resistant                        | General measures of hand washing, gown and gloves to be followed                  |
| ECG leads                       | Staphylococcus aureus (MRSA)                 | Risk of environment contamination to be minimized during patient transport (e.g. Patient can be placed in a gown) |
| Blood-pressure cuffs            | Methicillin sensitive                        | Non-critical items should be dedicated for use of a single patient only           |
| Ventilators                     | Staphylococcus aureus (MSSA)                 | Active surveillance to search out the asymptomatic careers of multi-drug resistant organisms (MDRO) so that they can be isolated |
| (button, circuits)              | Coagulase-negative                           | Surface cleaning (walls, tables, etc.) twice weekly, floor cleaning 2–3 times daily. |
| Suction system                  | Staphylococci                                | Thorough and more frequent terminal cleaning of patient bed area including bedrail, mattress during stay and after discharge, or death with environmental protection agency (EPA) registered disinfectant |
| Medical chart                   | Vancomycin resistant                         | Non-critical equipment (e.g.- stethoscope, blood-pressure cuff, dialysis machine, defibrillator, ventilator, thermometer, medication area, table, etc.) require cleaning followed by disinfection by low-intermediate disinfectant [e.g. Ethyl alcohol or isopropyl alcohol in concentrations of 60-90% (v/v)] (Rutala 1996) |
| Ultrasound machine              | Enterococci (VRE)                            |                                                                                  |
| Stethoscope                     | *Gram-negative Bacteria*                     |                                                                                  |
| White-coats                     | Acinetobacter baumannii                      |                                                                                  |
| Cell-phones                     | Pseudomonas aeruginosa                       |                                                                                  |
| Hand                             | Klebsiella spp.                              |                                                                                  |
| washing sink                    | beta-lactamase (ESBL)                        |                                                                                  |
| Computer                         | Carabapenem resistant                        |                                                                                  |
| keyboard                         | Extended-spectrum                            |                                                                                  |
|                                 | Enterobacteriaceae (CRE)                     |                                                                                  |
|                                 | Viruses                                      |                                                                                  |
|                                 | Varicella (chicken pox)                      |                                                                                  |
|                                 | Respiratory syncytial virus (RSV)            |                                                                                  |
|                                 | Herpes zoster                                |                                                                                  |
|                                 | Hepatitis A                                  |                                                                                  |
|                                 | Rotavirus                                    |                                                                                  |

26.4 Bundle Care

Bundle is a group of evidence-based care components for a given disease that, when executed together, may result in better outcomes than if implemented individually.

26.4.1 VAP Bundle (Wip et al. 2009)

- Head elevation at 30–45° (semi-recumbent position) (LOE IA)
- Twice daily oral care with chlorhexidine solution (LOE IA)
- Daily sedation vacation if feasible and assessment of readiness to extubate (LOE IA)

The other strategies to prevent VAP (Wip et al. 2009)
Table 26.3  showing spread of common micro-organisms through airborne and droplet transmis-
sion and their preventive measures (Bhattacharya 2006; Guidelines n.d.)

| Organisms                                      | Airborne infection                                                                 | Droplet infection                                      |
|------------------------------------------------|------------------------------------------------------------------------------------|--------------------------------------------------------|
| Common Bacteria                                | Mycobacterium tuberculosis                                                        | Bacteria                                               |
| Bacteria atypically causing airborne transmission | *Staphylococcus aureus* (mainly transmitted through contact or droplets. Airborne dispersal of S.aureus directly associated with concentration of bacteria in anterior nares. 10% healthy career disseminate in air. Usually recovered from operating room, ICU, burn units, and neonatal ICU) | Hemophilus influenzae (meningitis, pneumonia)          |
|                                                | *Group A beta hemolytic streptococci* (mainly transmitted through contact or droplets. Outbreaks of surgical site infection have been traced from operating room personnel to patients. Usually recovered from operating room, ICU, burn units, and neonatal ICU) | Neisseria meningitidis (bacteremia, meningitis, pneumonia) |
|                                                | *Bacillus spp* (can survive long period in air due to capability of spore formation) | Mycoplasma pneumonia                                   |
|                                                | *Acinetobacter spp* (only gram-negative bacteria which withstand inactivating effects of drying) | Group A streptococci                                   |
| Viruses                                        | Measles virus (rubeola)                                                            | Staphylococcus aureus                                   |
|                                                | Varicella-zoster virus (VZV chicken pox)                                           | Bordetella pertussis                                    |
|                                                | Herpes zoster (shingles)                                                           |                                                        |
|                                                | Rubella virus                                                                      |                                                        |
|                                                | Swine flu (H1N1)                                                                  |                                                        |
|                                                | Influenza virus                                                                    |                                                        |
| Fungi                                           | Aspergillus spp.                                                                   |                                                        |
|                                                | Mucorales (Rhizopus spp)                                                           |                                                        |
| Preventive measures                            | Patient should be placed in a monitored negative pressure room with at least 6–12 air exchanges per hour. Room exhaust must be appropriately discharged outdoors or passed through high-efficiency particulate aerator (HEPA) filter before recirculation within hospital Disposable N-95 mask should be worn by all persons entering room. Susceptible subjects should not enter room ideally Transport of the patient should be minimized. If it is unavoidable, patient should be masked | Private room preferred. Cohorting allowed if necessary Everyone should wear mask (ideally N-95) while entering isolation room or within 6–10 ft. of the patient. Transport of the patient should be minimized. If it is unavoidable, patient should be masked |

- Endotracheal tubes with subglottic suction port is preferred to prevent microaspiration (2A)
- Avoid intubation and re-intubation whenever possible (2B)
- Closed endotracheal suction systems may be better than open suction (2B)
- Consider non-invasive ventilation whenever possible (2B)
Table 26.4 showing spread of micro-organisms through the contaminated environment and their preventive measures (Guidelines n.d.)

| Bacteria                    | Contaminated environmental vehicle                                                                 | Preventive measures                                                                                                                                 |
|-----------------------------|------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| Legionella spp.             | Aspiration of contaminated water or inhalation of contaminated aerosol (cooling tower, faucets,   | Cold water should be stored and distributed at temperature <20-degree C. Hot water should be stored above 60-degree C and circulated with a minimum return temperature of 51 degree C (American Society of Heating 2000). Near point-of-use preset thermostatic mixing valve should be added and maintained periodically to prevent burn. Additional chlorine and flushing of water (American Society of Heating 2000; Snyder et al. 1990) |
|                             | respiratory therapy equipment, room-air humidifiers, etc.)                                          |                                                                                                                                                      |
| Pseudomonas aeruginosa      | Distilled water                                                                                     | Separate sink for hand washing and disposal of contaminated fluids (Ayliffe et al. 1974)                                                               |
| Burkholderia cepacia        | Contaminated disinfectant                                                                          | Dialysate should be $\leq 2000$ cfu/mL                                                                                                               |
| Stenotrophomonas maltophilia| Contaminated mouthwash                                                                             | Water should be $\leq 200$ cfu/mL (Favero and Petersen 1979)                                                                                         |
| Sphingomonas spp.           | Dialysis machine                                                                                    | Ice and ice machine should be cleaned periodically. Open storage compartment in patient area is avoided (Newsom 1968). Sterile water should be used in ice bath (Pien and Bruce 1986). |
|                             | Nebulizers                                                                                          |                                                                                                                                                      |
|                             | Ventilator temperature probe                                                                       |                                                                                                                                                      |
|                             | Water bath                                                                                         |                                                                                                                                                      |
| Serratia marcescens         | Contaminated antiseptic (e.g. chlorhexidine)                                                       |                                                                                                                                                      |
|                             | Contaminated disinfectants (glutaraldehyde and quaternary ammonium compounds)                      |                                                                                                                                                      |
| Acinetobacter spp.          | Medical equipment that collect moisture (e.g. ventilator, humidifier, vaporizers, etc.)            |                                                                                                                                                      |
|                             | Environmental surface                                                                             |                                                                                                                                                      |
|                             | Room humidifier                                                                                    |                                                                                                                                                      |
| Enterobacter spp.           | Intravenous fluids                                                                                 |                                                                                                                                                      |
|                             | Rubber piping of a suction machine                                                                 |                                                                                                                                                      |
|                             | Blood gas analyzer                                                                                  |                                                                                                                                                      |
|                             | Unsterilized cotton swab                                                                            |                                                                                                                                                      |
|                             | Humidifier water                                                                                   |                                                                                                                                                      |
| Non-tubercular mycobacteria (NTM)| Inadequately sterilized medical equipment                                                           |                                                                                                                                                      |
|                             | Dialysis, reprocessed dialyzers                                                                    |                                                                                                                                                      |
|                             | Contaminated disinfectant solution                                                                 |                                                                                                                                                      |

S. Sahu et al.
• Monitor endotracheal cuff pressure (to be kept >20 cmH₂O) to avoid air leaks around cuff (2B)
• Ventilator circuits should not be changed routinely (2B)
• Heat moisture exchanger is better than heated humidifier (2B)
• Any condensate collected in the tubing should be discarded (2B)

26.4.2 Central Line Bundle (all LOE IA) (The Joint Commission 2013)

• Femoral route for central venous cannulation should be avoided. Upper extremity should be preferred for insertion. If on emergency basis femoral cannulation must be done, it should be removed as soon as crisis period is over and replaced with jugular or subclavian vein cannulation.
• Maximal sterile barrier precautions (cap, mask, sterile gown, sterile gloves) should be taken and full-body should be covered with sterile drape during central venous catheter (CVC) insertion.
• Skin should be cleaned with 2% chlorhexidine with 70% w/v ethanol followed by drying for at least 30 seconds before CVC insertion.
• Sterile, transparent, semipermeable dressing should be used to cover the catheter site and it should only be replaced while it becomes damp or soiled or get loosened.
• Need of CVC should be assessed daily and should be removed as soon as possible when it is not required.

26.4.3 Other Strategies to Prevent Central Line Associated Blood-Stream Infection (CLABSI) (The Joint Commission 2013)

• Ultrasound-guided insertion should be in protocol if machine and expertise are available.
• Catheter insertion site should be checked and palpated daily through dressing for any tenderness.
• Patients’ body should be cleaned daily with 2% chlorhexidine wipe to reduce CLABSI.
• Needleless intravascular catheter access system should be used, and stopcock should be avoided. Closed catheter system should be preferred to open system.
• Injection port should be cleaned with chlorhexidine, povidone-iodine, or 70% alcohol every time during injection and should be accessed only with sterile device.
• Routine replacement of CVC is not required.
• Administration sets including add-on devices (e.g. triway) should be replaced daily in patients receiving blood, blood products, or fat emulsions.
• In case of intravenous fluids other than blood or blood product, administration set should not be replaced <96 h and should be changed at least every 7 days.
• Needleless connectors should be changed every 72 h.

26.4.4 Strategies to Prevent CAUTI (Parida et al. 2013)

• Catheter should be inserted only when it is indicated really and should be removed as soon as possible when there is no requirement.
• Asepsis should be followed during insertion (sterile gloves, sterile draping, and proper cleaning.
• Closed drainage system should be maintained. For unobstructed flow of urine, catheter should be placed and taped above the thigh and urinary bag should hang below the level of bladder.
• Urobag should never be in contact with floor.
• As it is closed system, changing indwelling catheters or drainage bags at fixed interval is not recommended. It should be changed only if there is indication like infection and obstruction or when closed system is compromised.

26.5 Environmental Control

26.5.1 Design of Intensive Care

(a) Intensive care unit should be adjacent to operation theater (OT) complex and emergency department or easy and rapid accessibility of sick patients. It should be away from general ward for prevention of infection.
(b) Proper heating, ventilation and air conditioning (HVAC) system should be established and monitored periodically for proper function. HVAC system is designed to
  • Maintain indoor air temperature and humidity at comfortable levels for patients and staff.
  • Remove contaminated air.
  • Protect patients and susceptible staffs from airborne pathogens.
  • Minimize risk for transmission of airborne pathogens from infected patients (Streifel 1999).

1. HVAC system includes (in sequence)(American Conference of Governmental Industrial Hygienists (ACGIH) 2001):Outside air inlet → filters [low efficiency (20–40%) filter has low resistance to airflow and it removes large particulate matter and many micro-organisms allowing smaller particles to pass onto air-conditioning coils](Streifel 1999) → Humidity modification equipment [temperature is maintained within 20–23 degree C and humidity is maintained between 40 and 60% above which is an independent risk factor for fungal
growth (American Institute of Architects 2001). Recirculated air is also added in this chamber → High-Efficiency Particulate Air (HEPA) filter [99.97% efficient for removing particles ≥0.3 μm diameter. It is mandatory to use in positive pressure isolation room for immunocompromised patients and operating rooms designated or orthopedic implant procedures to prevent airborne infection (Aspergillus spores are 2.5–3.0 μm in diameter)] (Streifel 1999) → FANS → Registers/ Diffuser/ Griller (for proper distribution of conditioned air) → Ductwork [After distribution of conditioned and filtered air, a portion of air is returned through this duct system to be delivered back to HVAC unit for getting diluted with outside air and again filtered through HEPA filter] → Air exhaust [after returning through duct system, rest of the air is exhausted. Air from toilet or other soiled areas is usually exhausted directly to atmosphere through separate exhaust].

Any malfunction or damage of any of the above-mentioned components leads to outbreak of airborne and droplet infection in ICU. So, regular monitoring and surveillance of these components are very important.

2. Ventilation—According to guideline, Air-Change per Hour (ACH) must be >12 in positive pressure area or protective environment (PE) where immunocompromised patients are kept and treated. In negative pressure area or Airborne Infection Isolation (AII) room, ACH should be ≥12 in renovated or newly constructed ICU after 2001 and ≥6 in ICU constructed before 2001. Peak efficiency for particle removal in the air-space occurs between 12 and 15 ACH (Streifel 1999; Memarzadeh and Jiang 2000).

3. Laminar airflow ventilation system is designed to move air in a single pass, usually through HEPA filters either along a wall or ceiling, in one-way direction through a clean zone in parallel stream. Uni-direction flow minimizes air-turbulence, thus precipitation of micro-organisms and spores. Airflow rate of 0.5 m/s minimizes proliferation of micro-organisms. It is important in PE room to reduce airborne healthcare-associated infection. (Walmsley et al. 1993).

4. Pressurization—Isolation should be with both positive and negative pressure ventilation. There should be at least 1 isolation room for every 6 beds in ICU. In PE room ideal pressure differential is > +8 Pa and in AII room pressure differential must be < −2.5 Pa. Pressure differential is the difference between isolation unit and adjacent room or hall or corridor. (Streifel 1999; American Institute of Architects 2001).

5. Air movement must be always from clean to dirty area.
6. Adequate space around each bed in ICU should be there (2.5–3 m or 20 m²).
7. Washbasins should be installed between every other bed.
8. Alcohol gel dispensers should be at the ICU entry, exit, every bed space, and ventilator.
9. Separate medication preparation area. It should be >3 ft. away from wash basin.
10. There should be separate areas for clean storage and soiled and waste storage and disposal.
11. Electricity, vacuum, or air outlets should not hamper access around beds.
12. Appropriate location of sharps.
13. Seamless floors and avoiding use of carpets (wet carpet helps in growth of micro-organisms and during cleaning it releases micro-organisms and spores).

26.6   **Antibiotic Stewardship**

Antimicrobial stewardship program is a multidisciplinary approach which includes clinical pharmacist, clinical microbiologist, infection control professionals, and hospital epidemiologists. With active participation of microbiology lab, hospital pharmacy, and finally hospital administration, this program will be successful. The goal of this stewardship is as follows:

- To decrease unnecessary use of antibiotics, thus decreasing cost.
- To prevent antibiotic resistance by decreasing inappropriate use of antibiotics.

The different ways to achieve this goal are as follows: (The Core Elements of Hospital Antibiotic Stewardship Programs n.d.)

1. Regular audit of antimicrobial use with direct interaction and feedback by antimicrobial stewardship program senior member.
2. Continuous education and discussion about advancement in prescription, guidelines of dosing, de-escalation, etc. should be practiced in health-care setting. In this discussion all physicians and paramedical staffs should be present.
3. Institutional guidelines should be established based upon evidence of local microbiological data and resistance pattern. In this way, antibiotics can be utilized in better way.
4. After culture sensitivity report is available, immediate de-escalation of antibiotic is strictly recommended and must be practiced. Audit should be done on de-escalation practice.
5. Knowledge of pk/pd. characteristics of antibiotics should be shared during discussion so that optimal dosing of antibiotics is practiced.
6. Close vigilance on appropriate dosing, active use of information technology (hospital information system) to track electronic medical record, computerized physician order entry can improve the antibiotic stewardship program.
7. Antimicrobial cycling and combination therapy to prevent emergence of resistance is not recommended as these are not found to be essential.
8. Early switching from parenteral to oral antibiotic when parenteral antibiotic is no longer indicated, especially in resource limited setting to decrease cost of therapy is recommended.
9. Optimization of duration of antibiotics should be followed as per latest clinical guidelines. It decreases cost of therapy, unnecessary antibiotic consumption as well as side-effects. It should be actively incorporated in program.

10. Use of microbiology lab should be optimal.

### 26.7 Maintenance and Surveillance

Environmental disturbance during construction, renovation, or repair in or near ICU significantly increases Aspergillus spore count in indoor air. Sudden outbreak or cluster of cases increases suspicion of environmental source to be culprit. In case of construction work, patients should be relocated to another temporary ICU area.

All water-damaged materials should be replaced, if moist materials are not dried within 72 hours, those should be replaced (Vujanovic et al. 2001). Fungistatic compounds should be incorporated into building material in area at risk of getting high moisture. All windows of ICU should be sealed. Door should be closed as much as possible. Entry should be restricted for visitors to reduce dust intrusion and infection transmission.

#### 26.7.1 Air Sampling

- Both particulate sampling and microbiological sampling are done.
- In particulate sampling the numbers and size range of particulates are known, thus it indirectly evaluates the efficiency of filter in removing respirable particles (<5 μm diameter). Particle count in ICU or operation room should be evaluated against counts in comparison area, like corridor, ward, etc. It helps to have information about the ICU air quality and control of dust dispersion (Streifel 1999).
- Though colony or spore count is not significantly correlated with infection rate in ICU, microbiological air sampling is done nowadays as part of epidemiological investigation in case clusters. Molecular typing can determine whether isolates from air matches with patient isolates or not (especially in case of aspergillosis). At least 1000 ml or 1 m³ air should be sampled from ICU (Thio et al. 2000). It is considered that 15 CFU/m³ gross colony count of fungal organism and < 0.1 CFU/m³ of Aspergillus fumigates and other opportunistic fungi in HEPA filtered area are the maximum limit to prevent infection (American Institute of Architects 2001).
- Air sampling is done after construction or renovation of ICU, especially of isolation rooms and then periodically.
26.7.2 Water Sampling and Prevention of Infection (Guidelines n.d.)

- Analysis should be done using standard quantitative methods for endotoxin in water used to reprocess hemodialyzers and for heterotrophic and mesophilic bacteria in water used to prepare dialysate and for hemodialyzer reprocessing.
- To minimize growth and persistence of gram-negative waterborne bacteria, cold water should be stored and distributed at temperature below 20-degree C and hot water should be stored above 60-degree C with minimum return temperature 51 °C thermostatic mixing valve is installed near point of use.
- Addition of additional chlorine in the water.
- All water systems should be inspected annually to ensure proper function of the thermostats.

26.7.3 Maintenance and Repair of HVAC System (Guidelines n.d.)

- HVAC system should not be shut down regularly without any purpose like maintenance or filter change, etc. as during starting machine it suddenly releases micro-organisms (e.g. Aspergillus spore) in huge amount accumulated in system.
- Regular manometer test to ensure the pressure differential in positive and negative pressure areas.
- Regular Testing of Filters- HEPA filter efficiency is especially monitored with dioctyl phthalate (DOP) particle test using the particles sized 0.3 μm diameter. Low-medium efficiency filters are also tested regularly (Dryden et al. 1980).
- Low-medium efficiency filter should be changed frequently to prevent dust build-up on HEPA filter.
- Regular cleaning of ductwork vents should be done. Filter should be replaced as per need and the replaced filter should be disposed into plastic bag immediately to prevent potential exposure of patients and staffs as HVAC system is shut down at that time.
- Air intake system should be kept free from bird droppings as much as possible to minimize the concentration of fungal spores in entering air.
- Temperature and humidity of the air should be regularly monitored. Excessive humidity and moisture accumulation in HVAC system can increase proliferation of fungi (Aspergillus, etc.) and bacteria (Pseudomonas aeruginosa, Staphylococcus aureus, Acinetobacter spp. etc.) causing significant spread of nosocomial infection in ICU. Water is present in cooling units and humidifying boxes. Duct system also can create conditions of high humidity and excess moisture.
### 26.8 Special Concerns for Specific Pathogens

| Micro-organism | Risk-factors + major mode of transmission | Recommendation for prevention | Role of environmental sampling |
|----------------|------------------------------------------|--------------------------------|-------------------------------|
| 1. MRSA 2. Vancomycin intermediate staphylococcus aureus (VISA) 3. Vancomycin resistant enterococci (VRE) | 1. Colonized patient in ICU 2. Medically high-risk patients (e.g.- long stay in ICU) 3. Multiple and/or prolonged broad-spectrum antibiotics 4. Immunosuppressed patient like post-transplant | 1. Strict adherence to hand hygiene. 2. Cohorting of patient 3. Direct patient-care items should be disposable whenever possible especially during managing patient with multiple-resistant micro-organism (Layton et al. 1993) 4. Routine cleaning and disinfection of house-keeping surface and patient-care area with low-intermediate level disinfectants like, alcohol, sodium hypochlorite or quaternary ammonium compounds at recommended dilution and adequate contact time (Byers et al. 1998) | Routine environmental sampling is not required, yet laboratory surveillance of environmental surface should be done during suspected episodes of contamination or outbreak and renovation or construction. For MRSA, nasal swab and swab from hand web are taken from HCWs for culture. For other organisms, swab from hand web are taken |
| Clostridium difficile | 1. Antibiotic therapy, mainly beta-lactam antibiotics 2. Gastrointestinal procedures and surgery 3. Advanced age. 4. Indiscriminate use of antibiotics Transfer of the pathogen to the patient via the hands of health-care workers is thought to be the most likely mechanism of exposure (Fekety et al. 1981) Hand is contaminated through direct infected patient or patient-care items and bed area | 1. All the above-mentioned preventive measures 2. Restriction of use of antimicrobial agents (Johnson et al. 1992) 3. Environmental cleaning with specific chemical germicide (chlorine containing chemicals like 5000 ppm sodium hypochlorite 1:10 v/v dilution or phosphate-buffered hypochlorite 1600 ppm) | |

According to literature, three new technologies seem to be successful to disinfect the ICU environment even in inaccessible areas (Blazejewski et al. 2011)
• Hydrogen peroxide vapor.
• Ultraviolet light decontamination for terminal cleaning.
• Ultramicrofibers associated with copper-based biocide for daily cleaning.

26.9 Education of Health Care Workers and Monitoring

• Continuous classes (both classroom and bedside) to educate the health care workers is one of the most important strategy to have success in control of infection in ICU.
• Pictures, animations, and videos are good options through which knowledge of good hygiene and consequences of infections can be shared very rapidly.
• Feedback should be taken from HCWs.
• Close monitoring of hand-hygiene practice is single most important factor to reduce infection in ICU significantly.
• Incidence and prevalence data of all types of infection in ICU are to be sincerely collected and analyzed and based upon which annual/biannual audit should be done.

References

American Conference of Governmental Industrial Hygienists (ACGIH). HVAC components, functions and malfunctions (topic 8-4). In: Industrial ventilation: a manual of recommended practice. 24th ed. Cincinnati: American Conference of Governmental Industrial Hygienists, Inc.; 2001.

American Institute of Architects. Guidelines for design and construction of hospital and health care facilities, 2001. Washington: American Institute of Architects Press; 2001.

American Society of Heating. Refrigerating, and air-conditioning engineers. ASHRAE guideline 12–2000: minimizing the risk of legionellosis associated with building water systems. Atlanta: ASHRAE, Inc.; 2000. p. 1–16.

Ayliffe GAJ, Babb JR, Collins BJ, Lowbury EJ, Newsom SWB. Pseudomonas aeruginosa in hospital sinks. Lancet. 1974;2:578–81.

Bhattacharya AK. Isolation guidelines for hospitals. J Indian Acad Clin Med. 2006;7(2):105.

Blazejewski C, et al. New methods to clean ICU rooms. Infect Disord Drug Targets. 2011;11(4):365–75.

Byers KE, Durbin LJ, Simonton BM, Anglim AM, Adal KA, Farr BM. Disinfection of hospital rooms contaminated with vancomycin-resistant Enterococcus faecium. Infect Control Hosp Epidemiol. 1998;19:261–4.

Dryden GE, Dryden SR, Brown DG, Schatzle KC, Godzeski C. Performance of bacteria filters. Respir Care. 1980;25:1127–35.

Favero MS, Petersen NJ. Microbiologic guidelines for hemodialysis systems. Dial Transp. 1979;6:34–6.

Fekety R, Kim KH, Brown D, Batts DH, Cudmore M, Silva J Jr. Epidemiology of antibiotic-associated colitis: isolation of Clostridium difficile from the hospital environment. Am J Med. 1981;70:906–8.

Guidelines for environmental infection control in health-care facilities. Available from: http://www.cdc.gov/ncidod/dises/hicpac/pdf/guidelines/epidemiology_of_environmental_infection_control.pdf
Humphreys H, Lee JV. Water quality for endoscopy washer-disinfectors. J Hosp Infect. 1999;42:76–8.

Johnson S, Homann SR, Bettin KM, et al. Treatment of asymptomatic Clostridium difficile carriers (fecal excretors) with vancomycin or metronidazole: a randomized, placebo-controlled trial. Ann Intern Med. 1992;121:297–302.

Layton MC, Perez M, Heald P, Patterson JE. An outbreak of mupirocin-resistant Staphylococcus aureus on a dermatology ward associated with an environmental reservoir. Infect Control Hosp Epidemiol. 1993;14:369–75.

Mehta Y, Gupta A, Todi S, Myatra S, Samaddar DP, Patil V, Bhattacharya PK, Ramasubban S. Guidelines for prevention of hospital acquired infections. Indian J Crit Care Med. 2014;18(3):149–63.

Memarzadeh F, Jiang J. A methodology for minimizing risk from airborne organisms in hospital isolation rooms. ASHRAE Trans. 2000;106:731–47.

Mukhopadhyay C. Infection control in intensive care units. Indian J Respir Care. 2018;7:14–21.

Muyldermans G, de Smet F, Perrard D, et al. Neonatal infections with Pseudomonas aeruginosa associated with a water-bath used to thaw fresh frozen plasma. J Hosp Infect. 1998;39:309–14.

Newsom SWB. Hospital infection from contaminated ice. Lancet. 1968;2:620–2.

Parida S, et al. Urinary tract infections in the critical care unit: a brief review. Indian J Crit Care Med. 2013;17(6):370–4.

Pien FD, Bruce AE. Nosocomial Ewingella americana bacteremia in an intensive care unit. Arch Intern Med. 1986;146:111–2.

Russotto V, Cortegiani A, Raineri SM, Giarratano A. Bacterial contamination of inanimate surfaces and equipment in the intensive care unit. J Intensive Care. 2015;3:54.

Rutala WA. APIC guideline for selection and use of disinfectants. Am J Infect Control. 1996;24:313–42.

Snyder MB, Siwicki M, Wireman J, et al. Reduction of Legionella pneumophila through heat flushing followed by continuous supplemental chlorination of hospital hot water. J Infect Dis. 1990;162:127–32.

Streifel AJ. Design and maintenance of hospital ventilation systems and prevention of airborne nosocomial infections. In: Mayhall CG, editor. Hospital epidemiology and infection control. 2nd ed. Philadelphia: Lippincott Williams & Wilkins; 1999. p. 1211–21.

The Core Elements of Hospital Antibiotic Stewardship Programs. Available at http://www.cdc.gov/getsmart/healthcare/implementation/core-elements.html.

The Joint Commission. Preventing Central Line-Associated Bloodstream Infections: Useful Tools, An International Perspective. 2013. http://www.jointcommission.org/CLABSIToolkit

The WHO Guidelines on Hand Hygiene in Health Care 2009. http://whqlibdoc.who.int/publications/2009/9789241597906_eng.pdf

Thio CL, Smith D, Merz WG, et al. Refinements of environmental assessment during an outbreak investigation of invasive aspergillosis in a leukemia and bone marrow transplant unit. Infect Control Hosp Epidemiol. 2000;21:18–23.

Vujanovic V, Smoragiewicz W, Krzysztonia K. Airborne fungal ecological niche determination as one of the possibilities for indirect mycotoxin risk assessment in indoor air. Environ Toxicol. 2001;16:1–8.

Walmsley S, Devi S, King S, Schneider R, Richardson S, Ford-Jones L. Invasive Aspergillus infections in a pediatric hospital: a ten-year review. Pediatr Infect Dis. 1993;12:673–82.

Wip C, et al. Bundles to prevent ventilator-associated pneumonia: how valuable are they? Curr Opin Infect Dis. 2009;22(2):159–66.