CHAPTER 1

Evolution and Organization of Pediatric Intensive Care Unit

Introduction

Modern set up of Intensive care units (ICUs) owe its origin to the polio epidemic of 1952 at Copenhagen.[1] Dr Bjorn Ibsen and his team could reduce patient mortality by greater than half (90–40%) by caring for patients in a earmarked area of the hospital and by giving manual positive pressure ventilation using a rubber bag through a tracheostomy.[2] They admitted the patients with respiratory failure in a special unit providing respiratory care between 28 August and 3 September 1958. Total of 200 patients were admitted in this unit. They underwent tracheostomy, manual positive pressure ventilation using 50% oxygen and regular suctioning.[2] They utilized 400 extra nursing auxiliaries and medical students each working for 8 hr to provide manual ventilation along with 27 technicians everyday to look after these patients.[2] These findings remain relevant to intensive care even today. Now critical care has expanded enormously and almost every hospital has some form of ICU. ICU patients occupy approximately 10% of inpatient acute care beds but the structure and organization of these ICUs tends to differ across hospitals. In view of a need for uniform guidelines regarding the structure and organization of ICUs, ISCCM (Indian Society of Critical Care Medicine) has formulated guidelines regarding ICU planning and designing in India in 2003 which were updated later in 2010.[3]

LEVELS OF PICU CARE

Prior to designing the ICU one should decide which level of ICU is suitable for hospital. Role of each level of ICU is well-defined. In general hospital and district hospital the ICU is more like high dependency unit (HDU) where close observation and monitoring can be carried out. ICUs in large tertiary hospital use complex management to support all body systems. ISCCM has proposed the following levels of ICUs.[3]

Level I

Level I ICU is recommended for small private nursing homes, small district hospitals, and rural area centers. This ICU should be 6–8 bedded with ability to provide resuscitation including short-term cardiorespiratory support and defibrillation. It should have ability to ventilate a patient for minimum 24–48 hr and should have facilities for noninvasive monitoring like: ECG for heart rate and rhythm, NIBP, SpO_2, temperature, etc. Level 1 ICU should be able to arrange safe transport for patients to secondary and/or tertiary centers. It should be managed by a doctor trained in ICU knowledge and technology. It should also have basic imaging backup and clinical laboratory.[3,4]

Level II

Larger general hospitals should setup level II ICUs. This ICU should have bed strength of 6–12 and managed by a qualified intensivist. Duty doctors and nurses should also be trained in the critical care. It should be able to provide invasive and noninvasive ventilation and multisystem life support. They should have ability to manage long-term ventilation and invasive monitoring. 24 hr access to ABG and electrolytes are must as microbiological support besides routine diagnostic support.[3, 4]

Level III

ICUs in tertiary level hospitals shoulb be of level III. These are preferably a 10–16 bedded 'closed' ICU, headed by an intensivist. This ICU should be capable of providing long-term acute care of highest standard. It should have all recent methods of monitoring, noninvasive as well as invasive like continuous $ScvO_2$ monitoring, cardiac output, etc. investigations like X-ray, 2D ECHO, USG, bronchoscopy and dialysis should be available by the bedside of the patient. It should also have intra and inter-hospital transport facilities. Level III ICU should also have vision for research and should be participating in national as well as international research programs.[3, 4]

LOCATION OF PICU IN HOSPITAL

Dedicated PICU to infants and children should be separate entity from the NICU as well as adult ICU.[5] Safe, easy and rapid transport of critically ill children should be considered at the time of planning the location of PICU. The unit should be in close proximity to areas like operating room, emergency department, acute pediatric wards, departments of radiology other diagnostic facilities. Number of lifts should be sufficient to carry these critically ill patients to these places as and when required. Corridors, ramp and lifts should be large enough to enable easy movement of bed. Hospital staff should not pass through the unit and no traffic of goods should be allowed through PICU. PICU should have a single point for entry and exit and it should be manned all the time. But emergency exit points should also be present to be used only in emergencies and disasters. Entry to ICU should not be direct and there should be some barriers from outside entry. Outside PICU there should also be provision for family waiting area for at least one or preferably two persons per admitted patient.[3, 5, 6]

SIZE OF PICU

Defining ideal PICU size is not easy but recommendation in Indian scenario are: 10–16 beds for level III PICUs, 6–12 beds for level II and 6–8 beds for level I.[3] PICUs with beds < 6 are not cost-effective and may not give enough sufficient clinical experience and exposure to P ICU staff similarly PICUs with > 16 beds may be difficult to run, stressful for PICU staff and may adversely affect patient outcome.[3]

ROOM LAYOUT AND BED AREA

Layout

Layout of PICU room can either be open ward type or divided into cubicles. Room layout should be such as to allow staff to see all patients from central station. Bed space of 100 sq ft has been recommended as minimum in Indian circumstances with bed space of 125–150 sq ft area considered desirable.[3] even higher recommendations up to 250 sq ft per bed have also been made.[6] Nursing station, equipment area, doctors and nurses rooms, toilet and apace for patient movement are additional space requirements amounting to about 100–150% of patient room area. One to two rooms should have capability for isolation where immunocompromised patients can be kept. These rooms should have 20% space extra compared to other rooms.[3]

Beds should have enough space around them for performing routine ICU procedures like central line or chest tube placement and also for easy access for electrocardiography, portable ultrasound and bedside electroencephalography machine.[5] Standard curtains or unbreakable removable or fixed partitions made of wood, aluminium or fiber can be used to create partition between two room for privacy of patients.[3]

Utilities Per Bed

Every intensive care unit is expected to have proper lighting, electrical power, compressed air, oxygen, vacuum, water, and environmental control systems which support the needs of the children and staff of critical care team under normal as well as emergency situations. Standard of these facilities must exceed regulatory and accreditation agency codes. According to the ISCCM guidelines (2010) one compressed air outlet, two wall oxygen outlets, two vacuum outlets and at least 12 electrical plug points are required for level I and level II PICUs. For level III PICU, 3 vacuum outlets, 3 oxygen outlets, 2 compressed air outlets and 12–14 electrical outlets are recommended by ISCCM. One monitor per bed should be available which should be placed at a height comfortable for doctors as well as nurses.[3]

Beds

To allow easy access for emergency airway management, the head end of the patient's beds should be approximately two feet away from the head wall.[3] Bed's head end and foot end should be maneuverable to keep head end up or low. To prevent pressure sores, there should be provision of at least two or preferably more air/water mattress. All beds should have a railing to avoid accidental fall of small children. An emergency alarm button should be available at every bed in order to activate code system in case of emergencies. A bedside cart should also be provided to keep patient belongings and also required patient items.[3]

Central Nursing Station

Central nursing station is like the nerve center of the PICU. It should be located in a way that allows monitoring of all patients by healthcare staff which can be either direct or indirect monitoring by video monitoring. In most PICUs, central station looks after 6–12 beds arranged in L or U fashion. This central nursing station should have area of sufficient size to comfortably accommodate all necessary staff functions. Adequate space should also be provided for central monitors, computers and its printers when automated systems are functional. Adequate space along with seating arrangement should be planned for both nurses and physicians for medical

record keeping. File cabinets, shelf and other storage required for medical record forms should be located in a way that they are accessible to all personnel requiring their use. For communication at least two telephone lines are recommended.[3, 5, 6]

ENVIRONMENTAL REQUIREMENTS

Heating, Ventilation and Air-conditioning System of ICU

The ICU should ideally be centrally air-conditioned and also should have central heating for control of temperature. Safe and suitable air quality should be maintained all the times. A minimum of six total air changes required for every room per hour. Two air changes per hr should be composed of outside air.[3] If central air-conditioning is not available, cubicles are recommended to have fifteen air changes every hr and other patient areas should have these at least three times in one hour.[3] The sluice and laboratory and dirty utility, need five changes every hour, but two in an hr are sufficient for other staff areas.[3] Re-circulated air must pass through suitable filters in central air-conditioning systems. It has been recommended that air filtration should be 99% efficient with particles down to 5 microns.[3]

Temperature of ICU should be kept at a level which is considered comfortable for the patients as well as ICU personnel. In PICUs having enclosed patient cubicles, the temperature should also be adjustable in each cubicle with option of temperatures between 16 and 26°C.

Backup power sources like invertors and generators to ensure an uninterrupted power are must for PICU. Power supply back up should start automatically in the event of a power failure and should be sufficient to run air conditioner and equipment. Stabilization of voltage is also mandatory and UPS (uninterrupted power supply) system is preferred in the PICU.

Lighting

PICU should be designed to allow natural light as much as possible. Each patient should have an access to natural sunlight. Windows form an important part of sensory orientation. Preferably most beds should have a view of windows to reinforce orientation of day and night. There are proven advantages of access to outside natural light in PICU.[7,8] Natural lighting also decreases power consumption hence the electricity bill. It may also benefit staff morale and outcome of patient. Studies have also shown that use of synthetic artificial daylight in this kind of setting may deliver better results for those working in night time and may also be helpful in maintaining the circadian rhythm.[7, 8]

Overhead illumination and light from the surrounding areas should be enough to carry out routine nursing tasks, including paperwork. At least 20 foot-candles (fc) of total luminance should be ensured and at the same time it should not exceed 30 fc.[3] Night lighting should not be brighter than 6.5 fc for regular use and 19 fc for intermittent periods to minimize sleep disruption during patient monitoring.[3] Separate provision for lighting for emergencies and bedside procedures should be made. It should be located in the ceiling above the patient and should be able to illuminate the patient with minimum of 150 fc shadow-free.[3]

Noise Control in ICU

Technology development has also increased noise levels in PICU environment well above the international recommendations. Some of the noise polluters in ICU include, telephones, mobile phones, alarms from medical equipment air-conditioning besides routine things like staff conversations, opening and closing doors, etc. The adverse effects of noise on admitted patients include sleep deprivation, heart rate and blood pressure variations, impairment of immune function and catabolic metabolism.[8, 9] Similarly noise also impacts staff negatively resulting in increased mental stress, annoyance, diminished intelligibility of speech, adverse job performance and ultimately patient safety.[8] Noise levels in most hospitals are usually between 50 and 70 dB with many episodes above this range. These are much higher than recommendation made by the International Noise Council. As per these recommendations that noise levels in hospital PICU should not be louder than 45 dB (A) during daytime, 40 dB in the evening, and 20 dB at night-time.[3] For these reasons, floor coverings which absorb sound are recommended to be used; walls and ceilings should also be constructed of materials having high sound absorption capabilities. Glass doors, counters and partitions are also effective in decreasing noise levels.

Equipment

Following points should be considered when choosing equipment for PICU the:

- Proven use in pediatric patients
- Accuracy and adaptability established for pediatric population
- Ease of use by PICU staff
- Trouble shooting guidance
- After sale support of the company for maintenance services
- Cost-benefit analysis.

A suggested list of equipment for a tertiary level PICU is shown in Table 1.1. This is not an exhaustive list and more equipment can be added or modifies as per requirement of individual unit.

Equipment Storage

Vital supplies which are used frequently and those required for emergencies should be stored within or close to PICU so that they are available readily and also are easy to find.

Table 1.1: List of equipment for 12-bedded ICU

Sr. no.	*Name of equipment*	*Number*	*Specifications*
1.	Noninvasive ventilators	3	With provision for CPAP and IPAP
2.	Over bed tables	1 for each bed	ALL SS with 1–2 cupboards in each to store drugs medicine, side tray for X-rays, BHT, on wheels
3.	Head end panel	1 per bed	With 2 O_2 outlets, 2 vacuum, 1 compresses air and 12 electric outlets, provision for music, alarm, trays for 2 monitors, 2 drip stands, 1 procedure light
4.	Freeze	1 + 1 for use or use of staff and doctors	With deep freeze facility
5.	Infusion pumps	2 per bed in ICU	Volumetric with all recent uopgrading drug calculation
6.	Bedside monitors	1 per bed	2 invasive BP, SpO_2, NIBP, ECG, RR, temp probes with trays
7.	Ventilators	6	With pediatric and adult provision, graphics, and non-invasive modes
8.	Syringe pumps	2 per bed in ICU	Pediatric infusion pump
9.	Defibrillator	2 with TCP facility	Adult and pediatric pads with transcutaneous packing facility
10.	ICU beds	1 for each bed	Electronically maneuvered with all positions possible with mattress, now beds are available which give lateral positions also
11.	Resuscitation	2 for ICU	To hold all resuscitation equipment and medicines
12.	Pulse oxymeter (small units)	2	As standby units
13.	ABG machine	1 + 1	Facility for ABG and electrolytes second 1 as standby
14.	Computers	2	With laming, internet facility and printer to be connected with all departments
15.	HD machines	1	User friendly
16.	CRRT	1	High flow/speed model
17.	Glucometer	2	
18.	CO, SVR, $ScvO_2$ monitor	1	As described
19.	Airbeds	6	To prevent bedsores
20.	Intubating video scope	1	To make difficult intubations easy
21.	ICU dedicated ultarsound and Echo machine	1	With recent advances to look, instantly even at odd hours vascular filling, central lines, etc.
22.	Bedside X-ray	1	
23.	ETO sterilization	1	To sterilize ICU disposables regularly
24.	Spinal board	2	For spine trauma patients
25.	Rigid cervical spine collars	4	For stabilizing cervical spine
26.	Ambu mask different sizes	10 sets including 2 for pediatric use	Silicon, ETO sterilization
27.	Pollution control buckets	1 set for each bed	
28.	Trays for procedures	For putting central lines, ICD, catheters, etc.	
29.	IA balloon pump	1	
30.	Fiberoptic bronchoscope	1	

An area should be provided for the storing and securing of large equipment when not in use. Storing space should be adequate to provide ease of searching the location as well as retrieval of desired item. A refrigerator is essential for some of the pharmaceutical products.

Clean and Dirty Utility Room

Utility rooms should be divided into two separate rooms: Clean and dirty which should not be interconnected. These utilities must be temperature controlled. Air supply from dirty utility should be exhausted outside. Clean linen and sterile supplies should be stored in clean utility room. Dirty utility room should have a separate sink with hot and cold mixing faucets. Covered bins for waste materials and soiled linen must be provided. A sink or other designated area for emptying and cleaning urine bottles and bedpans is also necessary.

Waste Disposal

Biomedical waste is well-recognized to be a major health hazard to environment including patient, healthcare workers and general public. Biomedical waste must be properly segregated at the source itself. Color coded containers (yellow, blue, red and black) should be kept by the bedside of each patient to dispose of different types of wastes. All government regulations related to biomedical waste disposal should be strictly complied with. As this is a dynamic issue, hospital authorities need to keep abreast with latest government advisories regarding biomedical waste management.

Hand Hygiene and Prevention of Infection

Hand hygiene is recommended as most effective method of infection. WHO steps of hand hygiene should be displayed prominently and PICU staff should ensure that these steps are hand hygiene are followed. Every bed should have attached alcohol based hand rub, to be used before caregiver touches the patient. A sink like one in operating room with foot or elbow operated water supply system and antiseptic soap solution should be available at an easily accessible point, where two persons can wash their hands at same time.

Stat Laboratory

All ICUs should have 24-hr active clinical laboratory services. If this service cannot be provided by the central laboratory of hospital, a satellite laboratory should be set up adjacent to the ICU(s) to serve this function. This satellite facility should be able to provide basic chemistry and hematology evaluation, along with arterial blood gas analysis.

Conference Room

A conference room should be set up for intensivist and staff for continuing education, discussion of difficult cases, staff education and other necessary meetings related to quality improvement. This room should also have a small library facility which should provide ready access to important intensive care, journals, books and policy manuals.

Human Resources for PICU

Development of human resource is one of the vital components of PICU. Human resources include intensivist/s, nurses, resident doctors, respiratory therapists, physiotherapist, nutritionist, technicians, computer programmer, biomedical engineer, clinical pharmacist and other support staff like cleaning staff, guards and class IV. All of them should be qualified, highly motivated dedicated, and ready to work in stressful conditions for longest periods of time. One of the limiting factor in PICU is scarcity of such individuals and very high turnover.

Team Leader

Intensivist is the PICU team leader. He or she should be a pediatrician trained qualified, and experienced in pediatric critical care. He or she should spend > 50% of his or her time in PICU. PICU intensivist should be a full time practitioner particularly for PICU in tertiary centers. He/she should have the following responsibilities:

- Establishing protocols and policies with the help of an expert group
- Implementation of these policies and protocols involving admission and discharge criteria for smooth functioning of PICU with
- Assurance and improvement of quality
- Advising administrative authority about equipment needs
- Continuing medical education of medical, nursing and ancillary staff
- Maintaining PICU statistics related to mortality and morbidity
- Being part of infection control committee.[3]

Medical Staff/Resident Doctors

Pediatrician with good airway and pediatric advanced life support skills and active PALS certification should be part of medical team. He should have MCI endorsed postgraduate level qualification. Other residents can be graduates or postgraduate depending upon level of PICU. This team should be present round the clock in PICU. The ideal doctor to patient ratio has not been decided in literature but it is recommended that one doctor should not

look after > 5 critical patients. These include children who are on ventilator or suffering from multiorgan dysfunction syndrome needing invasive monitoring.[3]

Nursing Staff

One nurse should be available for every child who is being ventilated or who has multiorgan failure. This nurse should have structured training for working in ICU. In no circumstance there should be < 2 nurses for 3 patients of this severity as this will adversely impact outcome. One nurse for 2 or 3 beds is acceptable for patients who are not very sick and who do not require intensive monitoring.[3]

Ancillary Staff

The PICU should be adequately staffed including physiotherapists, respiratory therapists and nutritionist for imroving patient care. In addition, radiographers, technicians and biomedical engineers should also be available in hospital all the time for emergencies like need for urgent chest X-ray in a child with suspected pneumothorax or troubleshooting problems requiring immediate attention like central gas supply problems, power failure, malfunctioning equipment, etc. Clerical staff is required for communication and paper work important for smooth functioning of the unit. It is also very important to have cleaning people who are efficient and sensitive to patient care needs. Social workers play an important role to help support families emotionally and even financially in the stressful circumstances of PICU stay.

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