Prevention of healthcare-associated infections in paediatric intensive care unit

Anand Wagh¹ · Ajay Sinha²

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Abstract

Introduction Healthcare-associated infections put a tremendous burden on health services around. In the last few decades, there has been a tremendous advancement in foetal and maternal care, and it has led to premature babies born as early as 25 weeks of gestation being nursed and cared for in neonatal and paediatric intensive care units. However, these children can pick up a number of uncommon and rare hospital-acquired infections including central nervous system (CNS) infections.

Methods The authors have given their own insight as to the prevention of healthcare-associated infections in paediatric intensive care settings and reviewed the current literature on the topic.

Conclusions Healthcare-associated infections are largely preventable provided adequate prevention and protective measures are put in place and prevention guidelines are strictly followed.

Keywords Healthcare-associated infections · Nosocomial infections

Introduction

Critically ill children cared on paediatric intensive care unit are predisposed to healthcare-associated infection (HCAI) (Figs. 1, 2, 3, and 4). Patients admitted with primary neurological disorder and post neurosurgical intervention pose unique vulnerability to infection and challenges of diagnosis as well as treatment. Nosocomial infections are a major and potentially preventable cause of morbidity and increased cost in paediatric intensive care units (PICUs). In this review, we summarise our approach to preventing HCAI on the PICU.

the UK [1–3]. Highest prevalence are in paediatric intensive care (15.5%) and neonatal intensive care unit (10.7%) in developing countries [2, 10]. Comparison of infection rates across paediatric and neonatal intensive care units would be difficult and prone to inaccuracies because of variations in PICU physical structures and severity of patient illness. As opposed to catheter-related urinary tract infection and ventilator-associated infection being more common on adult neuro-intensive care units, blood stream infections and ventilator-associated pneumonia are predominant HCAs on paediatric intensive care unit [4].

Epidemiology

Healthcare-associated infections (HCAs) are inevitable collateral damage of intensive care support. The reported prevalence varies between resource rich and resource poor countries. Reported prevalence is as low as 4% in the USA and 5.7% in

Risk factors

Children critical enough to need intensive care treatment are most vulnerable. Younger age, non-elective admissions and patient-harboring conditions with expected higher risk of mortality at admission to intensive care are known risk factors for HCAI [10]. As number of interventions and organ system support escalates, there would be a greater risk of HCAI. Source of infections would be endogenous microorganisms that are commensals or exogenous from the intensive care environment. Interactions between susceptible hosts, a more virulent hospital-acquired infective agent and facilitated by PICU environmental factors complete the chain of infection [8].

✉ Ajay Sinha
Ajay.sinha@alderhey.nhs.uk

¹ Department of Paediatric Intensive Care, Alder hey Childrens' NHS Foundation trust, Liverpool, UK

² Department of Neurosurgery, Alder hey Childrens' NHS Foundation trust, Liverpool, UK

Fig. 1 Initial MRI T2WI-bilateral abscess (preterm twin prolonged PICU stay—*Citrobacter* infection)

Host factors

Age—neonates and infants have immature immune system and blood stream infections are more common in this group of patients [20, 24]. Children older than 5 years and adolescents run similar risk of HCAI as adults with Ventilator Associated Pneumonia and Catheter associated Urinary Tract Infection being more common [1, 24].

Immunity—use of glucocorticoids on neuro-intensive care or other immunosuppressive agents after organ transplantation makes patient more vulnerable [5, 12]. In children, immunisation status affects host defences. The higher the severity of illness score, the greater will be the risk of contracting HCAI [24].

Breach in integrity of skin and mucosa e.g. indwelling catheters [central lines, drains] or surgical site will facilitate microorganisms invasion. Loss of natural defence mechanisms like effective cough and mucociliary clearance of

Fig. 3 MRI T2WI flair multiloculated abscess (*-E. coli* sepsis in neonate)—NICU-acquired infections

secretions with ventilation and sedation or reduction in gastric acidity with H2 blockers [12] and indwelling nasogastric tubes can lead commensals to cause invasive infections.

Environmental factors

Transmission of infection is caused by the same pair of hands which care for the patient on intensive care unit. Various factors like high patient to healthcare staff ratio and device utilisation ratio, less ideal infection prevention and control prevention practices, carers and visitors immunisation status and reservoirs of infection (equipment and devices) affect exposure to nosocomial organisms. Hospital practice of giving prophylactic antibiotics which change the commensal flora and cause overgrowth of pathogen would affect the prevalence of HCAI.

Fig. 2 Final MRI T2WI-post craniotomy for abscess excision and VP shunt for hydrocephalus

Fig. 4 MRI T1WI-post surgical drainage-delayed scan showing frontal lobe encephalomalacia

Chart 1 Infection control programme model [12, 23]

Transmission of micro organisms in paediatric intensive care

Pathogenic microbes are transmitted by one of the three routes, contact (direct or indirect), droplet and airborne spread [8, 17]. These three routes of transmission help stratify the infection control measures.

Direct contact of infected or carrier host with susceptible host or contamination of host environment due to poor hand hygiene leads to direct contact and spread of microorganisms.

Droplets (> 5 µm in diameter) from respiratory tract of a potentially infected healthcare worker can lead to inoculation in a susceptible host [7]. Droplets do not remain suspended in air and do not propel more than a meter in distance, and strict contact precautions prevent cross infection.

Spread of infection by aerosolisation (airborne particles <5 µm) caused dissemination of microorganisms by air current e.g. varicella outbreak on intensive care unit. Such patients require source isolation cubicles with controlled air currents [7].

Types of nosocomial infections and pathogens

Most common type of HCAI is blood stream infection associated with central lines [45%], followed by ventilator-associated lower respiratory tract infections [24].

Central line-associated blood stream infections (CLABSI)

Around 50% of HCAI in neonates and infants are blood stream infections. Gram-positive bacteria—*Coagulase Negative Staphylococci* (CONS) and *Staphylococcus aureus* are the most common accounting for one third of blood stream infections [9, 24]. Gram-negative bacteria including *Enterobacteriaceae* and non fermenting bacteria such as

Pseudomonas sp., *Acinetobacter* Sp and *Stenotrophomonas* sp. are responsible for 25% of BSI. *Candida* sp. blood stream infections are also being increasingly recognised.

Lower respiratory tract infection and ventilator-associated pneumonia (VAP)

Respiratory syncytial virus (RSV) is the commonest viral agent causing yearly outbreaks. Other viruses (*Rhio virus*, *Adeno Virus*, *Influenza* and *Parainfluenza Virus*) spread by large droplets from respiratory tract with reported secondary attack rates up to 30%. Viral pneumonias can predispose patients to secondary bacterial infections. VAP is the second common HCAI in PICU with incidence between 0.7 and 5.7 episodes per 1000 ventilation days. Endotracheal intubation provides a ready conduit to the lower respiratory tract with increasing infection risk. Pathogenic organism can be endogenous respiratory flora (*H. Influenzae*, *Moraxella* Sp, *Streptococcus pneumoniae*) or translocation of gram-negative bacteria such as *Pseudomonas* Sp, *Escherichia coli*.

Skin and surgical site infections The skin is the largest organ forming a physical protective barrier. A breach in skin integrity by surgical procedure or insertion of catheter or pressure sores leads to interruption in defence against infections. Interaction between inoculation of virulent organism, break in integrity with the presence of foreign body (sutures, implants) and host defences determine local surgical site infection or widespread septicaemia. Unsurprisingly, skin flora like *Staphylococcus aureus* is the commonest pathogen but *Pseudomonas* *Aeruginosa* and other gram-negative bacteria are common hospital-acquired pathogens. Worryingly, more infections with multidrug-resistant organism like methicillin-resistant *Staphylococcus aureus* (MRSA), carbapenemase-producing *Enterobacteria* (CPE) and fungi are of growing importance.

In procedures like neurosurgical cerebrospinal fluid shunts coagulase-negative *Staphylococci* (CONS) form the commonest pathogen.

Infection control and prevention of healthcare-acquired infection on paediatric intensive care unit

HCAI are associated with significant morbidity, mortality and financial burden. Protecting patient from preventable HCAI is every team member's responsibility. Though infection control and microbiology teams will be providing specialist input there needs to be an ongoing all round concerted effort to avoid HCAI.

Design and structure of intensive care unit

There is expert consensus “best practice guideline” for specified clinical areas [6, 15, 17].

Patient areas in PICU should be a combination of open-plan area and isolation cubicles (Fig. 5). New units are planned with minimum ratio of one isolation cubicle to every 2–3 open beds. Each bed space should be 25.5 m² with design recommendations to facilitate medical and nursing team to care for patients effectively and safely [6, 15].

Health-building notes provide detailed guidelines to develop new or extension of existing hospital building [6].

Infection control programme

Strategies for infection prevention and control have evolved to current system where there are standard precautions followed for every patient by each healthcare professional in order to prevent spread infection. However, depending on the isolated microorganisms and the mode of transmission, there needs to be special precautions e.g. droplet precautions to prevent transmission of pathogen from respiratory secretions [13]. Airborne precautions where infectious microorganisms remain suspended in air would necessitate isolation in a negative-pressure cubicle with special air handling (source isolation).

Contrary to these, immunocompromised patients should be cared for in a positive-pressure room to protect a susceptible host. [7, 9, 16, 22].

Hand hygiene

Cross infection between patients can be due to indirect contamination with same hand caring for patients. The World Health Organisation initiative on hand hygiene emphasises five moments for hand hygiene (before and after touching a patient, before clean/aseptic procedure, after exposure to body fluid, after touching patient surroundings [8, 13, 14, 17]. Nowadays, alcohol-based hand gels are available to use for visibly clean hands. These are particularly effective in killing microorganisms without risk of antibiotic resistance.

It is vital to have hand hygiene compliance monitored and maintained at highest level.

Personal protective equipment (PPE)

PPE not only protect the healthcare workers but also cross infection. For specific viral infections with airborne spread, it may be advisable to use specific face mask as per local guidelines.

Aseptic non touch technique (ANTT)

Poor practices of accessing vascular access devices are fundamental cause of HCAI [19]. Regardless of a vascular access device being peripherally or centrally placed, ANTT should be standard practice [13, 17]. Focus of ANTT is to minimise microorganism contamination during preparation, administration and delivery of intravenous therapy.

Care bundle for HCAI

Team-based approach to implement and monitor compliance to specific healthcare-associated infections can improve HCAI rates. There has been stepped intervention programme introduced [3]. Since introduction of multimodal stepped interventions, there has been significant and sustained improvement in CLABSI rates in paediatric and adult intensive care setting [4, 5]. There are standard care bundles for central line-associated blood stream infections (CLABSI), ventilator associated pneumonia (VAP) and surgical site infections (SSI) [11, 13, 14, 17].

Chart 2

CLABSI care bundle

(insertion and maintenance and access)

- Aseptic insertion of an appropriate device
- Correct siting of the device
- Effective cutaneous antisepsis: and for continuing care of the device
- Hand decontamination and asepsis for any contact with the device
- Daily observation of the insertion site
- Clean, intact dressing

Chart 3

VAP care bundle

- Elevation of head of bed (30–45°)
- Daily sedation review and assessment of readiness to wean and extubate
- Regular mouth care (2–4 Hourly)
- Change of ventilator circuit when visibly soiled
- Hand hygiene (before and after contact with ventilator circuit)

Charts II and III

Screening of patients

There are different ways to screen patient for colonisation. It can be at admission screening or weekly screening for

Fig. 5 Design of PICU at the recently built Alder Hey hospital, Liverpool, UK—open plan areas along with isolation cubicles

antibiotic resistant micro-organisms e.g. Methicillin-resistant *Staphylococcus aureus* (MRSA) or pre-operative screening to determine peri-operative antibiotics prophylaxis as well as specific topical antimicrobial agent application. There are increasing numbers of antibiotics-resistant organism screening tests available. However, various factors need to be considered before implementing these screening programme (likelihood of colonisation, cost, availability of timely reporting, capacity to isolate screened patients,) as they are yet to prove effective in reducing the incidence of HCAI.

Surveillance

Surveillance is a systematic method of collecting, consolidating and analysing data concerning the distribution and determinants of a given disease or event, followed by the dissemination of that information to those who can improve outcomes [8, 14, 16, 21, 22]. There are standardised definitions and templates for monitoring of CLABSI (central line-associated blood stream infections (CLABSI)/ventilator associated pneumonia (VAP)/surgical site infection (SSI)/catheter-associated urinary tract infections (CA UTI). Standard surveillance definitions have been developed by the Centres for Disease Control and prevention (CDC), which allows monitoring of trends, identifying practices associated with prevention of HCAI and comparison of rates within and between facilities [24].

Impact of HCAI

HCAIs are results of system failure and they are associated with significant adverse outcomes [2, 19, 21]. There is increase in length of intensive care and hospital stay as well as mortality [10]. There are significant financial implications, and the price paid by patient and families to recover from potentially preventable infection is very high [18].

Conclusions

In summary, there needs to be collaborative working between paediatric intensive care staff, microbiologist and infection

control team and a concerted effort to minimise the incidence of HCAI. Introduction of infection control care bundles goes a long way in control of HCAI. Every PICU should have a designated nurse and intensivist infection control lead to ensure implementation of care bundles and to maintain regular of PICU infections. Judicious use of antibiotics in consultation with microbiologist helps keep check on this preventable condition.

Compliance with ethical standards

Conflict of interest The authors declare they have no conflict of interest.

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