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Infection Control Practices in Health Care Set-Up

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1. Introduction

“..... the very first requirement in a hospital is that it should do the sick no harm”

- Florence Nightingale

In India, Egypt, Palestine and Greece, the concept of hospital with hygienic practices was present as early as 500 BC. Later, hospitals became overcrowded as it were only meant for military personnel [1]. From 18th Century onwards new hospitals were established for civilians also. The transmission of infections in the hospital were also known to mankind since the sick were housed together for treatment. But no epidemiological data or surveillance system was available. But the enormity of the problem of Hospital Acquired Infections in pre-Lister era can be best understood by the writing of John Bell in 1801 who described the concept of “Hospital Gangrene” [2]. Lord Joseph Lister first used carbolic acid as an antiseptic in 1865 and published his work in 1867 which started the antiseptic era and he has been remembered as “Father of Antiseptic Surgery”.

Louis Pasteur in his celebrated lecture to Academic de Medicine on 30th April, 1873 said, “If I had the honour of being a surgeon.... not only would I use absolutely clean instruments (free from germs) but after cleaning my hands with great care would only use sponges previously raised to a heat of 130-150^o F. I would still have to fear germs suspended in air and surrounding of the patient” [2].

So with progressive awareness in later part of 16th century, regarding the transmission of infection among hospitalized patients continued to be a great concern for everyone related to hospitals but still hospital acquired infections remain a problem worldwide even today. World

Health Organisation (WHO) conducted a survey and the results of the survey in 1988 reported that “Hospital Acquired Infection is a considerable problem even in hospitals in which means and interests in control of Hospital Acquired Infections exist” [2].

British Medical Council established Hospital Infection Control Programme in 1941 and a part time post of “Control Of Infection Officer” was created, which was renamed as “Infection Control Doctor” in 1988. The first full time “Infection Control Nurse” was appointed in 1959 [1]. National Nosocomial Infections Surveillance (NNIS) system of the Centre for Disease Control and Preventions (CDC) was developed in early 1970s to monitor the incidence of Hospital Acquired Infection, the risk factors and causative organisms [3].

The term nosocomial infection is derived from *nosus* means disease and *komeion* means to take care of and has been used for many years. The hospital acquired or nosocomial infections have been defined as infections that occur to patients during hospitalization but are neither present nor incubating during admission to the hospital. In simple words, any infections acquired in a hospital which was not present or in its incubation period during admission to the hospital are called nosocomial infections.

In the past, nosocomial infections or Hospital Acquired Infections were restricted only to the hospitals, but in recent years, spectrum of health care and interactions of different types of healthcare facilities including hospital, long term care, rehabilitation or ambulatory care facilities have been expanded and nosocomial infections have broadened its horizon. Hence, the term Healthcare Associated Infection (HAI) is a more appropriate term. The Centers for Disease Control and Prevention (CDC) defines HAIs as infections that patients acquire during the course of receiving treatment for other conditions or that Healthcare workers (HCWs) acquire while performing their duties within a healthcare setting [4]. The bacterial HAIs are usually observed, 48 hours after admission to healthcare setup, because for most of the routinely isolated bacteria the incubation period is 48 hours. But each infection must be assessed individually as the incubation period varies with the type of pathogen, dose of inoculum and patient’s immune status. Some HAIs may be observed even after discharge of the patient especially, Hepatitis B virus (HBV), Hepatitis C virus (HCV), Human immune deficiency virus (HIV) etc. Even CDC has changed the name of section of Hospital Infections Programme to the Division of Healthcare Quality Promotion [5]. The National Health care safety network (NHSN) of CDC defines HAI as a localized or systemic condition that results from presence of infectious agent or its toxin and that was not present or incubating at the time of admission to the Hospital / Health care facility [6].

2. HAI is on the rise

In last century mankind has experienced tremendous advancement in Medical field in understanding the causes and thereby improvement in diagnostic and therapeutic approach of any disease. Similarly, progress in engineering field has changed the look of Health care system. But with all these advancements also, HAIs are on the rise mainly because of -

- i. Increase in immunocompromised patients

- ii. Interward and interhospital or interhealth care facility transfer
- iii. Emergence of antibiotic resistant bacteria prevalent in Health care facilities
- iv. Increased work load – Staff pressure, Lack of facilities, Lack of concern ???

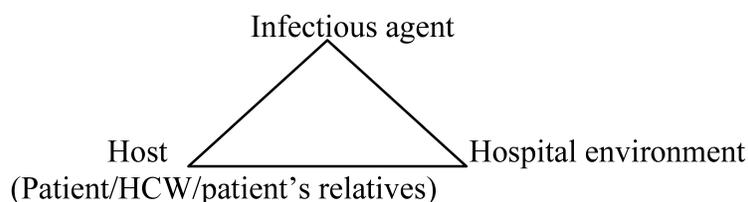
The last one is most dangerous. Though scenario is slightly better in developed world the picture is grim in other developing countries. According to WHO report 2002 [7] worldwide more than 1.4 million people suffer from HAI. Actually HAI vary from 5-25% in developed countries, whereas data from developing country is not available as it is not reported properly. It may be >40% in Asia, Africa and South America [8]. Klevens et al, 2007 had reported that HAIs killed 99,000 patients in American hospital [9] and 37,000 deaths in Europe [10]. In US, 5-10% of all hospitalized patients can get HAI. In India data are sparse, Mukherjee V had reported in 2001 that HAI occurred in 30-35% of all hospital admissions in India [11]. Childs D reported that HAIs kill more patients every year than do AIDS, breast cancer and automobile accidents together worldwide [12]. HAIs are the 8th most common cause of death in US. The mortality rate range from 12-80% in ICUs of developed countries [13].

Impact of HAI

The major impact of HAI are outcome of disease is adversely affected. HAI is the major cause of: i) increased morbidity and mortality, ii) increased average length of stay (ALS) of patients in the Health Care set up, iii) increased diagnostic and therapeutic interventions and iv) increased cost of Health Care. HAI adds financial burden to patients, health care organization, State and also National Health Care system. HAI also have negative impact on effectiveness and productivities of Health Care organization. In case of HAI, patients are not protected by Health insurance and the health care organization comes under consumer protection act.

The triad of infectious diseases as described in textbooks are i). the affected host ii). an infectious agent and iii). the environment, both animate and inanimate [14]. HAIs also follow the same triad as the affected host may be the patients, health care workers(HCW), patient's relatives, the infectious agent may be Methicillin Resistant Staphylococcus aureus(MRSA), Vancomycin Resistant Enterococci(VRE), Pseudomonas aeruginosa, other Gram negative bacteria or simply Candida, Aspergillus or viral e.g. Cytomegalovirus, HBV, HIV etc and most important the hospital environment.

Hence, the epidemiological triad of HAI are –



2.1. The high risk areas for HAI

Nurseries, Intensive care units (ICUs), Operation theatres (OTs) and Post operative wards, Labour room, Dialysis unit, Organ transplant unit, Oncology wards, Burn units, High Dependency units (HDU) etc are mainly high risk areas for HAI.

2.2. Host factors responsible for HAI

- i. Repeated hospital admissions
- ii. Increased number of patients receiving intensive care or long term care facilities
- iii. Extremes of age i.e. in elderly patients the immunity is waning and in newborn the immune system is immature
- iv. Increased survival of low birth weight or premature babies treated in NICUs
- v. Increased incidence of road accidents leading to head injury, spinal cord injury in trauma ICUs
- vi. Patients with diabetes, malnutrition
- vii. Patients with HIV / AIDS etc

2.3. Source of HAI

HAIs acquired by a patient may be endogenous (autogenous) and exogenous. Endogenous infections are caused by patient's own flora or by carrier state, whereas exogenous infections result from transmission of organisms from various sources via different routes [15]. Exogenous sources may be other patients with infectious diseases. HCWs carrying MRSA, Multidrug resistant (MDR) Gram negative organisms on hands or dresses, contaminated disinfectant solutions, environmental surfaces especially frequently – touched surfaces e.g. bed rails, furnitures, door latches, toilet seats, telephones etc and even floor, window panes, air conditioners, renovation work, inefficient sterilization of equipment and devices. Moreover, medications or devices, necessary to cure patient's primary medical condition can also predispose to HAI. The important ones are -

- i. Overuse or injudicious use of antimicrobials
- ii. Indwelling medical devices such as urinary catheters, endotracheal tubes, ventilators, artificial heart valves, joint prosthesis etc which break the body's natural barrier to infection, which can also lead to biofilm formation and form a nidus for chronic persistent infection.
- iii. Improper maintenance of operation theatres and ICUs etc

2.4. The mode of transmission of HAI may be

Contact (direct or indirect), droplet, airborne, common vehicle (food, water, medical devices, blood or blood products etc) and vector borne (mosquitos, flies, rats etc)

Contact transmission : The organisms which are transmitted by contact are MRSA, VRE etc.

Direct contact transmission occurs direct body surface to body surface contact and commonly occurs to HCW [16], while giving patient care. Indirect contact transmission occurs with contaminated inanimate objects e.g. needles, dressings, contaminated hands of HCW, endoscopes etc.

Droplets are generated while coughing, sneezing, talking or performing suctioning, bronchoscopy etc. The droplets (large particles $>5\mu\text{m}$ in size) transmitted from infected person through air (short distance ≤ 3 feet) and deposited on host's conjunctiva, nasal mucosa or mouth. But the droplets are not suspended in air [15].

Airborne transmission occurs by airborne droplet nuclei (small particle $\leq 5\mu\text{m}$ in size) which are evaporated droplets containing the microorganisms that remain suspended in air for few hours or days. Mycobacterium tuberculosis, Varicella, Rubella, Influenza viruses etc can be transmitted by droplet nuclei [15].

2.5. Infecting agents

The organisms causing HAI are mostly antibiotic resistant, which adds to the increased morbidity and mortality of patients.

- Antibiotic resistant pathogens associated with HAI are –
- Major Gram positive pathogens
- Vancomycin Resistant Enterococci (VRE)
- Methicillin Resistant Staphylococcus aureus (MRSA)
- Methicillin Resistant Coagulase negative Staphylococci (MRCONS)
- Vancomycin Resistant Staphylococcus aureus (VRSA)
- Vancomycin Intermediate Staphylococcus aureus (VISA)
- Penicillin Resistant Pneumococci
- Major Gram negative pathogens :

Specially Extended spectrum β -lactamase (ESBL producing) or multi / Extreme drug Resistant Gram negative bacteria e.g.

- Pseudomonas aeruginosa
- Enterobacteriaceae : Klebsiella pneumoniae, E.coli, Citrobacter sp., Enterobacter sp. etc.
- Acinetobacter baumani
- Penicillinase producing Neisseria gonorrhoeae (PPNG)
- Burkholderia species, Stenotrophomonas maltophilia and amongst fungi especially Fluconazole resistant Candida species are also becoming important agents causing HAI specially in ICU patients [17].

The terms Multidrug resistance and Extreme drug resistance in Gram negative bacteria was introduced by Falagas in 2011 [18]. Multidrug resistance (MDR) is indicated by non-susceptibility to one or more antibiotics belonging to 3 or more antibiotic classes, whereas Extreme drug resistance (XDR) is indicated by resistance to all available antibiotics.

In 2009, Peterson et al used the acronym ESCAPE for MDR organism causing HAI [19].

E : Enterococcus faecium/E.faecalis

S : Staphylococcus aureus

C : Clostridium difficile

A : Acinetobacter baumani

P : Pseudomonas aeruginosa

E : Enterobacteriaceae

10-12 % of all HAIs are caused by Enterococci which is the 3rd most common cause of blood stream infection in hospitalized patients. Vancomycin resistant Enterococci (VRE) was first isolated in vitro in 1969 and was described clinically in 1988. The main mechanism is alteration of cell wall precursors. Several resistant genotypes have been detected, of which vanA and vanB are most clinically significant. Vancomycin resistance is transferable to Staphylococcus aureus in vitro. As a life saving measure, treatment option with MDRO is very selective. MRSA strains can be treated by Vancomycin and Linezolid, VRE can be treated by Linezolid; ESBL producers can be treated by β – lactamase inhibitors; both ESBL and AmpC producers can be treated by Carbapenems. But Carbapenem resistant organisms can be treated by Colistin.

Recent studies in India have reported ESBL in 70 – 90% of Enterobacteriaceae, 29% Pseudomonas aeruginosa and 26% of Acinetobacter spp. which is a serious problem [20]. Recently from our hospital prevalence of AmpC β – lactamase and metallo β lactamase (MBL) producing P.aeruginosa strains have been reported as 19.3% in 2009 and 11.4% in 2010 respectively [21], [22].

3. HAI : Types by site

- i. Unary tract infections (UTI) – UTI are mostly catheter associated which are called CA – UTI. CA – UTI are the second most common cause of health care associated Blood stream infections. As per National Health care Safety Network [23], CA – UTIs are defined as the patient having indwelling urinary catheter or 48 hours before onset of UTI. No time period is fixed that the patient must be having catheter to call UTI as CA – UTIs. Richards et al have reported in 1999 that 95% of UTIs in hospitals are CA – UTI. In CA – UTI not only bacteruria occurs but Candida albicans and Candida non-albicans species are also isolated and so a new term microburia has been introduced [24].
- ii. Hospital acquired pneumonia (HAP) – is the second most common hospital acquired infection and accounts for 15% of HAIs [25]. Highest morbidity and mortality amongst

all types of HAIs occur in HAP [26] and roughly the mortality range from 24 to 76 % in different health care settings [27]. Ventilator associated pneumonia (VAP) is the commonest cause of HAP which occurs after 48 hours of initiating mechanical ventilation [25], [28]. VAP occurs 25% of all ICU infections and caused by multidrug resistant bacteria e.g. *Pseudomonas aeruginosa*, *Acinetobacter baumannii* or Carbapenemase producing *Enterobacteriaceae*, MRSA, VRE etc. *Burkholderia* sp. and *Stenotrophomonas maltophilia* both have a tendency to colonize respiratory tract rather than to cause invasive disease and are mostly resistant to Carbapenems, because of production of metallo-beta-lactamase (MBL). The high mortality, prolonged ICU stay and excessive cost associated with VAP is a real challenge to medical fraternity.

- iii. Surgical site infections (SSI) – SSIs are the most common nosocomial infection. SSIs are caused by MRSA, VRSA, VISA, VRE, *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, ESBL and AmpC β – lactamase producing *E. coli*, *Klebsiella*, *Proteus* etc and also by MBL and *Klebsiella pneumoniae* carbapenemase (KPC) producing Gram negative bacilli. SSIs occur when microorganisms gain access to areas of the body, exposed during surgical procedures and then multiply in the tissues. Mangram et al have defined SSIs which manifests within 30 days of a surgical procedure or within one year if the implant is left in place during the operative procedure and affect either the incision or deep tissue at the site of operation [29]. The intraoperative factors as proper skin preparation, following sterile techniques, traffic in the operating room contribute more to SSIs compared to patient related factors e.g. diabetes mellitus, pre existing colonization with MRSA etc [30]. SSIs are most commonly reported from surgical ward and CDC in US requires 16 wound and patient characteristics to define SSIs [31]. Though SSIs are preventable, about one fifth (approx. 22%) of all health care associated infections are due to SSIs (CDC report). Kirkland et al reported that 60% of patients with SSIs are ICU patients, average length of stay in hospital is >5 days and 5 times more likely to be readmitted in hospitals [32]. Hence, rates of SSIs are increasingly considered as a performance indicator for quality of health care provided.
- iv. Catheter Related Blood Stream Infections (CR – BSIs) – These accounts for 50% of all ICU related bacteremias. CR – BSIs specially central line associated blood stream infections (CLABSIs) in ICU have been reported from USA as 1.8 to 5.2 per 1000 CVC catheter days where as studies from 8 developing countries reported the incidence as 12.5/1000 catheter days [33]. CR – BSIs are actually defined as bacteraemia or fungaemia in a patient who has an intravascular device and a positive result of blood culture from peripheral vein, clinical manifestations and no other apparent source for BSI. The causative agents are *Staphylococcus aureus* even MRSA, Coagulase negative *Staphylococci* (CONS), *Enterococcus* species even VRE, *Candida* species, *Pseudomonas aeruginosa*, ESBL and Carbapenemase producing *E. coli* and *Klebsiella*, *Burkholderia* species etc. *Candida* species are known to cause CRBSIs in Neonatal ICU (NICU). Traditionally, Amphotericin B and Fluconazole are the only treatment options for invasive fungal disease in the neonate. Though *C. albicans* is mostly sensitive to Fluconazole, but Fluconazole resistant *Candida* species and toxicity with

Amphotericin B has made antifungal treatment more difficult for neonates. The new azole drug Voriconazole is used for invasive aspergillosis but this drug has not been studied in neonates and possibility of its effect on developing retina which is observed in adults and older children cannot be ruled out [34].

3.1. Scenario in our hospital, in last 5 years

Our hospital is a tertiary care hospital in a rural set up. Though actual incidence of HAI is difficult to calculate, mostly because of improper reporting system, in last 5 years, there is definitely an increase in isolation of Multiple drug resistant organisms (MDRO) from different clinical specimens.

In a study conducted from September 2007 to June 2008, out of 366 *Staphylococcus aureus* strains studied 189 (51.6%) strains were MRSA. Because of changing patterns of antibiotic resistance and emergence of MRSA, renewed interest in macrolides lincosamides and Streptogramin_B (MLS_B) have been developed. Clindamycin, a semisynthetic derivative of Lincosamides has excellent tissue penetration (except in central nervous system), rapid oral absorption and no dose adjustment is required in renal insufficiency and it is one of the most efficient antibiotics in treating skin and soft tissue infections including osteomyelitis. Though the chemical structure of macrolide, lincosamides and streptogramin_B are very different, their mechanism of action is identical i.e. to block protein synthesis by inhibiting peptidyl transferase. Bacteria develop cross resistance due to overlapping binding sites in 23 SrRNA. Three types of MLS_B resistance are observed -

- i. Constitutive MLSB (cMLSB)
- ii. Inducible MLSB (iMLSB) and
- iii. MSB phenotype

For detection of iMLS_B phenotype, D – zone test as per National Committee for Clinical Laboratory Standards (NCCLS) guideline 2004 is done [34]. In our study, out of 366 *Staphylococcus aureus* strains iMLS_B (18.6%), cMLS_B (3.8%) and MS_B (0.8%) phenotypes were detected respectively [35].

In another study, out of 280 *Staphylococcus aureus* strains 51.8% strains were MRSA. Out of these MRSA strains 61.4% were isolated from pus and wound swab and 13.8% MRSA strains were isolated from different ICUs (Medicine ICU, Neonatal ICU, Pediatric ICU, OT – ICU etc). 35.2% MRSA strains were iMLS_B phenotype [36]. The MRSA strains were detected by Cetoxitin (30µg) disc diffusion test as per Clinical and Laboratory standards Institute guidelines [37]. These MRSA strains were further confirmed by doing PCR to detect mec A gene for MRSA and fem A gene for *Staphylococcus aureus* [38]. The increasing incidence of MRSA strains in our hospital could be compared with our study done in 1997 and at that time only 30.6% MRSA strains were isolated [39].

Presently, MDROs isolated from health care set up are mostly caused by different Gram negative organisms, which produce newer β – lactamases like ESBL, AmpC β – lactamases and metalloβ-lactamases (MBL).

From 2008 to 2010, out of total 250 *Pseudomonas aeruginosa* strains studied 40%, 42% and 11.2% were ESBL, AmpC β – lactamases and MBL producers respectively [40]. Amongst these ESBL and AmpC β – lactamase producers 27.2% *P.aeruginosa* strains produced both ESBL as well as AmpC β – lactamases. ESBL producing strains were detected by Combined disc method [41] and ESBL E - test strips [42]. AmpC β – lactamase was detected by Double disc synergy test and Disk potentiation test using 3 – aminophenyl boronic acid [43]. Metallobetalactamase (MBL) were detected by Imipenem – EDTA Double disc synergy test [44], Disk potentiation test [45] and were further confirmed by MBL E – test (AB bioMerieux) [46].

From different ICUs 59.4%MRSA strains were isolated and amongst Gram negative MDROs 21.5% only ESBL producers, 9.6% were only AmpC β – lactamase producers, 13.3% were both ESBL and AmpC β – lactamase producers and 15.6% strains were MBL producers [47]. 90.5% MBL producing strains were resistant to all 08 antibiotics used as per CLSI guidelines [37] and all 100% MBL producers were sensitive to Colistin [47].

In one of our study, 56 *E.coli* strains were isolated from different ICUs (Fig.1). 26(46.4%) strains isolated from different ICUs, produced both ESBL and AmpC β – lactamases(Fig.2). Maximum MBL producing *E.coli* strains 4 (7.8%) were isolated from Medicine ICU and High Dependency Unit(HDU). Only 01 *E.coli* strain was isolated from patient of HDU which produced all 3 types of β – lactamases i.e. ESBL, MBL and AmpC β – lactamases. The unpaired t test was performed with MBL producing and non – MBL producing *E.coli* stains isolated from MICU and HDU, NICU, PICU and OT – ICU and the probability of the result assuming null hypothesis was 0.043 and hence was significant.

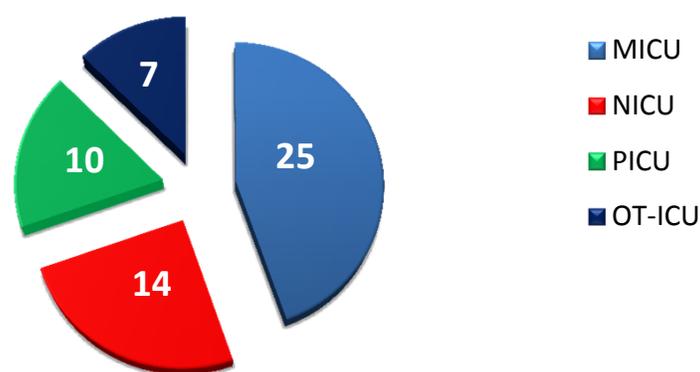


Figure 1. Isolation of *E.coli* strains from different ICUs (n = 56)

4. Infection control programme: Need of the hour

Every country develops a National Infection Control Programme to reduce the risk of Health Care Associated Infections (HAI) and thereby to achieve the national health care objectives with the help of a National Expert Committee. Each health care facility is required to develop an infection control programme to chalk out the annual work plan for monitoring and

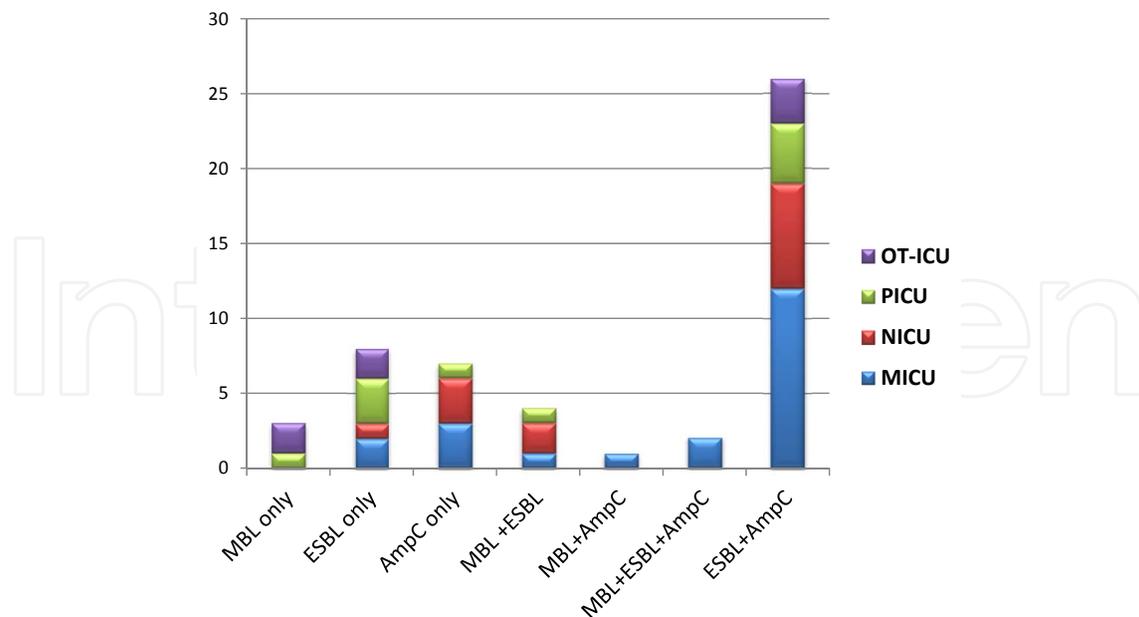


Figure 2. Isolation of ESBL, AmpC & MBL producing E.coli strains from different ICUs (n = 56)

surveillance of HAI, for educating, training health care workers (HCWs) in infection control practices, for controlling out breaks to ensure good health care to patients and prevention of infections for patients and staffs.

4.1. Hospital Infection Control Committee (HICC)

To have need based Infection Control Programme every Health Care facility should form a Hospital Infection Control Committee (HICC) which provides a forum for multidisciplinary input and cooperation and information sharing and include administrators, Clinical Microbiologists, Pharmacologists, HCWs specially ICU and OT incharges, housekeeping, maintenance staffs etc.

4.1.1. HICC must have

- A chairperson from administrators
- Infection Control Practitioner / Officer
- Infection Control Nurse

HICC should meet regularly in every months but not less than 3 times a year.

4.2. Infection control team

Infection Control Team is responsible for day to day activities of HICC in a health care facilities. It usually should have Infection Control Practitioner and other members who give scientific and technical support to carry out surveillance programme and to implement infection control

policies, to manage critical incidents, to conduct training activities and to review the impact of training amongst Health Care Workers (HCWs).

4.3. Infection control manual

Every Health care facilities should have their own Infection Control Manual which is usually prepared by Infection Control Team and approved by HICC and updated. The manual should always be accessible to Health Care Workers (HCWs).

4.4. Infection Control Practices : are grouped into 2 catagories [48] –

- i. Standard precautions – i.e. basic infection control precautions
- ii. Additional precautions – i.e. transmission based precautions

Standard Precautions include basic infection control practices which must be applied to all patients at all times without taking consideration of diagnosis or infection status. Standard precautions are essential to provide a high level of protection to patients, HCWs and visitors (relatives of patients).

4.4.1. Standard precautions include

- Hand hygiene
- Use of personal protective equipments (PPE)
- Precaution of needle stick / sharp injuries
- Proper handling of patient care equipments
- Environmental cleaning and spills management
- Biomedical waste management

4.4.2. Hand hygiene

Hand hygiene is the most important simplest practice to reduce the transmission of HAI, which has been described in early 19th century by Ignaz Semmelweiss, a 2nd year medical student that puerperal sepsis was mainly transmitted by the contaminated hands of clinicians who conducted delivery just after performing autopsy without washing their hands [49], [50]. Semmelweiss also proved in 1847 that incidence of puerperal sepsis, fever and maternal mortality due to puerperal sepsis could be greatly reduced by washing hands.

In 2005, WHO introduced first Global safety challenge ‘Clean care is Safer care’ for patient safety [51]. In 2006, guidelines on Hand Hygiene in Health care were published. The first Global hand washing day was observed on 15th October 2008. In April 2009, 3.6 million HCWs worldwide, registered themselves to comply with WHO’s global challenge on Hand Hygiene. On 5th May 2009, WHO launched guidelines on Hand Hygiene and the theme was ‘Save lives : Clean Your Hands’ [52], [53]. There may be resident flora and transient flora which can colonize

the hands of HCW. The transient flora colonizes the superficial layer of skin and are removed by hand hygiene. The pathogens like MRSA, VRE, Multidrug resistant Gram negative bacilli, Candida species causing HAI colonize hands of HCW during patient care simply while taking blood pressure or taking temperature etc. or from environment like the uniform, patient's locker, bed rail, bed linens, furnitures etc. The organisms like Staphylococcus aureus, MRSA, VRE can survive for months on inanimate objects.

Hand hygiene includes washing hands with soap and water, antimicrobial soap, antiseptic agents, alcohol – based hand rub or surgical hand scrub. Hepatitis C virus (HCV), Rhinoviruses, Adenoviruses and Rotavirus nucleic acid can be found on hands of HCW [52].

If hands of HCWs are visibly dirty or contaminated with proteinaceous material, blood or other body fluids of patients, the hands are to be washed with soap and water. An alcohol based hand rub must be used by HCWs when hands are not visibly soiled such as before having any direct contact with patients including taking pulse or blood pressure or lifting a patient, before donning sterile gloves and also after removing gloves, after contact with inanimate objects in patient's immediate environment or if moving from a contaminated body site to a clean body site of the patient etc.

The maximum incidence of hand contaminations are reported from critical care areas. Hence, to prevent cross transmission, motivation, training, availability of alcohol based hand rubs and repeated reminders are required for HCWs. In most Health care set up, actually following the hand hygiene practice is below 40% where it is indicated [54]. The most important cause for poor hand hygiene compliance is lack of knowledge of guidelines of protocols on hand hygiene, lack of institution priority, lack of role model among the colleagues or superiors (specially clinicians), lack of HCWs etc [55].

The HCWs are to be specifically explained that wearing gloves does not replace hand hygiene and contamination may occur while removing the gloves. Actually, hand hygiene should be a habit of HCW while giving patient care.

Selection of hand hygiene products and its easy availability is one the most important step to promote hand hygiene practices during patient care. The new CDC guidelines does not suggest any specific spectrum for a hand hygiene agent and any health care set up can select an agent depending on cost spectrum and the common causative organisms of HAI [56]. Hand hygiene agent used for post contamination must be bactericidal, fungicidal (yeast), virucidal. The agent having activity against unenveloped viruses should be used in paediatrics (rotavirus) or in oncology units (parvovirus) etc. The agent with mycobactericidal activity should be used in tuberculosis and chest wards, fungicidal activity (moulds) in organ transplant units or AIDS patients are to be considered. Preoperative hand hygiene agent should at least contain bactericidal and fungicidal (yeasts) to reduce the risk of SSIs. Any hand hygiene agent should not cause skin irritation and should dry on its own. WHO advocates to follow formula for resource poor settings [57].

Formulation I contains ethanol 80% v/v, glycerol 1.45% v/v and hydrogen peroxide 0.125% v/v.

Formulation II contains isopropyl alcohol 75% v/v, glycerol 1.45% v/v and hydrogen peroxide 0.125% v/v.

4.4.3. Personal Protective Equipment (PPE)

PPE includes gloves, protective eye wear (goggles), masks, cap, apron, gown, shoe covers etc. PPE should be used when there is a chance to have contact with patient's blood, body fluids, excretion or secretion while giving patient care by – HCWs, support staffs including attendants, sweeper, laundry staffs, laboratory staffs and family members. Masks alongwith goggles or a face shield may be used for complete protection of the face [58]. PPE should be chosen according to the risk of exposure and always where contact with blood and body fluid may occur. HCWs may be well trained when and how to use PPE and should be explained properly that use of PPE does not replace hand hygiene. Disposable PPEs e.g. gloves, masks, protective eyewear, gowns should never be reused. PPEs should always be changed between patients. All HCWs should follow hand hygiene after removal of PPE. Single use PPE must be discarded or reusable PPE may be put in a bin to send it to laundry and then for sterilization.

Respiratory protection : To prevent inhalation of microorganism the respirator with N-95 or higher filtration can be used. These are recommended if exposure to patients with tuberculosis, SARS CO-V, influenza, Swine flu etc occurs or suspected.

In the current CDC guidelines regarding isolation precaution Respiratory Hygiene / Cough Etiquette are recommended for HCWs, patients and their relatives. Spatially separation (>3 foot) should be followed in persons with respiratory infection in common waiting areas of health care set up. To avoid inhalation of droplet nuclei, droplet precautions e.g. wearing mask are to be implemented for HCWs. Masks should never be confused with particulate respirators which are used to prevent inhalation of small particles contaminated with infectious agent.

4.4.4. Safe injection practices

The recommendations include :

- Always sterile, single use disposable needle and syringe for each injection is to be used.
- CDC recommends single dose vials instead of multiple dose vials, when used for multiple patients. Multidose vials are always discouraged, because HCWs commonly contaminate the vials.
- The intravenous fluid infusion sets are to be used for one patient only and discarded after use.

4.4.5. Infection control practices for lumbar puncture procedure^[59]

The health Care Infection Control Practices Advisory Committee (HICPAC) in 2005 recommended that the HCW placing a catheter or injecting material into the spinal or epidural space must use a facemasks to prevent droplet transmission of oropharyngeal flora.

4.4.6. Patient care equipment

To prevent patient to patient transmission, instruments must be cleaned and sterilized. All patient care equipment soiled with blood, body fluids, secretions or excretions must be

handled with care to prevent exposure to skin and mucous membranes, clothing and environment. All reusable equipments are to be cleaned and sterilized before using for another patient.

4.4.6.1 .High level disinfection (HLD), Intermediate level disinfection (ILD) and Low level disinfection (LLD) [60].

High level disinfection (HLD) is a process that kills all microorganisms except large numbers of bacterial spores. The Food and Drug Administration definition of HLD is a sterilant used for a shorter contact time to achieve 10⁶ log kill of an Mycobacterium sp. HLD chemicals can also be used for sterilization only with extended exposure time. The examples are glutaraldehyde 2%, Hydrogen peroxide 7.5%, Hydrogen peroxide and peracetic acid 1% / 0.8%, Hypochlorite and hypochlorous acid i.e. 650-675 ppm and 400-450 ppm respectively etc. HLD can be used for heat – sensitive semi critical patient care equipments e.g. Gastrointestinal endoscopes, bronchoscopes etc.

Intermediate level disinfection (ILD) – ILD is defined as a disinfection procedure that is cidal for Mycobacteria, vegetative bacteria, most viruses and fungi but does not kill bacterial spores. Tuberculocide germicide does not prevent transmission of tuberculosis in health care set – ups. The term tuberculocide is used to denote germicidal potency of disinfectant. The examples of ILD are hypochlorite, alcohols, phenols etc. ILDs are mainly used for soiled noncritical patient care items or surfaces contaminated with visible blood/body fluids/sputum/faeces/Mycobacteria.

Low level disinfection (LLD) is a process that kills most vegetative bacteria, some fungi and some viruses (lipophilic viruses) etc in ≤ 10 minutes. LLD includes some chlorine based products, phenolics and quaternary ammonium compounds or 70-90% alcohol. LLD is used for non critical patients care items.

4.4.6.2. Critical, semicritical & non critical devices

The definition of HLD, ILD and LLD correlates well with Spaulding's classification of devices [61]. The Equipment/device is defined as **Critical** if the medical device enter into a normally sterile tissue or vasculature and for reprocessing sterilization is required. The examples are cardiac catheter, needle, surgical instruments, implants etc.

The medical devices are called **Semicritical** if the device can come in contact with mucous membrane or non intact skin. For reprocessing, sterilization is desirable but HLD is acceptable. The examples are respiratory therapy equipment, some endoscopes etc.

The **Noncritical** devices can be defined as devices that come in contact with intact skin, e.g. Blood pressure cuff, Stethoscopes etc and for reprocessing ILD / LLD can be used.

4.4.6.3. Environmental surfaces

In 1991, CDC has proposed an additional category as 'Environmental surfaces' to Spaulding's classification that do not come in contact with patients but serve as reservoir of resistant

pathogens [60]. Environmental surfaces include clinical contact (medical equipment or high touch) surfaces and housekeeping surfaces. CDC defines clinical contact surfaces that can transmit infection by contaminating hands of HCWs and other patients. These surfaces includes light switches, telephones, doorknobs, beddings, X ray machines, edges of privacy curtains, walls of the toilets etc. They should be disinfected with LLDs and ILDs.

Housekeeping surfaces (wall of the patient room, floors and sinks) are rarely involved in direct spread of infection and same LLDs and ILDs can be used for decontaminating these surfaces.

For further readings of cleaning and disinfection of noncritical, semicritical and critical patient care equipments, clinical contact and housekeeping surfaces guidelines available at www.nevadaaware.com/home/GuidelinesEnvInfectControl908.pdf. may be consulted [62].

4.4.6.4. Cleaning and decontamination of specific equipment can be discussed as follows

Endoscopes : Recently, in many operative and diagnostic procedures Endoscopes are used and hence, effective decontamination is essential for patient's safety [63]. Some endoscopes are available in both flexible and rigid construction. Modern flexible fibre optic scopes (bronchoscopes, cystoscopes, gastroscopes, sigmoidoscopes etc) cannot withstand high temperatures. These are very delicate, having multiple small channels and blind ends. Hence, they are very difficult to clean and decontaminate. Endoscopes and accessories which come in contact with sterile tissue are classified as critical items and sterilization or HLD should be done ideally. Endoscopes and accessories that come in contact with mucous membrane are put into semicritical items and should be treated with HLD after use. Endoscope sterilization or HLD involve the following steps i.e. disassembling the components, cleaning and disinfection with HLD, rinsing the endoscope and its channels with sterile water to remove disinfectant, then flushing the channels with 70-90% ethyl or isopropyl alcohol and drying by forced air. Then the endoscopes are stored by hanging vertically with caps.

A logbook is to be maintained after each use and reprocessing by noting the patient's name, hospital registration number, the clinician who performed the endoscopy and HCW who did reprocessing and serial number of endoscopes etc. If any endoscope is used in a patient who has been subsequently diagnosed with CJD (Cruitzfeild Jacob disease), further follow up investigation must be done.

Ventilators : Mechanical ventilators are essentially used in Intensive Care Units (ICUs) and are common source of infection. Ventilator associated pneumonia is one of the commonest HAI after catheter associated UTI (CA-UTI). All HCWs must be trained to follow hand hygiene and use PPE while reprocessing ventilators or any other respiration devices. All disposable devices must be discarded. The ventilators should be cleaned to remove organic soil. The circuits and filters should be disposable so that it can be changed between patients.

Suction equipment : Preferably separate machine should be used for each patient. A fresh catheter must be used for every suction. After use the contents are discarded and bottle should be washed with detergent and water and then dried up. The tubing, lids, non return valve and bottles are autoclaved if required.

Dental equipments : Infection Control Practices regarding HBV and HCV are very important for dental equipments [64]. The instruments must be thoroughly cleaned before disinfection. High speed dental handpieces should be sterilized in between patients. Critical items like extraction forceps, scalpel blades, periodontal scalers etc. must be sterilised after each use. The semicritical items which come in contact with oral tissue i.e. bone amalgam condensers or syringes are sterilized and if cannot withstand heat, HLD may be done.

Ophthalmic instruments : Thorough cleaning of instruments followed by steam sterilization and if the instruments cannot withstand heat, low temperature sterilization with Ethylene oxide (EtO) can be done.

Surgical instruments : These may be cleaned manually or mechanically and sterilized [60]. Autoclaving is usually done but if the instrument is heat sensitive, low temperature sterilization with EtO can be done [60].

5. Transmission — Based additional precautions

These include airborne precautions, droplet precautions and contact precautions. These are taken when patients having or suspected of having infection with highly transmissible / epidemiologically important organism for which additional precautions are needed in addition to standard precautions [65].

Air borne precautions : These are to be taken when patients with disease spread by droplet nuclei ($<5 \mu\text{m}$) in diameter or suspected cases are taken care of. Diseases like open/active tuberculosis, measles, chicken pox, pulmonary plague and haemorrhagic fever with pneumonia can be spread by droplet nuclei. Alongwith standard precautions the patients should be placed in a single room with negative pressure which receives ≥ 12 air changes per hour (≥ 12 ACH after 2001 construction). The air flow in a negative pressure room should be from outside and also should be exhausted outside but may be recirculated if the air is filtered through a High Efficiency Particulate Filter. The rooms should be closed and patients transport and movement is to be limited i.e. only when necessary. During transportation, patient must use a surgical mask to prevent dispersal of droplet nuclei. Anyone who enters the room must wear a special high filtration particulate respirator (N 95) mask.

Droplet Precautions : These are taken for large particles droplets ($>5 \mu\text{m}$ diameter) and the diseases transmitted are pneumonias, pertusis, diphtheria, influenza type B, mumps and meningitis. The patient is placed in a single room or in a room with another patient infected by same agent. Surgical mask should be used by HCWs and during transportation patient should put a surgical mask.

Contact precautions : These are used to prevent transmission of antibiotic resistant bacteria, enteric infections and skin infections. HCWs must use gloves and gowns. The movement and transportation of patient should be limited.

Patient placement : Adequate spacing is required to prevent transmission of HAI. Optimum spacing between beds is 1 – 2 meters. Single room with hand washing facilities with attached toilet and bathroom is preferable to reduce transmission.

Environmental Management Practices : Safe drinking water supply, appropriate cleaning practices, housekeeping practices, laundry, pest control (mice, rodents etc) appropriate waste management facilities must be ensured to reduce HAIs. In isolation rooms, food should be served on disposable crockery and cutlery.

6. Infection control precautions in special situation

6.1. Sever Acute Respiratory Syndrome (SARS)

SARS is caused by a novel coronavirus – SARS Co – V [66] which could be found in sputum, tears, blood, urine and faeces. The virus is predominantly transmitted through droplets discharged during coughing, sneezing and talking by the patient.

Both Standard precautions and additional precautions are to be taken to prevent transmission. The patient must be placed in a single room and PPE must be used by all HCWs giving patient care, cleaning staffs, all laboratory staffs and sterilizing service workers. All waste from a SARS patient room should be treated as infectious waste. The specimens from a SARS patient should be transported in a leak proof bag (i.e. a plastic biohazard specimen bag). All infection control precautions must be followed while caring for SARS patient. A post mortem examination of SARS patient or probably having SARS is a very high risk procedure and should be avoided if possible. Staffs of the mortuary or funeral care home must be informed that the deceased had SARS. Embleming is not recommended. Even the preparation of the deceased should be discouraged.

6.2. HIV

The risk of acquiring HIV infection after needle stick or sharps injury is less than 0.5% [67]. Standard precautions using PPE and proper disposal systems for needles and sharps should be followed. The HCWs should be trained in safe sharps practices. The serological testing of patients must be done as early as possible if there is needle prick or injury by sharps. Post exposure prophylaxis should be started according to National guidelines.

6.3. HBV and HCV

For HBV and HCV same precautions and infection control practices has to be followed as HIV. All HCWs at risk of exposure to HBV must be vaccinated. No post exposure therapy to HCV is available but seroconversion of HCWs must be documented. For occupational exposure to blood borne pathogens, counselling and clinical and serological follow up must be provided.

6.4. Tuberculosis

HCWs have varying risks for exposure to tuberculosis. Multidrug resistant tuberculosis (MDR - TB) arises in countries where tuberculosis control is poor and increased incidence of HIV infection because of HIV/TB co-infection. As for infection control measure rapid detection and treatment of tuberculosis is to be done. Standard Precaution and additional airborne precaution is to be followed. During transportation, patient must wear surgical masks.

HCWs working in areas such as chest clinic, bronchoscopy unit, radiology unit, TB laboratories are at greater risk of occupational exposure to TB and MDR - TB. Hence, they have to follow Infection Control Practices.

Viral haemorrhagic fevers : Viral haemorrhagic fevers include Ebola, Marburg virus disease etc. The case fatality rate of Marburg virus disease is 25% whereas with Ebola virus 50 – 90% case fatality occur [67].

Human to human transmission occurs by direct contact with infected blood, secretions, organs, semen, even vomitus of the patient etc. Standard precautions, isolation precautions, and additional precautions are to be followed.

7. Multidrug resistant organisms and infection control practices

The multidrug resistant organisms are prevalent in Health care set up now a days because of overuse and misuse of antimicrobials. The empirical use of antimicrobials in health care set up has to be stopped and must be guided by antibiotic sensitivity test with proper dosage schedule.

In every health care set up, an antimicrobial use committee should be there, which establishes prescribing policies, audits antibiotic use etc. Antimicrobial use committee may be a subcommittee of HICC or an independent committee working hands in hands with HICC.

Transmission of MRSA, Vancomycin Resistant Enterococci (VRE) occurs through hands of HCWs, hence, transfer of staffs and patients should be reduced. Early detection of cases and placing MRSA/VRE/MDRO infected patients in a single room or in a large ward putting all MRSA infected patients (cohorting). The operating surgeons should not do surgeries until declared negative for carriage of MRSA / MDRO. Early detection of the organism and measures for managing any outbreak especially in nurseries and postoperative wards should be planned.

The same strategy has to be adopted for ESBL, AmpC β – lactamase and MBL producing Gram negative organisms.

All HCWs and patient's visitors strictly follow standard and contact precautions.

8. Biomedical waste management

Biomedical waste is defined as any waste generated during diagnosis, treatment or immunization of human beings or animals or in research activity. Hospital waste include biological or nonbiological waste, which is a reservoir of pathogenic microorganisms and require safe and reliable handling and disposal. The risk of transmitting infection is maximum with sharps contaminated with blood [68]. The steps to be followed in biomedical waste management are: generation, segregation, collection, transport, storage, treatment and final disposal.

The basic principle of Hospital waste management is to segregate hazardous and nonhazardous waste. The clinical waste (infectious) is subclassified into sharps or nonsharps. About 75 – 90% of biomedical waste is nonhazardous and 10 – 25% is hazardous. Sharps should be discarded in puncture proof containers with covers. The Govt. of India under the provision of the Environmental Act 1986, notified the Bio – Medical Waste (Management and handling) (second amendment) Rules 2000 [69]. The biomedical waste are classified into Category 1 to 10 which are segregated at source in any Health care set up. After categorization, wastes are to be put in colour coded plastic bags like yellow, red and black. The waste bags should be tied once filled to $\frac{3}{4}$ th of their capacity and should be labeled with appropriate biohazard symbol or cytotoxic waste symbol etc. On all the bags, the labels with information on the point of generation must be pasted.

Infectious nonsharp waste should be put in yellow bags which include soiled dressing, microbiology waste, cotton etc. and then incineration or deep burial is to be done. The deep burial should be 2 – 3 meters deep and atleast 1.5 meters above the ground water table.

Except anatomical waste red bags may be needed for nonsharp waste if autoclaving/microwaving/chemical treatment followed by landfill is the option (Red bags should not be incinerated as red colour contains cadmium which cause toxic emissions. Plastic disposable items e.g. gloves, catheters and i.v. sets should be put into blue/white transparent bags for shredding and disinfection before disposal by landfill. Sharps (syringes, needles, scalpel blades) should be discarded in blue/white translucent puncture proof container). Needles should not be recapped or bent by hand. Needle should be destroyed in a needle destroying machine. Sharps are then subjected to autoclaving/microwaving/chemical treatment/shredding.

Incineration ash and solid chemical waste such as discarded medicines should be collected in black bags for disposal in secured landfill [69].

9. Surveillance of Hospital Acquired Infections(HAI)

The rates of HAI serve as indicators of quality and safety of patient care at the Health care facility. The Hospital infection Surveillance system is for early detection of outbreaks or appearance of a new organism or new MDRO or even new antimicrobial resistant organism. Surveillance should be done at hospital level and at Regional or National level.

The most commonly utilized sources of surveillance are Microbiology reports and are part of 'alert organism surveillance'. The methods are mainly daily analysis of Microbiology reports, laboratory records and clinical assessment, infection prevalence, HAI incidence study, targeted surveillance etc [70].

9.1. Calculation of rate of infection

This can be estimated by Prevalence rate, Incidence rate, Attack rate (cumulative incidence rate), Antimicrobial resistance rate (no. of MRSA/100 admissions) and incidence rate (MRSA/1000 patient days). Prompt feedback to clinicians and HCWs is most essential part to reduce the incidence of HAI and to identify the areas for improvement in quality patient care. Even molecular methods can be adopted for typing and early detection like Restriction fragment length polymorphism (RFLP), Multilocus sequence typing (MLST) etc.

In case of outbreak, the immediate control measures should be undertaken to break the chain of transmission. The control measures including, isolation or cohorting of infected case, strict hand washing and aseptic practices should be immediately implemented. Follow up of patients both clinically and Microbiologically should be done, in any outbreak.

Time to time uptodate information must be given to hospital administration, public health authorities, district, state and National Health bodies. In the final report, the cause of outbreak whether facilities available for detection of causative organisms in health care set up, measures taken to control out break and contribution of each member in Infection Control Team should be mentioned in detail.

Major outbreak generally occurs in Health Care set up due to Staphylococcus aureus/MRSA/Pseudomonas aeruginosa in NICU, or Salmonella sp. in any wards or MRSA/ESBL producing MDRO or MBL producing Pseudomonas aeruginosa/Carbapenem resistant Enterobacteriaceae in OTICU or Post operative ward etc. need special attention.

9.2. Surveillance of infections in HCWs

Surveillance in HCWs is specially required for blood borne pathogens e.g. HIV, HCV and tuberculosis, detection of carrier stage for Salmonella typhi in kitchen staffs or surgeons/residents/HCWs working in OT/Post operative wards/different ICUs should be screened for throat or nasal carriage of Staphylococcus aureus especially MRSA.

9.3. Antibiotic policy

Every health care set up must have its own antibiotic policy and a system for monitoring of antibiotic prescription

10. Routine monitoring of health care set up

Though for developed countries it is said that routine monitoring of Hospital Environment e.g. bacteriological sampling of air, floor or surfaces is not required unless and until there is

an outbreak. But we have experienced that routine monitoring of OT specially for *Clostridium perfringens* and *Clostridium tetani* has reduced tetanus and gas gangrene in post operative patients to actually zero in our hospital.

We collect minimum 5 swabs for each OT from the sites like 1. OT table, 2. Overhead lamp, 3. Boyle's apparatus, 4. Instrument trolley, 5. Floor near OT table routinely on Monday morning. After fumigation on Saturdays and closing the OT for 40 - 48 hours about 80 – 100 swabs on every Monday morning are collected. With proper cleaning of wound and implementing all aseptic practices, no tetanus or gas gangrene cases have been reported in last 10 years, even from Trauma ICU and Emergency OTs where Road accident cases are handled. Moreover, our Infection Control Nurse, collect swab from different wards and ICUs from 5 minimum sites and maximum 10 sites e.g. 1. Disinfectant solution, 2. Dressing trolley, 3. IV stand, 4. Fabric, 5. Switch Board, 6. Gauge Piece, 7. O₂ Cylinder, 8. Ventilator 9. Suction machine, 10. Gown.

On every Tuesday, approximately 50 – 80 swabs, moistened with Brain Heart Infusion broth are collected from those above mentioned sites and cultured on Nutrient agar and then incubated at 37°C overnight. Colony counts and detection of organisms are done by Infection Control Technician and Microbiologists in the Infection Control Team. Disinfectant solutions where cheater forceps are kept and gauze pieces which are used in dressings, eye drop from ophthalmology wards, pads from Labour room and Gynaecology & Obstetric wards are compulsorily taken for monitoring. If any organism is grown from disinfectant solution, gauze pieces or eye drops, immediately the clinician and ward sister is informed telephonically to discard it. Though our hospital is a tertiary care hospital but it is in a rural set up and caters patients from different nearby villages also. By observing this protocol, major outbreaks in Ophthalmology or Post operative wards could be reduced to almost nil in last 10 years.

10.1. Hospital infection report form

Every Health care set up must have their own Hospital infection Report form The Hospital infection report form must include name of the patient, age & sex, registration number, laboratory number, date of admission, bed number, ward, name of the clinician, clinical diagnosis, history of any major invasive procedure or operation (date/OT used/duration of ICU stay), nature of infection, antibiotics received etc. The form should be filled up by clinician, sent to Microbiology laboratory and informed to Infection Control Team.

11. Educational programmes for hospital staffs

We also take different educational programmes like CMEs and Workshops for HCWs, technicians and doctors from time to time about infection control practices e.g. hand hygiene, antimicrobial resistance, sterilization of OT etc.

The only silver lining to the serious problem of HAI is 36% of all HAIs are preventable if Infection Control Practices are followed by HCWs. Hand hygiene is the simplest and most effective measure before and after each patient contact to reduce the risk of HAI.

12. Team work

In fact, Infection control in any Health care set up is a team work. Each and every staff involved in patient care should take part in Infection Control Programme, then only Infection Control Programme can run successfully.

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