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INFECTION PREVENTION AND CONTROL: GENERAL PRINCIPLES AND ROLE OF MICROBIOLOGY LABORATORY

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ABSTRACT

The healthcare-associated infections HAIs are international health problem and its major cause of death worldwide with wide range complications among healthcare workers, patients, and visitors, And these complications are very expensive from the humanitarian and economic aspects and cause increase in healthcare resources waste as increase medications and medical supplies consumption, intensive uses of diagnostic laboratory services, sharp rising hospital's admission rates and other harmful effects on patient's life. As currently, medical laboratory specialists are the cornerstones of diagnosis of infectious diseases, the number of medical laboratories science colleges has increased, with a high number of highly qualified specialists with a strong background on microbiology and epidemiology of various disciplines that include clinical chemistry, microbiology, hematology, immunology, and histopathology. Those specialists work in laboratories of varying sizes and resources. Most of those specialists perform most tasks from different disciplines, including the microbiological tests. Therefore, the junior laboratory specialist must be fully familiar with the basic tasks and activities of infection control and prevention. The aim of this review is to know the general principles of infection control and prevention and the role of medical laboratory specialists, hoping that the medical laboratory specialists will play a valuable and effective role in the field of infection control and prevention, thereby preventing hospital infections and antibiotic resistance and providing a safe environment for the patient, health care providers and the community.

INTRODUCTION

Healthcare-associated infections (HAIs), or nosocomial infections, affect patients in a hospital or other healthcare facility, and are not present or incubating at the time of

admission, HAIs are an important cause of morbidity and mortality of hospitalized patients.[1,2,3] Risk factors for healthcare-associated infection include intrinsic and extrinsic factors. The major intrinsic factors are age, birth weight, underlying diseases, and immune status. The major extrinsic factors are presence of invasive devices and procedures.[2] HAIs create additional suffering and come at a high cost for patients and their families. Infections prolong hospital stays, create long-term disability, increase resistance to antimicrobials, represent a massive additional financial burden for health systems, generate high costs for patients and their family, and cause unnecessary deaths.[1] Infection prevention and control (IPC) is a discipline that aims to prevent or control the spread of infections in healthcare facilities and the community.[1,4] As each medical technologist/microbiologist needs to make efforts to understand the characteristics of the examinations for infectious diseases and send out information useful for clinical practices and they also need to be aware of themselves as good practitioners of IPC measures to prevent hospital infections, the knowledge IPC practices and role of microbiology laboratory are core scope beyond this review. Having microbiology laboratory as a part of the hospital diagnostic laboratories is a huge advantage for HAIs prevention and control. Ideally, a microbiology laboratory should be set up inside the hospital and working every day on a 24-hour basis.[3]

Basic Principles of Infection Prevention and Control

The chain of infection: The process of infection can be represented as a chain, along which microorganisms are passed from a source to a vulnerable person. Breaking a link at any point in the chain will control the risk of infection by preventing the onward transmission of microorganisms. The six links of chain of infection include: the infectious agent, reservoir, portal of exit, mode of transmission, portal of entry, and susceptible host.[5]

Opportunities to break the chain of infection

Transmission may be interrupted when

- The infectious agent is eliminated, inactivated or cannot survive in the reservoir (E.g. rapid identification and management of organisms, cleaning and disinfecting of the environment).
- The portal of exit is managed through good infection prevention and control practices (E.g. Hand Hygiene, appropriate use of PPE, safe packaging and disposal of waste).
- Transmission does not occur due to good infection prevention and control practices (E.g. Hand Hygiene, isolation of infected patients, air flow control where appropriate).

- The portal of entry is protected (E.g. Aseptic non-touch technique, safe catheter care, wound care).
- Reducing the susceptibility of patients receiving healthcare (E.g. Treatment of underlying disease, recognizing high risk patients).[5,6]

Infection Prevention and Control Program

Infection prevention and control program (IPCP) is scientific approach and practical solution designed to prevent harm caused by infection to hospitalized patients and health care workers (HAWs). The important components of the infection control program are (i) developing and implementing guidelines/manual (ii) basic measures for infection control, i.e. standard precautions (iii) education and training of HAWs (iv) protection of HAWs, e.g. (immunization), identification of hazards and minimizing risks. (v) routine practices essential to infection control such as aseptic techniques, reprocessing of instruments and equipment, antibiotic usage, management of blood/body fluid exposure, handling and use of blood and blood products, sound management of medical waste (vi) effective work practices and procedures, such as environmental management practices including management of hospital/clinical waste, support services (e.g., food, linen), use of therapeutic devices (vii) surveillance (viii) incident monitoring (ix) outbreak investigation (x) infection control in specific situations and research (xi) implementing IPC activities using multimodal strategies (xii) Workload, staffing &bed occupancy management.[4,7]

Objectives of infection prevention and control program

- To have hospital IPC manual in place with clear role and responsibilities.
- To interpret and implement all activities according to hospital IPC manual.
- To conduct outbreak investigations of epidemics.
- To monitor the IPCP and promote improved practice, including inspection of waste disposal, laundry and kitchen.
- Monitoring and advice on the safe use of antibiotics.
- Continuing education and training of staff in prevention and control of HAIs; and
- To sensitize patients on preventive aspects for control of airborne infections.[7,8,9,10]

Organization of an infection prevention and control program

Infection control committee: Infection control committee (ICC) members are for multidisciplinary as medical, nursing, engineering, administration, pharmacy, central sterile services department (CSSD) and microbiology laboratory. The ICC formulates the policies

for the IPC. The ICC meets regularly and not less than three times a year. ICC is responsible for developing and updating HAIs prevention manual which should contain instructions and practices for patient care and preparing the yearly work plan with adequate resources for the effective functioning of the IPCP.[4,11]

Infection control team: The infection control team (ICT) consists of members of staff with specialized knowledge and interest in IPC. The ICT will include the microbiologist who will usually be the infection control officer, infection control nurses and members of the scientific or technical staff with responsibilities in infection control. The role of the ICT is to implement the annual program and policies and responsible for the following: (i) Surveillance of infections and monitoring methods of control. (ii) Rapid identification and investigation of outbreaks. (iii) Providing advice on the isolation of infected patients. (iv) Giving advice, making day-to-day decisions and liaising with staff in all areas. (v) Providing, monitoring and evaluating policies and procedures for prevention of infections and its spread. (vi) A staff education program. (vii) Preparing the annual IPCP and reporting to the ICC.[12,13,14]

Infection Control Officer (ICO): Infection Control Officer (ICO) is a senior member of the medical staff with ready access to committees and sufficient authority to command respect and suitably qualified and interested in IPC. The microbiologist is usually the logical choice. The functions of the ICO with the other members of the team are to assess risks of infection, to advise on preventive measures and to check their efficacy in all parts of the hospital including catering, laundry and CSSD in domestic, pharmaceutical and engineering departments, as well as clinical and other areas. ICO is carrying out targeted surveillance of HAIs and act upon data obtained. ICO recommends antibiotics policy for different areas of the hospital. ICO provide manual of policies and procedures for aseptic, isolation and antiseptic technique; investigate outbreaks of infections and take corrective measures; supervision of biomedical waste management activities; supervision of airborne isolation procedures.[12,15]

Importance of instauration infection prevention and control manual

A HAIs prevention manual is an important tool due to instructions and practices used for patient care. The policies and procedures for IPC manual (see Table 1) should be based on national and international published best practices. The manual should be developed and updated by the ICT and reviewed and approved by the ICC.[4] Health care staff must adhere to

IPC manual, guidelines and policies at all times and use critical thinking, risk assessment and problem-solving in managing clinical situations.[16]

Table. 1: Components for Institution Infection Prevention and Control Manual.

Organization/institution details
Date formation of institutional ICC
Name and designation of ICC committee members
Name and designation of ICO
Name and designation of infection prevention and control nurse
Roles and responsibilities of each member
Details of version and date of amendment
Technical description of standard precautions and high risk area management
Policies and procedures for improvement of hand hygiene compliance
Policies and procedures for identification of high risk areas and establish steps to mitigate risk of HAIs to patients, staff and visitor
Policies and procedures aseptic, isolation and antiseptic techniques
Policies and procedures for disinfection and sterilization of reusable equipments
Policies and procedures for biomedical waste management
Policies and procedures for laboratory based and ward based surveillance of infections
Policies and procedures with regards to staff health monitoring
Policies and procedures for patient visitors
Policies and procedures for staff training regarding IPC Measures
Policies and procedures for outbreak investigations
Policies and procedures for monitoring of emergence of antimicrobial resistance
Policies and procedures for hospital building renovation.[2,4,7,8,17]

Infection Prevention and Control Practice

The optimal defense against HAIs and antimicrobial resistance (AMR) is strict of HAWs, patients and visitors adherence to IPC practices, which can significantly contribute to halting the spread of untreatable infections and negate the need for antibiotics. Such practices include the use of standard infection control precautions and transmission-based precautions.[18]

Components of standard precautions

Personal protective equipments (PPE): Healthcare facilities must have the necessary equipment to implement the standard precautions for all HAWs, patients and visitors. PPE used in healthcare include gloves, aprons, long-sleeved gowns, goggles, fluid-repellant surgical masks, face visors, and respirator masks. The initial risk assessment of whether or not PPE is required is based on the level of risk of transmission to and from the patients.[19]

Principles of PPE. (i) PPE should be chosen according to the risk of exposure. (ii) The skin should not be exposed when PPE has worn; (iii) Step by step instructions regarding wearing

and removing off PPE to be displayed in all prominent areas in the hospital; (iv) PPE should be stored to prevent contamination in a clean/dry area until required for use; (v) PPE should be single-use only items unless specified by the manufacturer; (vi) PPE should be changed immediately after each patient and/or following completion of a procedure or task; and (vii) PPE should be disposed of after use into the correct waste stream i.e. healthcare waste or domestic waste.[4]

The gloves. The wearing of gloves has two main purposes as they act as a protective barrier for HAWs and they prevent the transmission of micro-organisms to patients during invasive procedures. Gloves must be (i) worn when exposure to blood and/or other body fluids is anticipated/likely; (ii) changed immediately after each patient and/or following completion of a procedure or task; (iii) changed if a perforation or puncture is suspected; (iv) Appropriate for use, fit for purpose and well-fitting.[20]

Gowns and Aprons. Gowns and aprons are to protect susceptible patients from infections and protect the wearer from contamination. Gowns and aprons are worn to protect uniform or clothes when contamination is anticipated/likely. Full body /Fluid repellent coveralls worn when there is a risk of extensive splashing of blood and/or other body fluids, e.g. in the operating theatre, also worn when a disposable apron provides inadequate cover for the procedure/task being performed.[20,21]

Eye/face protection. Masks, visors, and goggles protect the mucous membranes of the eyes and mouth from exposure to blood and body fluids in situations where splashes can occur. Eye/face protection should not be touched by hand while being worn.[20] Face masks/surgical masks are loose fitting, single-use items that cover the nose and mouth. They are used as part of standard precautions to keep splashes or sprays away from reaching the mouth and nose of the person wearing them. All patients with cough and confirmed TB patients should be encouraged to wear face masks all times to reduce the transmission of infections to other patients, visitors, and HAWs.[22]

Preventions of injury from needles and sharps management

The use of sharp devices exposes HAWs to the risk of injury and potential exposure to Bloodborne infectious agents, including hepatitis B virus, hepatitis C virus and human immunodeficiency virus (HIV).[22] Sharp injuries include regulatory requirements for employers and contractors in the healthcare sector in relation to (i) arrangements for the safe

use and disposal of sharps. (ii) Provision of information and training to employees (iii) Sharps handling must be assessed and kept to a minimum and eliminated if possible with the use of approved safety devices. (v) Needles must not be re-sheathed/recapped.[21]

Reducing risks if a sharps injury occurred. (i) Seek care immediately if you sustain a sharps injury. (ii) If the skin is penetrated, wash the affected area immediately with soap and water. Alcohol-based hand rub can be used to clean the area if soap and water are not available. (iii) Do not squeeze the affected area. (iv) Report the incident immediately to the department supervisor. (v) Ask about follow-up care, including post-exposure prophylaxis, which is most effective if implemented soon after the incident. (vi) Complete an accident/incident report form, including the date and time of the exposure and how it happened.[22]

Hand hygiene

Hand hygiene is the single most important way to prevent spread/transmission of infections. It is important that hand hygiene should be performed before any procedure for reason that places the patient at risk of infections; world health organization (WHO) defines five moments when healthcare workers should perform hand hygiene

1. Before touching a patient;
2. Before clean/aseptic procedures. liquid soap should be used;
3. After body fluid exposure risk;
4. After touching a patient; and
5. After touching a patient's immediate surroundings.[23]

Hand washing methods

Hand washes with soap and water. This method is usually used in case of hands are visibly dirty or soiled with blood or other body fluid after using the toilet. Hand washes with soap and water also used if exposure to potential spore-forming pathogens are strongly suspected or proven.[23]

Alcohol-based hand rubs. Have become more widely used after contact with inanimate surfaces or objects, before handling an invasive device for patient care, before and after touching the patient, after contact with the body fluids and excretions, mucus membrane and non-intact skin or wound dressing and if moving from a contaminated body side to another body side during patient care and after removing sterile or non-sterile gloves.[23]

Respiratory hygiene and cough attitude: Is an infection control component of standard precautions. Persons with respiratory symptoms should always practice respiratory hygiene and cough attitude this can be achieved by providing a mask to those who are coughing. Designate an area in the waiting room for patients with respiratory symptoms and consider isolating symptomatic patients are highly recommended.[24]

Cleaning of patients care environment: Keeping the patient environment area clean is a fundamental principle of preventing infection in the hospital setting and it is the responsibility of the person in charge to ensure that the care environment is safe for practice. The care environment to be (i) visibly clean, free from non-essential items and equipment to facilitate effective cleaning. (ii) The environment should be well maintained and in a good state. Staff should be educated on the use of the chemicals and annual competencies are recommended for specific disinfection and sterilization procedures. All cleaning, disinfection, and sterilization processes should comply with relevant guidelines.[24]

Disinfection and sterilization of patients care equipments

Any instrument or piece of equipment that is to be reused requires reprocessing/cleaning, disinfection and/or sterilization. The system is based on instruments and items for patient care being categorized into critical, semi-critical and non-critical, according to the degree of risk for infection involved in the use of the items. Disinfection is a process that inactivates non-sporing infectious agents, using either thermal (moist or dry heat) or chemical means. Items need to be cleaned before being disinfected. Sterilization destroys all microorganisms on the surface of an instrument or device, to prevent disease transmission associated with the use of that an instrument or device.[6]

Biomedical waste management

Sharps waste. Sharps are items that could cause cuts or puncture wounds. Examples of sharps, including needles, hypodermic needles, scalpels, and other blades, knives, infusion sets, saws, broken glass, and pipettes. Whether or not they are infected such items are usually considered highly hazardous healthcare waste and should be treated as if they were potentially infected.[25]

Infectious waste. Is materials suspected to contain pathogens (bacteria, viruses, parasites or fungi) in sufficient concentration or quantity to cause disease in susceptible hosts. This category includes:

- Waste contaminated with blood or other body fluids;
- Cultures and stocks of infectious agents from laboratory work;
- Waste from infected patients in isolation wards.[25]

Domestic waste. Non-hazardous or general waste is waste that has not been in contact with infectious agents, hazardous chemicals or radioactive substances and does not pose a sharps hazard.[25]

Waste segregation systems

- Black Plastic bag – Trivial risk. Used for domestic waste and final disposal to Landfill.
- Yellow container – High risk. Used for highly infectious or contamination risks. Type of container should be strong, leakproof plastic bag or container capable of being autoclaved.
- Brown container/plastic bag. Should be labeled with the appropriate hazard symbol and used for chemical and pharmaceutical waste.
- Yellow. Should be marked "SHARPS" and with a biohazard symbol used for sharps. Type of container must be Puncture-proof container.[25]

Hospital linen management

Clean linen should be stored in a clean and designated area, preferably an enclosed cupboard. If clean linen is not stored in a cupboard, then the trolley used for storage must be designated for this purpose and completely covered with an impervious covering that is able to withstand decontamination.[6]

Soiled linen should be removed as close to the source as possible. Soiled linen should not (i) rinse, shake or sort linen on removal from beds/trolleys (ii) place used linen on the floor or any other surfaces e.g. a locker/table top (iii) re-handle used linen once bagged (iv) overfill laundry receptacles.[6]

Transmission-based precautions

Transmission-based precautions are designed to reduce the risk of airborne, droplet and contact transmission and always are used in addition to standard precautions to observe patients known or suspected to have highly transmissible or epidemiologically important pathogens.[26,27] **Airborne precautions** are used to prevent transmission of infectious agents that remain infectious across long distances when suspended in the air. Disease-causing microorganisms may be suspended in the air as small particles, aerosols or dust and remain

infective over time and distance, for example, *Mycobacterium tuberculosis* (pulmonary/laryngeal), *varicella zoster virus* (chickenpox), *herpes zoster* (shingles) and *measles*. Patient placement should be in an airborne infection isolation room, which is a single-patient room with special air-handling and ventilation capacity. Respiratory protection must be employed when entering the isolation room using the disposable N-95 respirator mask, which fits tightly around the nose and mouth to protect against both large and small droplets. This should be worn by all persons entering the room, including visitors.[27]

Contact Precautions are intended to prevent transmission of infectious agents that are spread by direct or indirect contact with the patient or the patient's environment. For example, *Methicillin-Resistant Staphylococcus aureus* (MRSA), *respiratory syncytial virus* infection, *varicella (chickenpox), herpes zoster, hepatitis A* and *rotavirus* infections. Patient placement is preferred to be in a single-patient room to limit the opportunities for transmission. Transporting patients should be limited as much as possible to reduce opportunities for disease transmission to staff members and other patients.[26,27] **Droplet precautions** are intended to prevent transmission of pathogens spread through close respiratory or mucous membrane contact with respiratory secretions. Microorganisms are also transmitted by droplets (large particles >5 μm in size) generated during coughing, sneezing and talking for example, *influenza virus*, *Bordetella pertussis*, *Mycoplasma pneumoniae*, *Severe acute respiratory syndrome-associated corona virus*, Group A *Streptococcus*, *adenovirus* and *rhinovirus*. Patient placement is preferred to be in a single-patient room to limit the opportunities for transmission. Transporting of patients who require droplet precautions should be limited.[26,27]

Improving Healthcare Facility Infection Control

Using the Hierarchy of Control Technologies: Controlling exposures to occupational hazards is the fundamental method of protecting workers. Traditionally, a hierarchy of controls has been used as a means of determining how to implement feasible and effective control solutions. The hierarchy falls into three general categories, which in the order of importance are as follows: (1) engineering controls, followed by (2) administrative and work practice controls and, supplemented by (3) personal protective equipment (PPE). (Table 2) describe categories of hierarchy of controls. These can be used together in combination or individually while other (higher level) controls in the hierarchy are being implemented.

Following this hierarchy normally leads to the implementation of inherently safer systems, where the risk of illness or injury has been substantially reduced.[28]

Table. II. Categories of the hierarchy of controls.

1-Engineer measures a-Isolation measures	Is by protecting people from hazard using designing, building refurbishment and organizing of health care facilities example placement of registration counters, outpatients waiting area and other health care facilities sections. Provision of running water and wash basin should be there in strategic locations.[5,29]
b-Ventilation measures	Is by ensuring adequate natural cross ventilation by keeping windows in strategic locations and provision of adequate mechanical ventilation. Ventilation recognized as an important factor of air dilution so to remove infectious droplets from the air.[5,29]
2-Administrative measures	To change the way people work by providing an infrastructure of policies, procedures and patient care practices intended to prevent exposure to and/or transmission of microorganisms to a susceptible host during the provision of health care. The role of healthcare facility administration includes risk assessment, identify point for the implementation of IPC activities, ensure proper implementation of administrative measures, utilizing existing infrastructure and consider a renovation, allocate budget to the maintenance of IPC measures, supervise and monitor IPC activates and address training of HCWs, patients and visitors.[29]
3-PPE measures	Refers to the availability and appropriate use of barriers that a susceptible host may wear to provide a physical barrier between him/her and an infectious agent/infected source. These barriers include gloves, gowns, masks, facial protection, eye protection (including face shields, or masks with visor attachments) and respirators. The health care organization plays a critical role in ensuring the availability of appropriate PPE for use by patients, HCWs, visitors, etc.[29]

Using the multimodal strategies

Multimodal strategies consist of several elements implemented in an integrated way with the aim of improving an outcome and changing behavior. The WHO multimodal improvement strategy includes the areas of system change (build it), training and education (teach it), monitoring and feedback (check it), reminders and communications (sell it), as well as cultural change (live it) supporting IPC in a patient safety perspective.[30] Implementing IPC control activities at the facility and national level using multimodal strategies is effective to improve infection prevention and control practices and reduce HAIs and combat AMR.[31] Lee *el. at*.,[32] described evidence that IPCP, including a WHO multimodal strategy with four or more elements, were associated with decreased respiratory infections and Multi-drug resistant organism infections and with improved adherence to hand washing practices in long-

term care facilities. The WHO multimodal strategy has been applied and proven effective in several studies of IPC practice as hand hygiene practices.[32]

Auditing and monitor workload, staffing and bed occupancy

Addressing bed occupancy and staffing factors will significantly reduce the cross-transmission risk and ultimately reduce HAIs and the spread of AMR in health care facility. Bed occupancy should not exceed the standard capacity of the facility, and health care staffing should be at acceptable levels in relation to patient workload. Zing *et al.*,[33] evaluated several studies that showed transmission of infection with MRSA was associated with bed occupancy and with low staffing and nurse-to-patient ratios. Higher numbers of permanent staff HCWs and improved nurse-to-patient ratios reduced HAIs. Low staffing levels and high workload are associated with inadequate adherence to hand hygiene protocols and increase MRSA infections. Long work hours were associated with increased rates of HAIs.[33]

Supervising and monitoring of infection prevention and control program

the supportive supervision is an act of observing the conduct of activity to make sure that is implemented as per plan and it consists of on-site visits, observing tasks being performed, imparting hands-on training, helping to organize tasks, enhance the motivation of staff and monitoring the activities and results.[30,31,34]

The Laboratory Role in Infection Prevention and Control

Microbiology laboratories (MLs) are an essential element of the infection prevention program at every health care facility. Effective prevention saves not only lives, but money and these savings are rarely credited to the MLs. Some of the major roles played by the MLs in IPC include contributions to (i) Recovering and identifying the causative organism (ii) Antimicrobial susceptibility testing for many of these organisms[3,35], (iii) surveillance (iv) outbreak detection and management (v) antimicrobial stewardship (vi) Participation in the ICC, and (vii) Education of HAIs prevention personnel.[3,35,36,37]

Recovering and identifying the causative organisms

Thus, the ability of the MLs to isolate and accurately identify microorganisms is as crucial to infection control as it is to the individual patient. Due to technological developments, the MLs have continued to increase the efficiency with which nosocomial organisms can be recognized and recovered. There are three main aspects to this. First, new instruments and

devices have become widely available. Second, newer nonculture tests have permitted the identification of agents of nosocomial infection such as immunologic and nucleic acid testing. Third, these newer tests and instruments not only permit the identification of additional agents, but also the more rapid diagnosis of both new and old pathogens.[35] MLs should be able to examine blood, cerebrospinal fluid, urine, stool, wound exudate or swab, respiratory secretions and perform basic serological tests (HIV, HBV, HCV, influenza). Different methods used in the diagnosis of infections such as classical methods which include (i) Direct smear (ii) Culture (iii) Antigen detection (iv) Serological tests and molecular methods which consist of (i) Hybridization (ii) Amplification (iii) Real-time amplification.[3]

Antimicrobial susceptibility testing

Antimicrobial susceptibility testing (AST) is an inexpensive, easy to use and readily available means that is often used to characterize microorganisms. The infection perventionist frequently reviews daily and cumulative AST reports (antibiograms) for emerging patterns of resistance.[38] Every IPCP must implement control measures to prevent the spread of multidrug-resistant organisms (MDROs). However, the success of any program to control MDROs depends upon the ability of the MLs to detect these organisms. Laboratory directors must keep current with the literature regarding manual, semi automated and automated systems' ability to detect emerging resistances and they must implement if necessary, additional methods to detect or confirm particular resistance patterns. Increasingly, such confirmatory testing will be performed using molecular methods. New AMR continues to emerge and existing resistances are increasing in frequency. The most important resistances emerging in HAls pathogens include extended spectrum β-lactamases among Enterobacteriaceae. glycopeptide resistance among enterococci, MRSA, and MDROs among nonfermenters such as *Pseudomonas aeruginosa, Acinetobacter*, and *Stenotrophomonas maltophilia*.[39] AST has been used successfully as effective tool in the investigation of several outbreaks.[38]

Participation in HAIs surveillance

Surveillance is the systematic collection, analysis, and interpretation of data on the frequency of disease. It is essential to the planning, implementation, and evaluation of public health practices and the timely dissemination of the data for public health action.[40,41]

Objective of surveillances

- Establish endemic baseline rate
- Reducing infection rates in the hospitals
- Identifying and containing the outbreaks
- Evaluating and monitoring infection control measures
- Monitoring AST.[40]

Types of surveillance to monitor HAIs

- Passive surveillance of HAIs refer to the identification of HAIs by patient care providers, who may not be formally trained in surveillance and may not consistently use standardized surveillance case definitions to identify HAIs. Examples of Passive surveillance consist of laboratory-based surveillance and ward-based surveillance.[40,42]

- Active surveillance is the identification of HAIs by trained personnel who proactively look for HAIs using multiple data sources. Active surveillance is conducted by trained staff using standardized case definitions and is more accurate than passive surveillance.[40,42]

- Targeted surveillance aimed at high-risk areas (e.g. Intensive Care Unit and Neonatal Units), type of infections (e.g. bloodstream and surgical site infections), or procedure directed (e.g., infections associated with central venous or urinary catheters) are the most cost-effective and manageable, and should be used in health care facilities.[41,43]

- In MLs, use strategies of traditional systems, passive and active surveillances remain the most common method for case finding in HAIs surveillance. Therefore, the most important role of the MLs is to promptly and accurately detect nosocomial pathogens and their AMR patterns. Virtual surveillance is active surveillance systems augmented by the inclusion of new computing technologies and the use of mathematical models. Virtual surveillance should be the goal of early detection of unusual patterns of microbial pathogens and HAIs.[44,45] Major surveillance challenges facing the MLs include the continued emergence of novel infectious agents (e.g., the H1N1 influenza A virus)[45], novel antimicrobial-resistant pathogens (e.g., vancomycin-intermediate/resistant *Staphylococcus aureus* [VISA/VRSA], carbapenem-resistant Enterobacteriaceae [CRE]), Vancomycin-resistant enterococci (VRE), multi-drug resistant *Pseudomonas aeruginosa*, multi-drug resistant *Acinetobacter baumannii*, multi-drug resistant *Mycobacterium tuberculosis* and *Clostridium difficile.*[3,45]

Outbreak detection and management

The outbreak may be defined as the occurrence of disease at a rate greater than that expected within a specific geographical area and over a defined period of time.[41,43,46]

Types of outbreaks: Common source outbreak is a type of epidemic caused by exposure of a group of people to a common risk factor, such as an infectious agent or a toxin or a chemical, etc. This can take two forms: (i) Point source outbreak is brief and simultaneous exposure and all exposed will develop the disease within one incubation period (ii) Continuous/ Intermittent common source refers to the source of an outbreak remains for a long time either continuously or intermittently (iii) The propagated or progressive outbreak of this type occurs from the transmission of an infectious agent from one susceptible an infected host to another. It can be through direct person-to-person transmission or indirect transmission through a vector, vehicle, etc.[47,48]

Outbreak investigation steps

When an outbreak is suspected, ten steps recommended are taken to investigate an outbreak. The laboratory is integral in several of the steps. The steps that are followed in an outbreak includes (i) Confirm the existence of the outbreak. (ii) Verify the diagnosis and determine the aetiology of the disease. (iii) Develop a case definition, start case finding and collect information on cases. (iv) Describe persons, places, and times and generate hypotheses. (v) Test the hypotheses using an analytic study. (vi) Carry out necessary environmental or other studies to supplement the epidemiological study. (vii) Draw conclusions to explain the causes or the determinants of the outbreak based on clinical, laboratory, epidemiological and environmental studies. (viii) Report and recommend appropriate control measures to concerned authorities at the local, national and if appropriate international levels. (ix) Communicate the findings to educate other public health professionals and the general public. (x) Follow up the recommendations to ensure implementation of control measures.[41,47]

Outbreak identification

Early identification of an outbreak is important to protect patients as infection may be transmitted to them by HCWs or through contaminated materials. A potential problem may be initially identified by nurses, physicians, microbiologists, any other HCWs or through a nosocomial infection surveillance program.[49] MLs have important roles to play in any potential outbreak situation, including early recognition of possible clusters and outbreaks, rapid notification and collaboration with the ICT to enable the ICT to

take appropriate measures to stop it from spreading at the very beginning. Additionally case finding and provision of molecular typing for determination of relatedness is requires maintenance of an organism bank.[3,45] The MLs, in association with the ICT, are the first to detect an outbreak and determine whether an outbreak is real due to unusual clusters of pathogens or resistance patterns or a potential pseudo-outbreak due to contamination of specimens outside or within the laboratory. In addition, the laboratory can help generate hypotheses and provide information on the epidemiology of the etiologic agent as to the potential source of an outbreak, its reservoir and its mode of spread through phenotypic methods and molecular typing of the suspected organisms and through testing the environment and/or personnel as necessary. Traditionally, the epidemic strain has been defined with phenotypic methods, which include genus, species, biotype, serotype, phage type, bacteriocin production and AMR patterns. Sometimes, isolates share the same phenotypic markers and when microbial pathogens are nontypeable by phenotypic methods or have only a few types, the poor discriminatory power this has led to the use of genotypic methods for typing. These molecular epidemiologic methods most often involve genotyping of microbial plasmid or chromosomal DNA and go far beyond the current limitations of phenotyping and provide more accurate data during outbreak investigations. Moreover, outbreaks of viruses and free-living microorganisms can now be adequately studied with current molecular epidemiologic methods. However, combining methods of microorganism identification provide stronger evidence for the presumed relationship between isolates. A major challenge to the MLs is in detecting outbreaks early enough to allow effective intervention and impact morbidity and mortality.[38] Effective and regular communication between MLs personnel and infection preventionists is essential to this effort, as many outbreaks are first noted at the MLs benches when technologists notice unusual clusters of organisms or antimicrobial resistance patterns.[45,50]

Participation in antimicrobial stewardship

Antimicrobial stewardship can be defined as a bundle of interventions to promote and ensure the optimal use of antimicrobial treatment that results in the best clinical outcome for the treatment or prevention of infection, with minimal toxicity to the patient and minimal impact on subsequent resistance.[51] Dyar *et al.*,[52] also defined antimicrobial stewardship as a coherent set of actions designed to use antimicrobials responsibly.[52] Determining antibiotic susceptibility patterns for microorganisms causing HAIs is vital for individual patient care. It can also help in planning antibiotic policy and designing the local antibiotic formulary.

The MLs should work closely with physicians and pharmacists to determine appropriate antibiotics to be included in susceptibility testing panels, so good communication between the laboratory, pharmacy, IPCP and a stewardship team are essential. For guiding directed antimicrobial therapy, patient-specific culture and susceptibility data are needed. These data should be available for every physician who prescribes antibiotics.[45,51] Morency-Potvin *et al.*,[51] described essential antimicrobial stewardship activities in the MLs which includes (i) Collaborate in educating local HCWs on microbiology issues that impact treatment and microbial resistance (ii) Promptly report unusual patterns of resistance, test supplementary agents and provide advice on therapy for patients awaiting results (iii) Optimize communication of critical test result values and alert systems (iv) Provide guidance for adequate collection of microbiology specimens (v) Develop alert systems for specific MDROs. A major challenge to effective stewardship is an inability to obtain antimicrobial susceptibility data from the MLs in a timely and efficient manner, therefore using rapid diagnostic and AST technologies for targeted critical specimen types is required. Importance of antimicrobial stewardship programs include but are not limited to, reduction of *C. difficile* infection incidence, reduction of AMR, improving antimicrobial dosing in renally impaired patients, improving the use of surgical antimicrobial prophylaxis, improved infection cure rates, decreased mortality rates, more rapid administration of effective antimicrobial therapy and appropriate de-escalation in critical infections and hospital cost savings.[51]

Participation in infection control committee

It is paramount that the Laboratory scientists or clinical microbiologist participates on the ICC and acts as a consultant to infection preventionists. MLs is the best department to provide expertise services in the interpretation of culture results, advice about the utility of microbiological approaches to an infection control problem and prepare specific reports to the ICC such as (i) Blood culture contamination report (ii) Facility antibiogram with contributing of pharmacy (iii) Legionella urinary antigen report (iv) Seasonal influenza and respiratory virus surveillance report. Microbiologist should describe how changes in the methods used for detection, identification and susceptibility testing of nosocomial pathogens will impact the IPCP.[13,14,41,45,53]

Education of HAIs prevention personnel

Infection control education is a core component of IPCP since they were established and they remain a constant feature in the modern healthcare context. HCWs should be equipped with the requisite knowledge, skill and attitude for good IPC practices. A variety of educational strategies are evaluated for their effectiveness as a measure of IPC. Some of the most practiced methods are simulation-based training[33], and hands-on training quasi-experimental settings where control and target groups are subjected to both didactic and practical sessions, scenario-based simulation training, e-learning followed by a questionnaire and focused group discussions and computer-assisted learning in IPC education. All the HCWs should be adequately educated in the basic principles of IPC and should undergo continuous training to acquire up-to-date knowledge and skills.[54] The use of multimodal strategies was identified in five interventional studies that successfully reduced HAIs by improving IPC knowledge and increasing hand hygiene compliance.[34] Laboratory specialists or microbiologist must not only keep themselves educated in their contribution to the ICT, but also keep the IPC personnel educated regarding the laboratory's contribution to the team. Education of future hospital epidemiologists and infection preventionists require training in infectious diseases and structured clinical microbiology training due to the important role of microbiology education as foundational knowledge in IPC practice.[39,41,55]

CONCLUSION

The IPC is very important approach in the health care facility as medicine becomes more invasive and the proportion of ageing and immunocompromised patients in our population continues to increase. Hospitals should come up with an in-house awareness programme where staff members, patients and visitors can be educated on maintaining hygiene. Moreover, MLs are becoming an integral part of HAI prevention programmes. The emergence of new pathogens, and new resistances in old pathogens, makes microbiology laboratory indispensable for successful prevention of HAI. MLs to be a part of the ICT, ICC and antibiotic committee. Only very close communication, collaboration and cooperation between microbiology laboratory and infection control personnel can fulfill the duties of successful infection prevention and control in healthcare institutions.

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