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OPTIMUM DESIGN OF INTENSIVE CARE UNIT- AN EVIDENCE- BASED HEALING ENVIRONMENT

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ABSTRACT

Successfully designing a new ICU requires clarity of vision and purpose and the recognition that the patient room is the core of the ICU experience for patients, staff, and visitors. The ICU canbe conceptualised into three components: the patient room, central areas, and universal support services. Each patient room should be designed for single patient use and be similarly configured and equipped. The design of the room should focus upon functionality, ease of use, healing, safety, infection control, communications, and connectivity. All aspects of the room, including itsinfrastructure; zones for work, care, and visiting; environment, medical devices, and approaches to privacy; logistics; and waste management, are important elements in the design process. Since most medical devices used at the ICU bedside are really sophisticated equipments, the ICU needs to be capable of supporting the full scope of medical informatics. The patient rooms, the central ICU areas (central stations, corridors, supply rooms, pharmacy, laboratory, staff lounge, visitor waiting room,) and the universal support services (infection prevention, finishings & and flooring, staff communications, signage & wayfinding, security and fire & safety) work best when fully interwoven. This coordination helps establish efficient and safe patient throughput and care and fosters physical and social cohesiveness within the ICU. Synchronisation of the universal support services in the ICU with the hospital's existing systems maintains unity of purpose and continuity across the enterprise and avoids unnecessary duplication of efforts.

Key Words: *Intensive care Unit, Telemedicine, Isolation, Infection Control, Resuscitation, Thermostat.*

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INTRODUCTION

Most healthcare providers have little experience designing and constructing an intensive care unit (ICU). ICU Design Guidelines can make the process easier and the finished project more efficient, effective, safe, and patient centred. ICU Design Guidelines are performance guidelines rather than prescriptive guidelines. A prescriptive guideline quantifies, as in the case of minimum square footage for a patient room, whereas a performance guideline describes functions to be accommodated. As an example, the space required for a patient room and medical equipment in a community hospital will be less than what may be required in a major tertiary care institution. In the case of a patient room, clinical protocols and equipment may evolve, rendering a prescriptive guideline obsolete (1). On the other hand, the prescriptive guidelines will describe things that must be done in the design of such space that may not be understood by the clinician, such as space for cleaning supplies and storage. This document proposes to describe optimum conditions rather than minimum requirements. Optimum design requires knowledge of both clinical best practice and building codes (2, 3).

The ICU Design Guidelines are based on the concept of 'form follows function' and that the configuration and performance of a critical care unit should be driven by the function and place it serves. The Guidelines are intended to apply to adult medical/ surgical ICUs. Some issues are changing so rapidly, such as information technology, they are referred to only briefly. During the design process, experts in information technology may be helpful along with the architects and engineers involved in construction.

THE GOAL: A HEALING ENVIRONMENT

Evidence shows that the physical environment affects the physiology, psychology, and social behaviours of those who experience it (4). The goal of the design process is to create a healing environment – the result of design that produces measurable improvements in the physical or psychological states of patients, staff, physicians, and visitors (5). Elements of a healing environment include: materials and finishes that reduce noise levels, minimise glare, and support infection control; floor plans, equipment, and other features, such as human engineering principles, may enhance efficiency and effectiveness of patient care and minimise workplace injury; stress-reducing furnishings and décor, incorporating natural light and views of nature; and thoughtful provision for the creature comforts of patients, families, and the staff. Optimal ICU design can help to reduce medical errors, improve patient outcomes, reduce length of stay, and increase social support for patients, and can play a role in reducing costs. A design based on the functional requirements of the critical care unit and the consensus opinion of experts should enhance patient, family, and staff satisfaction and in doing so, help to protect the institution's bottom line. Staff satisfaction with the work environment has been shown to correlate with patient satisfaction and to improve retention and staff commitment. Evidence-based design allows design teams to benefit from the accumulated and ever-changing experience of others, just as evidence-based medicine identifies best practices in health care. Evidence based design is defined as "a process for the conscientious, explicit, and judicious use of current best evidence from research and practice in making critical decisions, together with an informed client, about the design of each individual and unique project" (6).

CONSENSUS STATEMENT FOR ICU PLANNING AND DESIGN

Level I (Recommended for Hospitals including Nursing Homes up to 50 Beds, District Hospitals/ Community Health Centres up to 100 Beds)

- Number of beds - 6 to 8
- Should be able to perform cardiopulmonary resuscitation including intubation, short-term cardio-respiratory support including, non-invasive ventilation, and defibrillation

- Provision for short-term mechanical ventilation (desirable)
- Have syringe pumps/ infusion pumps
- Have multipara monitors with SPO2, HR and ECG, NIBP, temperature facility
- Access to ABG facility
- Access to ultrasound, X-ray and basic clinical lab (CBC, blood sugar, electrolytes, LFT and RFT).
- Desirable to have access to CT scan and microbiology
- Access to ambulance (ACLS desirable) and trained manpower for safe transport of the patients to higher level centres
- Access to 24×7 blood bank/ pharmacy/ nutrition (desirable)
- General infection control and, patients and staff safety measures should be observed.

Level II (Recommended for Larger General Hospitals up to 100 to 150 Beds)
It includes all recommendations of Level I in addition to the following requirements:

- Number of beds 8 to 12
- Facility for multisystem organ support.
- Central nursing station (CNS)/ central monitoring facility
- Provision of both invasive and non-invasive ventilation (preferably up to half to two-thirds of bed strength)
- Access to renal replacement therapy (RRT)
- Transcutaneous pacing facility
- Should have ABG, bedside X-ray and ultrasound 24 × 7
- Access to CT and MRI
- High dependency unit (HDU) facility and telemedicine are desirable

Level III (For Tertiary Care Hospitals >150 Beds including Medical Colleges and Corporate Hospitals)
It includes all recommendations of Level II; in addition, must have following facilities/ provisions: (Level III is further sub-classified into A and B on the basis of provision of extreme care services. Level III B provides extracorporeal therapies in addition to facilities available in Level III A)

Level III A

- Critical care unit should preferably be a closed ICU
- Protocols and policies are defined
- Must have provision of advanced cardio-respiratory monitoring—both invasive and non-invasive
- Intra- and inter-hospital transport facilities available
- Multisystem care and referral available round the clock
- Ultrasound and echocardiography in the ICU 24 × 7
- In-house blood bank, pharmacy and canteen services 24 × 7
- In-house CT scan and MRI facilities strongly recommended
- Bedside flexible bronchoscopy facility is desirable
- Bedside renal replacement therapy (RRT)
- Continuous renal replacement therapy (CRRT) and plasma exchange facility are recommended
- Optimum patient/ nurse ratio (1:1 on patients on organ support e.g. mechanical ventilation, RRT, multiple

inotropes; and 1:2 at least when patient is on non-invasive ventilation and/or requires less intense monitoring)
- Should follow guidelines of a professional body of critical care (ISCCM) or equivalent in terms of ICU structure
- Should be equipped for both long-term acute care and palliative care
- Team should be well versed with transplant critical care

Level III B All of the above plus ECMO-, and LV-assist devices in High Dependency Unit (HDU)
- This is an area where patient care level is intermediate between ICU and other floors.
- It should be located near the ICU or within ICU complex, near emergency or in a ward.
- Patients after recovery from critical illness, patients of single organ failure and not requiring invasive monitoring or mechanical ventilation but need close observation due to vulnerability for deterioration preferably be admitted in HDU.
- Size can be up to 50% of the main ICU.
- Doctor/ Patient ratio and Nurse/ Patient ratio may be relaxed (1:2 and 1:3 respectively).

Structural location of ICU in hospital
- Safe, easy, fast transport of a critically sick patient should be priority in planning for location of ICU.
- Ground floor should be avoided for ICU location.
- First floor is the ideal location in close proximity of Emergency and Operation Theatre.
- Higher floors are suitable if elevators are available close to ICU.
- Corridors, lifts and ramps should be spacious enough to provide easy movement of bed/ trolley (crisscross passage of two beds/ trolleys simultaneously)
- Close/easy proximity is also desirable to diagnostic facilities, blood bank, pharmacy, etc.
- There should be single entry/ exit point to ICU and should be manned. Thoroughfare cannot be provided through ICU. However, it is required to have an emergency exit point.

ICU DESIGN

ICU design can succeed in creating top-of-the-line ICUs only, if the critical care medicine (CCM) team and the hospital administration share similar design aspirations and clinical goals. Four core principles should be considered from the outset. First, an ICU is a semiautonomous mini-hospital. Second, designing an ICU is a complex and time-consuming process. Third, the successful design balances innovation with functionality, space availability, physical limitations, and cost. Last, the design should combine a healing environment with security for patients, staff, visitors, and all ICU equipment and supplies.

Types of ICU

Dormitory-like ICU
- Space per bed has been recommended from 150 to 200 sq ft in the patient care area. Some recommendations have placed it even higher up to 250 sq ft per bed. In addition, there should be 100 to 150% extra space to accommodate nursing station, storage, patient/ doctors/ staff movement area, equipment area, doctor's and nurse's rooms, teaching area, relative's area and toilets to include all the four zones of ICU.
- A buffer/ bare area is desirable between relative's area and doctor's area.
- However, in Indian circumstances and, after reviewing and receiving feedback from various ICUs in our country, it may be satisfactory to suggest an area of at least 150 square feet per bed be provided in patient care area (Zone 1) for comfortable working with a critically sick patient where all the paraphernalia including monitoring systems, ventilators and other machines like bedside X-ray, ultrasounds, etc. and bedside procedures like central lines,

intubation, tracheostomy, ICD insertion and RRT (renal replacement therapy/ dialysis) are common and require good space.

Single accommodation cubicles/ rooms

- Patient care area should be 200 to 250 sq ft. It may be prudent to make one or two bigger rooms or areas, depending upon needs like for bariatric patients (fat) and bedside procedures e.g. ECMO, RRT etc.
- It is recommended to have 10% (one to two) isolation rooms where immunocompromised/ infected patients may be treated. These rooms should have 20% extra space. Need for lamellar flow in isolation room in ICU has not found favour.

Partition between two rooms/ cubicles/beds

- It is recommended that there should be a partition between rooms for patient's privacy.
- Standard curtains soften the look and are placed commonly between two patients in most Indian ICUs however, curtains may become unclean or get displaced and breach the privacy.
- Two rooms may be separated by unbreakable fixed or removable partition which may be of aluminium, wood or fibre.
- However permanent partitions may take away the flexibility of increasing floor space temporarily when required.

Isolation rooms (Positive and negative pressure)

- To provide protective environment for patients at highest risk of infection, e.g. neutropenic and post-transplant. These rooms should have greater supply of air than exhaust air.
- Pressure differential of 2.5 –8 Pka, preferably 8 Pka. Positive airflow relative to the corridor (i.e. air flows from the room to the outside adjacent space).
- HEPA filtration is required in solid organ and haemopoietic cell transplant patients only.

A usual problem observed in ICU is getting access to the head of the bed in times of emergency and therefore keep bed 2 feet away from head-end wall. This can be achieved effectively by placing a 2 ft wide, 6 inches high wooden plank between the wall and head end.

Number of ICU Beds and ICUs in a Hospital

- Brainstorming sessions should be held to decide how many ICUs and ICU beds are needed for the hospital. It should also discuss on need for HDU, PICU and specialty ICU like neuro, cardiac and trauma intensive care
- The number of ICU beds requirement depends on the hospital's total bed strength, available need assessment data and future requirement.
- Various issues like available space, trained manpower and budget are also important factors for consideration in deciding number of ICUs and ICU beds.
- In a tertiary care hospital, number of ICU beds requirement may vary from 5 to 25% of the total hospital beds according to the focus of the hospital. However, it is recommended that the number of ICU beds in any hospitals should not be less than 5% of total hospital beds.
- ICUs having 12 beds are difficult to manage. Recommendations suggest that efficiency may be compromised once total number of beds crosses 12 in ICU.
- It is recommended that total bed strength of ICU should be between 8 and 12. To have more ICU beds, it is recommended that number of ICUs be increased rather than increasing numbers of beds in one ICU. In required

situations, ICUs with lesser or a greater number of beds may be created.

- The Canadian Department of National Health and Welfare has developed a formula for calculating the number of ICU beds required based on the average census in the existing unit and the desired probability of having an ICU bed immediately available for a new admission. (7)

Zones of ICU

ICU area can be categorised into 4 different zones —

1: Patient care zone

2: Observation area

3: Support area

4: Family support zone

1. Patient care zone

Courtesy of Memorial Sloan-Kettering Cancer Center, NY

1. Nurse server & secure ID card access reader
2. Slide & break away doors with E-glass
3. Inside opening of nurse server
4. Wireless clock (web-based)
5. Storage cabinets
6. Computer with double monitor
7. Barcode reader and lab label printer
8. Twin mobile articulating arms (BOOMS)
9. Wireless transmitter
10. Web cam
11. Closet and DVD player
12. Flat screen TV on articulating arm
13. Toilet
14. Decentralized nursing work area

Figure- 1: ICU patient room (ultra wide angle view)

a) Infrastructure

The design group must work through the room's core infrastructure elements (electrical power [standard and emergency]; heat, ventilation, and air conditioning; plumbing; lighting; flooring; walls; ceiling; communications; video camera(s) [webcam and video EEG], and connectivity [wired and wireless access]). The design concepts and specifications for these systems are usually opaque to clinicians. Thus, the team's clinical members need to familiarise themselves with the relevant design, architectural, and engineering issues and make sure that the end-user (patient and staff) requirements are clearly expressed to the architects. Subsequently, the design schematics should be reviewed with the entire team in simple language.

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An early operational decision that guides the room's functionality involves the selection of the medical utility distribution system. Should medical devices (eg, physiologic monitor, mechanical ventilator, and infusion pumps), utilities (e.g., medical gasses and vacuum, electrical and data outlets), communication systems, and storage for select supplies be incorporated onto stationary headwalls, floor mounted, or suspended columns (fixed in position or rotating), or ceiling- or wall- mounted mobile articulating columns/ arms (booms) (Fig 2)? The mobility of the booms offers greater flexibility, access to the patient, and enhanced bed positioning (including facing the window) than the stationary solutions. However, booms are more expensive to purchase, install, and maintain. Regardless of the utility system chosen, efficient access to the medical devices and utilities is a primary design requirement.

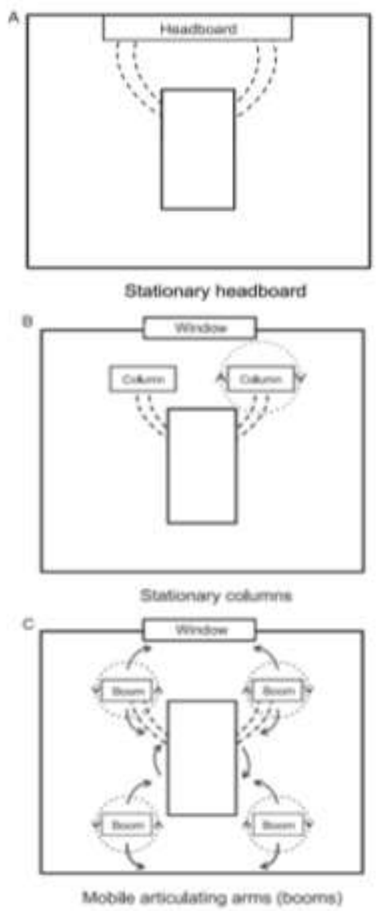

Figure- 2: A-C, ICU utilities and equipment mounted on (A) a stationary headboard, (B) stationary (left side) or rotating (right side) columns, and (C) mobile articulating arms (booms) that swivel and can be moved horizontally and/or vertically. The booms can be attached to the walls or ceiling, at the head of the bed, or at all four corners.

b) Core Bedside Medical Technologies

The essential medical devices and furniture for the ICU patient room include an ICU bed, physiologic monitor, mechanical ventilator, infusion and feeding pumps, pneumatic compression devices, computers, patient chair for ambulating patient, cardiac tables, webcam, storage areas, and waste disposal bins. Point-of-care testing

(POCT) and ultrasonography devices are increasingly being considered as core bedside equipment because these technologies speed diagnosis, improve therapeutic decision-making, and have decreased in size, footprint, and cost (6).

c) Recommendations for Indian ICUs: For Level I and Level II Indian ICUs Unit size 6 to 12 beds

Oxygen outlets 2, Vacuum outlets 2, Compressed air outlet 1, Electric outlets 12 of which 4 may be near the floor 2 on each side of the patient. Electric outlets/ Inlets should be of common 5/15 amp pins. They should have pins to accommodate all standard International Electric Pins/ Sockets. Adapters should be discouraged since they tend to become loose.

Utilities per bed as recommended for Level III Indian ICUs 3 oxygen outlets, 2 compressed air, 2 vacuums (adjustable), 12 to 14 electric outlets, a bedside light one-telephone outlet and one data outlet (8).

The patient room must have storage spaces for supplies, medications, and linens. Storage systems may include a mix of secured (electronic preferred over keys) and non-secured drawers, cabinets, and/or mobile carts. Nurse servers (cabinets with bidirectional and secure access from both outside and inside the room) should also be considered. Privacy and infection control violations are curtailed as the nurse servers can be supplied from outside the room (Figs 1, 3) [9].

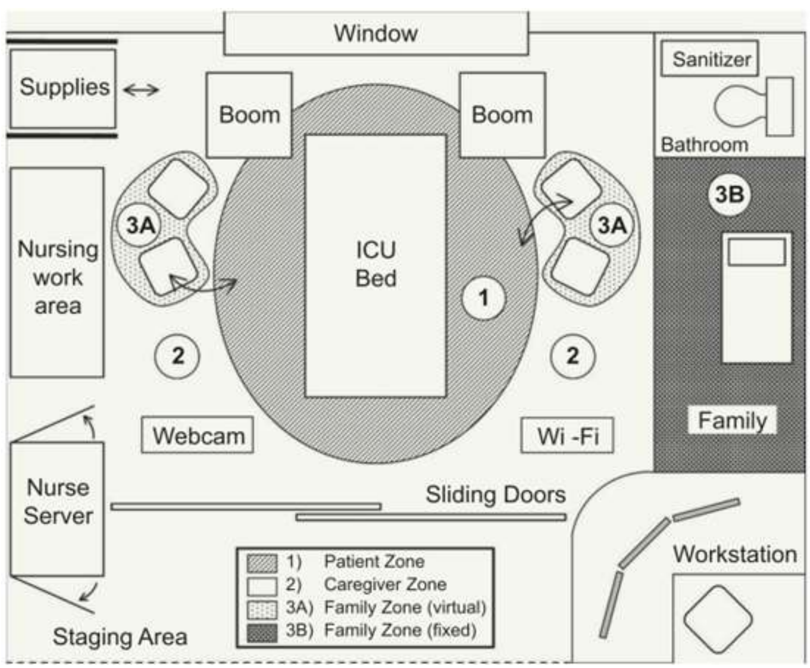

Figure - 3: The ICU patient room can be divided into three zones: (1) patient, (2) caregiver, and (3A) virtual or (3B) fixed family zones. Also shown are nurse server with bidirectional access, nursing work area, supply space (cabinet or cart), booms, bathroom with sanitiser (or macerator), webcam, Wi-Fi access point, and a workstation and staging area outside the room.

d) Waste Management Systems

Current guidelines mandate that ICU patient rooms have direct access to bathrooms. Designers should consider installing sanitisers (to clean reusable bedpans) or macerators (to destroy single-use bedpans) in the bathrooms (Fig - 3). However, these devices produce a fair amount of noise; thus, the bathroom walls should include sound-reduction barriers. Bathroom infection control is supported through frequent air exchanges and air filtering, as well as negative pressure systems that limit the dispersion of aerosolised waste back to the patient room. Even with bathrooms, portable commodes are still required. Trash (standard, infectious, sharps) and soiled linens can be placed in stand-alone rolling carts or in mounted bins or containers designed into the cabinets.

e) Room Environment

The emotional welfare of ICU patients, staff, and visitors is greatly impacted by the room's environment. Thus, a healing milieu that promotes serenity and encourages sleep should be developed. The essential healing elements include sound, light, temperature and time.

f) Sound

Noise is physically minimised through the use of sound-absorbent materials on the walls and ceiling, acoustic baffling within the walls, sound-proofed windows, and sound attenuators in the heat, ventilation, and air conditioning system. Physical limiters of sound, however, must be accompanied by control of alarms from devices, minimisation of announcements and alerts from ICU and hospital communication systems, and shifting of conversation from the front of the central stations to more distant central areas. Noise-cancelling headphones and sound-masking or white-noise systems also mitigate loud noises or generate positive sounds, respectively (10). The International Noise Council recommends that the noise level in an ICU be under 45 dBA in the daytime, 40 dBA in the evening and 20 dBA at night. For example, 16 A watch ticks at about 20 dBA, normal conversation is at about 55 dBA, vacuum cleaner produces about 70 dBA (7).

g) Light

ICU patient rooms are mandated to have windows. Natural light and a compelling view help maintain diurnal rhythms and mental stability. Beyond anti- glare coating, the flow of outdoor light should also be controlled with shades (solar and black-out), glass with integral blinds, or electronic glass. Controls for these systems (mechanical or electronic) need to be available to both staff and patients. In the unusual circumstance where access to outside windows is not possible, artificial ambient light systems may be considered (10).

Natural lighting in the unit can decrease power consumption and the electrical bill which is so relevant to Indian circumstances. Access to natural light also means that one may have access to viewing external environment which may be developed into green and soothing.

- Light for procedures: High illumination and spot lighting is needed for procedures, like inserting central lines, etc. They can descend from the ceiling, extend from the wall/panel, or be carried into the room. Spot lighting should be shadow free with 150 foot-candles (fc) strength.
- Light required for general patient care should be bright enough to ensure adequate vision without eye strain.
- Overhead lighting should be at least 20 foot-candles.
- Higher frequency fluorescent lights and coated phosphorus lamps may be good for assessing skin colour and tone
- Lights that come on automatically when cupboard doors or drawers are opened are useful.
- Floors lighting may be important for safety at the bedside and in the hallways at night and should be about 10 fc. Glare created by reflected light should be diffused.

- Light switches should be strategically located to allow some patient control and adequate staff convenience.
- A second remote control can be turned on/off by the nurses/ doctors to observe patients intermittently at night without entering the room and disturbing the patient. Hall lights controls should be subdivided into smaller independent areas and dimmer switches may be desirable. Dull blue lights at night help good sleep and outcome of patients. (7)

h) Temperature, Smell, and Time

Critically ill patients may have temperature dysregulation or be highly sensitive to changes in room temperature. Therefore, each patient room should have its own thermostat. Scent eliminators or generators may be used to provide fresh smells. Highly visible clocks (stand-alone, computer, or television display) with day and date help with patient orientation are desirable. (10)

i) Heating, ventilation and air-conditioning (HVAC) system of ICU

- The ICU should be fully air-conditioned which allows control of temperature, humidity and air change. If this may not be possible, then one should have windows which can be opened (‘Tilt and turn’ windows are a useful design). Suitable and safe air quality must be maintained at all times.
- Air movement should always be from clean to dirty areas. It is recommended to have a minimum of six air changes per room per hour, out of which two air changes per hour should be composed of outside air. Where air-conditioning is not universal, cubicles should have fifteen air changes per hour and other patient areas at least three per hour. The dirty utility, sluice and laboratory need five changes per hour, but two per hour are sufficient for other staff areas (8).

j) Room Controls and Environmental Sensors

Environmental controls (lights, window treatments, and thermostat) may be individualised or integrated within computer or nurse-call technologies. Continuous monitoring of the patient room by multi-parameter sensors (temperature, humidity, light, sound, room pressure, and particulate matter) helps maintain the healing environment. Web-based sensor applications can transmit alerts when norms are violated.

2. Central Areas/ Observation Area Zone- *Nursing Station, Administrative Centre, Interdisciplinary Team Centre:*

Central area design is governed by four tenets. First, the primary purpose of these spaces is to support bedside care. Second, the themes of healing, privacy, informatics, communication, and infection control should weave seamlessly between the patient rooms and the central areas. Third, the design of the central areas should foster a cohesive ICU environment. Lastly, the central area’s spaces should be sufficient to minimise hallway clutter (people, devices, and supplies).

Central stations provide areas for administrative, clinical, and uni- and interdisciplinary collaborative and social interactions. The layout of the central stations depends upon the physical arrangement and space availability of the ICU and the bed configurations (Figs. 4 & 5). One centrally located station may suffice in a small ICU, whereas multiple central stations and substations may be required in a large ICU with several bed pods. Ideally, central stations should have unobstructed views of the ICU beds.

Central stations commonly are composed of desks to greet visitors, and quiet areas for staff work, documentation, consultation, and conferencing.

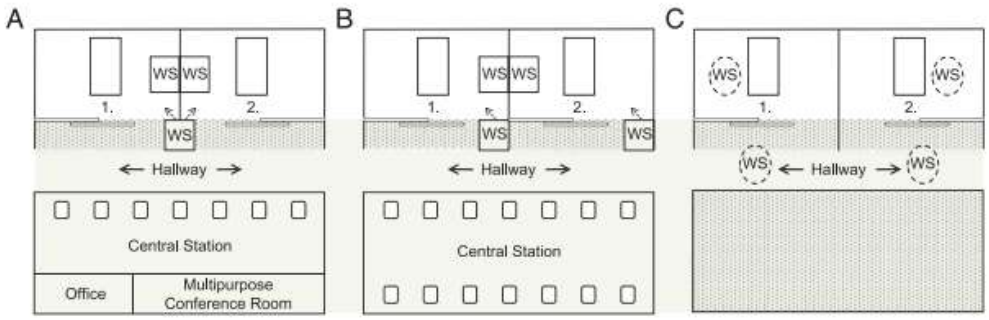

Figure - 4: A-C, Decentralised WSs may be constructed outside the patient rooms as one station per two rooms (1 and 2 in A) or one station per room (1 and 2 in B), or there may be no decentralized WS (C). Room-based WSs are present in A and B; mobile WSs are used outside and inside rooms 1 and 2 in C. A, ICUs may be built with a multi-tiered central station with office and multipurpose conference room, (B) have a central station only, or (C) have no central station. See 'Figure - 4 legend' for expansion of abbreviation.

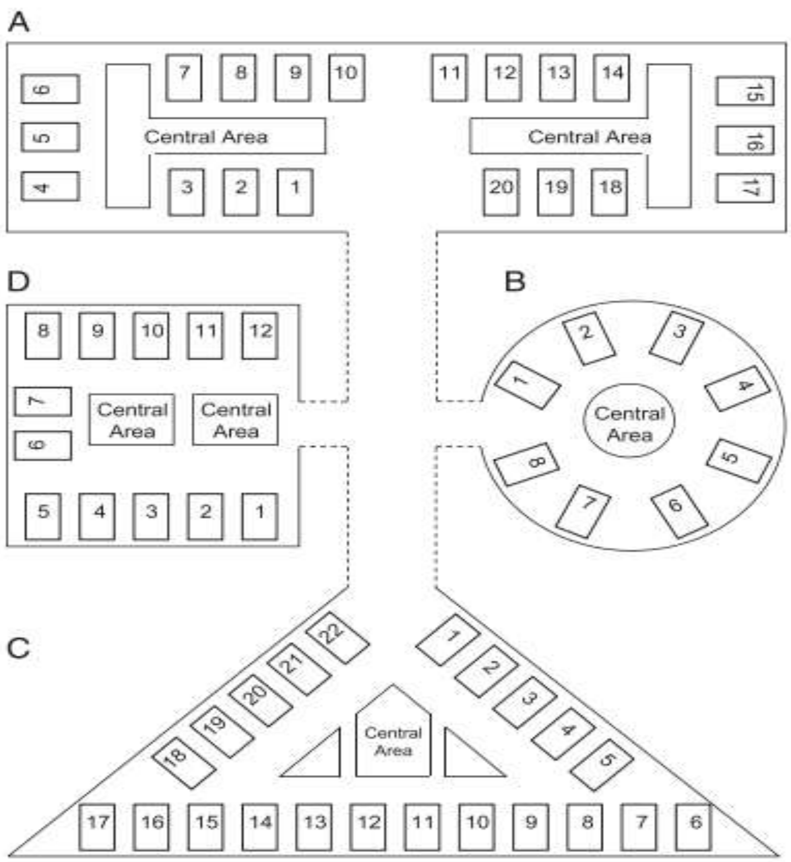

Figure - 5: ICUs can be configured in many patterns. A - Rectangular, B – Circular, C – Triangular, D - Square. They may have differing numbers of beds and central areas.

- **Front of ICU Room**

  ICU rooms may open directly onto the hallway, be set back from the hallway, or have a hybrid design. The hybrid design incorporates positive features of both prior approaches. The staging space may include a sink, hand-washing dispenser, storage space (gowns, gloves, and masks), coat hangers, and an identification board (white or glass board or electronic display).

3. Corridors/ Support Area Zones

ICU corridors that are well coordinated with the patient rooms, central areas, and ICU exits provide efficient circulation pathways and facilitate physical and social unity, especially in large ICUs with multiple central stations and bed pods (Fig 5). The inclusion of designated hallways for transport of patients and supplies that bypass the ICU front door and waiting room augments patient privacy and helps avoid traffic jams (**Fig - 6**). However, ideal corridor design may be difficult to achieve because of physical barriers (staircases, elevators, plumbing conduits, and electrical and network closets) and hospital hallways that are discordantly positioned.

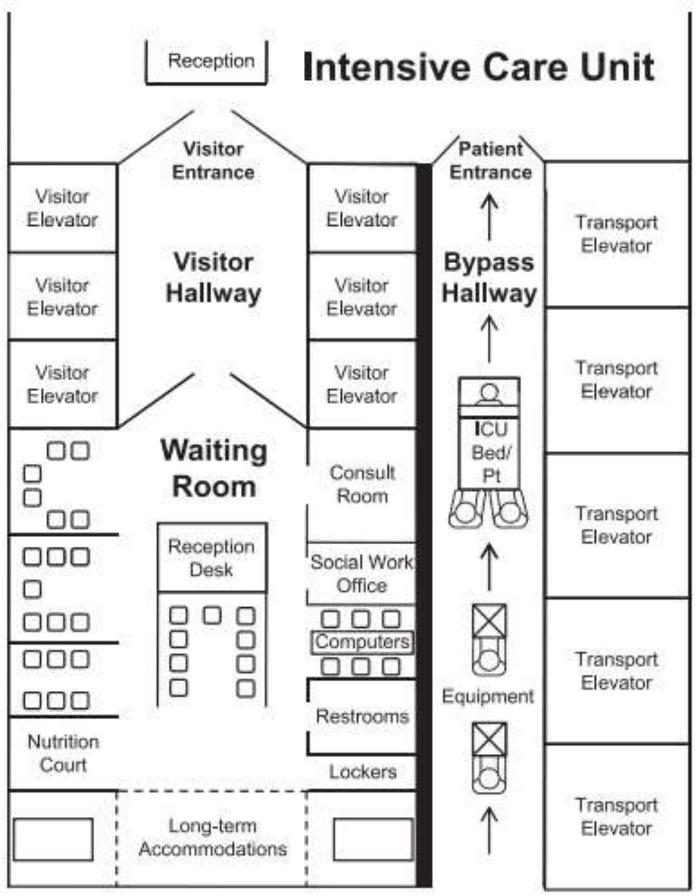

Figure - 6: The waiting room has direct entry into the ICU (i.e. on-stage) and has a reception desk, private seating areas, consultation room, computer area, social worker office, restrooms, nutrition court, and lockers and coat hangers. Long-term accommodations (beds and showers) can also be included. A bypass corridor for patient transport and staff and equipment movement circumvents the waiting room and provides privacy and prevents traffic jams (i.e., off-stage).

ICU hallways also set the emotional tone for the ICU through their finishings and artwork, sound control, and adjustable lighting. The minimum building code width for hospital hallways is 8 feet. However, hallways, especially in academic centres with large multidisciplinary ICU teams, also serve as intermediate spaces between the patient rooms and the central stations. These hallways are used to conduct rounds (with mobile computer carts), patient related consultations, family meetings, and therapeutic activities (i.e., early mobility). Therefore, in such dynamic settings, design teams should consider widening the hallways past the minimum code requirement and equipping them with power outlets for the carts. Respite areas within the hallways may also be a valuable local and supportive adjunct for ICU visitors.

Fixed barriers and bumper guards or damage-resistant wall finishings should be installed along the corridor walls to protect them from dents and breakage caused by heavy rolling equipment. The installation of half-globe mirrors improves safety at ICU entrances. (10)

i) ICU Logistics Spaces, Supplies, and Medical Devices

Bulk supplies, medical devices, and procedure carts are stored in large ICU supply and storage rooms (clean workrooms or clean supply rooms) and alcoves along the hallways. These storage spaces should have access to transport or cargo elevators as well as power and data outlets for device charging and data transmission. The strategic positioning of supply rooms and alcoves minimises travel distances from patient rooms and reduces hallway clutter. These efficiencies may be compromised in large ICUs with multiple pods (**Fig - 5**) unless core facilities are easily accessible from each pod or supportive logistical spaces are duplicated in each pod. Space should also be allocated off the main corridors for storage of occasionally used large devices (i.e., specialty beds) (6).

Options for supply storage include stationary or track-based shelving, closed supply cabinets or rolling exchange carts. Ideally, these storage units are outfitted with electronic inventory management systems as part of real-time locating systems/solutions (RTLS) (11).

The challenge to design teams is to 'right size' both the central ICU supply and bedside storage areas. This process requires accurate projections of ICU occupancy rates, supply usage, and clarity of ICU and patient-room resupply models (i.e., replenishing used supplies *vs* discarding unused supplies or exchanging supply carts) both when the room is occupied or between patients. Regardless of the logistics plan, an emergency stockpile of vital supplies and back-up equipment for the bedside needs should to be kept in the ICU.

Central spaces maintain a host of medical devices and carts that are intermittently used at the ICU bedsides. These devices may also supplement core bedside equipment (i.e., infusion pumps) or provide emergency replacement if bedside devices fail (i.e., free-standing physiological monitor). ICU design teams must also grapple with the cost-benefit ratios of owning and storing large imaging or therapeutic devices and/or constructing permanent facilities for them in valuable ICU space. For example, should the ICU have a mobile CT scanner, a suite with a permanent CT scanner, or none at all? Similarly, physical therapy and early mobility can be performed both at the bedside and in the hallways using mobile devices (12-14). Would such therapies be augmented with a local rehabilitation suite?

ii) Pharmacy

Medication management and ICU pharmacy space must be coordinated with the hospital's primary pharmacy. If the hospital's pharmacy system is centralised and ready-for-administration medications are regularly distributed, the design team needs to determine the minimal resources (secure and quiet medication preparation station) required for local and urgent pharmaceutical services. Medications may also be stored in secured cabinets, with refrigeration, if necessary, at the ICU bedside.

iii) ICU Laboratory testing and POCT (Point-of-care-testing)

Laboratory testing performed within the ICU usually falls under the rubric of POCT and focusses primarily upon whole-blood analyses. POCT devices, available as large and small platforms, may be positioned in an ICU stat laboratory, at a central station, on mobile carts, or at each ICU bedside (**Fig - 7**). These devices are usually connected through POCT device and data management middleware to the laboratory information system or the electronic medical record (15, 16). A combination of POCT modalities, locations, and middleware may be used depending on the ICU workflow, necessary testing, and available space and resources. As POCT is never a complete replacement for the central laboratory, pneumatic tube stations are still required to transport specimens to rapid-response or central laboratories located elsewhere in the hospital. With the increasing prevalence of drug-resistant pathogens, care should be taken to provide for separate handling of specimens from patients in isolation rooms.

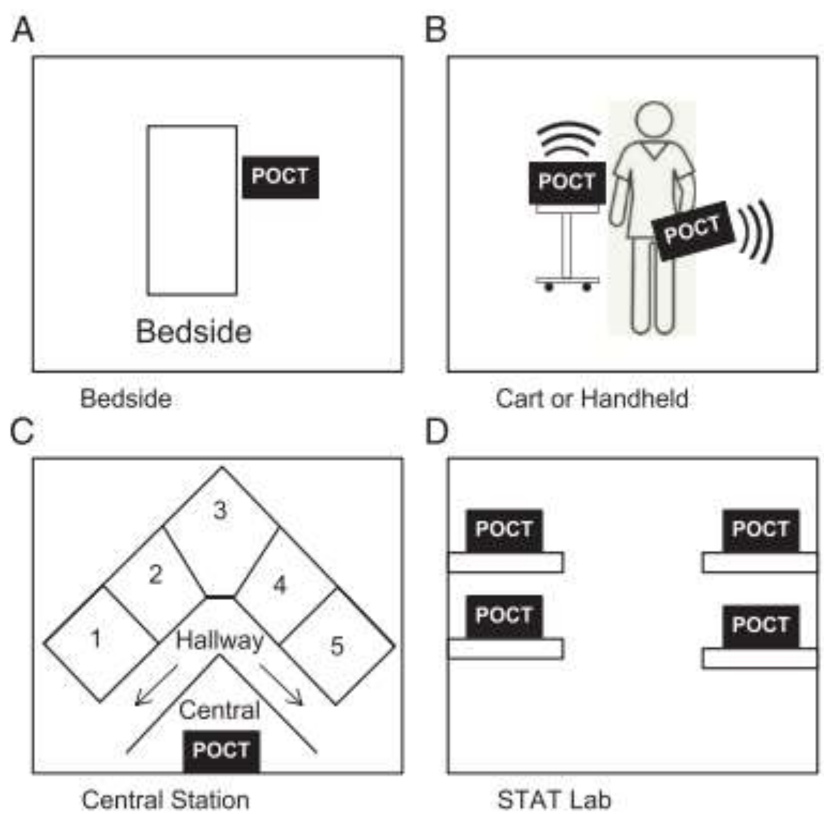

Figure- 7: POCT paradigms A, POCT based at every bedside. B, Mobile POCT on a cart or handheld. C, POCT based at a central station. D, POCT within a local stat (rapid response) laboratory. POCT 5 point-of-care testing.

iv) Staff Lounge

A lounge with tasteful appointments and amenities located within the ICU helps maintain the emotional and physical well-being of the staff and encourages staff members to stay in the ICU confines and socialise during breaks. Seating should accommodate the average number of ICU staff on breaks. Staff satisfaction is promoted through the provision of windows; comfortable chairs, couches, and tables; artwork; televisions; computers; a nourishment station (refrigerator, microwave, and sink); private changing areas; scrub dispensers; lockers; storage areas for heavy coats, shoes, or boots; bulletin boards; staff mailboxes; nurse nap alcoves; and bathrooms. The lounge must also have ICU communication and nurse-call systems. It is advisable to have separate changing room for nurses and doctors. Uninterrupted clean and sterile RO water at desirable temperatures must be supplied 24x7 to the doctors and nurses working in the ICU as well as to the relatives of the patients (8).

v) Visitor Waiting Room (Family Lounge)/Family support Zones

Placing the waiting room adjacent to the ICU allows visitors to easily access the ICU and clinicians to meet with families (Fig 7) (17, 18). Visitors should be greeted by a receptionist in the waiting-room area or at the ICU entrance. ICU visitors benefit from a tranquil environment with soft lighting, warm colours, nature-themed artwork (photographs, paintings, or video displays), and quiet background entertainment (wall- or ceiling-mounted televisions). If possible, the waiting room should have large windows supplemented by out-door patio access.

Small groups of comfortable chairs, separated by dividers, allow families to sit together with relative privacy. Facility guidelines recommend a minimum of 1.5 chairs per patient bed (19). The waiting room experience is enhanced through wireless Internet access, computers, power and USB outlets to charge visitors' phones and computers, vending machines, water fountains, bathrooms, lockers, and coat hangers. Family meetings and social support in the waiting room are promoted through the inclusion of consultation rooms and an office for the social worker, respectively. Long-term sleeping accommodations (rooms or alcoves) may also be considered if space permits and the ICU leadership is willing and capable of managing hotel-type facilities (20). Respecting the relatives, their needs and emotions and reacting with empathy may solve the concerns of family members. Depending on space available this may be designed. Facilities of cafeteria may be made available nearby for relaxation and discussion with each other. This will help in relieving the stress and anxiety.

4. Universal Support Services

Two principles govern the design of universal ICU support services. First, these services must be titratable throughout the ICU to meet the varying needs of patients, visitors, staff, and space. Second, the universal services in the ICU should be synchronised with the hospital's existing systems to maintain unityof purpose and continuity across the enterprise and to avoid unnecessary duplication of efforts.

i) Infection Prevention

To date, ICU infection prevention relies upon several core strategies. The first is the "behind the scenes" infrastructure that supports clean air. This includes air-cleansing systems, room-based air exchanges, and airborne infection isolation (positive- and negative- pressure) rooms. The second is the plumbing to provide water for sinks (inside and outside each patient room) and to eliminate waste in all patient rooms and device, supply, and garbage processing areas. The third is the ubiquitous installation of hand-sanitising fluid dispensers. The fourth is the use of nonporous surface materials that resist water seepage and the subsequent adherence and growth of bacteria, viruses, or fungi. The fifth is the strategic positioning of housekeeping closets (environmental storage or service rooms) and soiled utility rooms (soiled workrooms or soiled holding rooms) to both facilitate cleaning and minimise the transit of waste and contaminated devices from patient rooms. The sixth is the placement of controllers for patient-room systems (electronics, air, and plumbing)

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outside, rather than inside, the patient room. This positioning allows upgrades or repairs to be effected without opening up the ceiling in the patient's room and potentially exposing a care area to ceiling-based particulate or infectious matter.

The use of electronic surveillance of hand-washing compliance is now being advocated as an adjunctive mechanism. ICU designers should additionally explore the utility of advanced infection-prevention modalities. These include the use of surfaces (countertops, bedrails, door frames and handles, drawer handles, and curtains) and technologies (sealed keyboards and computer mice) that incorporate "self-cleaning" copper or silver. The design team may even designate "super isolation" zones that facilitate the grouping of highly infectious patients and the rerouting of traffic patterns (10).

ii) Finishings and Flooring

Beyond being integrated within the global motif, all ICU finishings should be durable and easy to clean and maintain. Floors, additionally, should be comfortable to walk on, slip-resistant, and seamless. Cabinetry throughout the ICU should be solidly constructed flame and static-resistant, if possible.

The walls, wall coverings, and countertops also need to be water resistant, especially near sinks and plumbing fittings.

iii) Floor, Wall and Ceiling Coverings

a) Floor

The ideal floor should be easy to clean, non-slippery, able to withstand abuse and absorb sound while enhancing the overall look and feel of the environment, carts and beds equipped with large wheels should roll easily over it.

In Indian context vitrified non-slippery tiles seem to be the best option which can be fitted into reasonable budgets, easy to clean and move on and may be stain-proof. Vinyl sheeting is another viable option, it can be nonporous, strong and easy to clean.

- The life of Vinyl flooring is not long and a small damage in one corner may trigger damage of entire flooring and make it accident-prone. It may require frequent replacement making it to be an inconvenient choice

b) Walls

- Durability, ability to clean and maintain, flame retardancy, mildew resistance, sound absorption and visual appeal are the major requirements.
- It has been very useful to have a height up to 4 to 5 feet finished with similar tiles as of floor for similar reasons. For rest of the wall soothing paint with glass panels on the head end at the top may be good choice.
- Wooden panelling has also found favour with some architects, but costs may go high.
- Door stoppers and handrails should be placed well to reduce abuse and noise to minimum; it helps patient movement and ambulation.

c) Ceiling

- Ceiling surface is most commonly seen by patient. Bright spotlights or fluorescent lights can cause eye strain and ceiling should be soiling and break-proof due to leaks and condensation.
- Tiles may not be the most appealing or soothing surface, but for all practical purposes, it is easier to remove individual or few tiles for repairs over ceiling in times of need.

- Ceiling design may be enhanced by varying the ceiling height, softening the contours, griddled lighting surfaces, painting it with a medley of soft colours (yellow, sky-blue, light grey) rather than a plain background colour, or decorating it with patterns or murals, to make it more patient- and staff-friendly.
- It is recommended that no lines or wires be kept or run over ceiling or underground because damages do occur once in a while and, therefore, it should be easy to do repairs if the lines and pipes are easily explorable without hindering patient care.
- Chair numbers and types: Individual units should decide about the number, usually enough number to accommodate the care-giving staff/ doctors and nurses and additional chairs may be stored and used whenever needed. Individual units should decide whether they want to allow the relative to sit by the side (short or long time) of the patient in the ICU. However, a chair/sofa-type chair on wheels with safety belt or vault is recommended for mobilising the patient (7).

iv) Staff Communications

Various communication technologies including phones, overhead speakers, nurse-call stations and bi-directional transmitters are available. Landline telephones continue to play a major role in providing reliable and secure ICU communications and should be installed universally and with redundancy. Overhead speakers also remain necessary to maintain ICU participation in hospital-wide broadcasts; however, overhead announcements must be used sparingly to minimise noise. Overhead systems can be integrated with other ICU communication systems and offer zoned broadcasts and automatic adjustments to ambient sound (10).

v) Signage and Wayfinding

Signs are a critical but easily underappreciated element of the design. Destination signs must be easily visible and clear in message. However, the text on these signs may be confusing and duplicative because building codes commonly mandate the concomitant display of official room designations in addition to the obvious purposes of the room (i.e., room 1234 and bed 4).

Good directional signage guides ICU staff and visitors to their intended destinations using the most effective and appropriate pathways (21). The process of developing directional signs requires virtual ICU walkthroughs that broadly look at each corridor and destination from every direction that the sign may be viewed. Large hospitals are now also introducing kiosks that provide electronic wayfinding from the hospital's entrance to the desired end points.

Signs also provide information about the area. The front entrance signage usually has permanent text (i.e., ICU name and visiting hours). In contrast, signs at each patient room have temporary text (i.e., patient name and ICU team); thus, room-based signs should include erasable whiteboards or programmable electronic displays (10).

vi) Security

Security and a warm setting need to be balanced within the ICU design. Electronic identification card access for staff is useful at all secure doorways. Time- limited electronic access cards may also be distributed to ICU visitors. Communications at visitor entrances are best handled by dedicated clerks; however, staffing limitations usually preclude full-time personnel. Thus, closed-circuit televisions and electronic buzzer systems should be installed at ICU entrances. Overall, the ICU is optimally monitored by a mix of hospital-based video cameras and locally based webcams.

5. Disaster Preparedness and safety issues

Major disasters that have been reported during last two decades within India are: – Fire – Floods – Breaking of central oxygen supply – Major power failure – A/C failure – Human violence which include terrorist attack and violence by relatives of patients/ political activists – Infection breakouts.

i) Fire and Safety

Although there are many elements of the design that are critical to preventing and controlling fire and smoke; four deserve special mention within the design process (22, 23). The first is the focus on using products and finishings that possess a low fire load and release limited quantities of heat and toxic smoke. The second is the construction of fire- and smoke-rated compartments within the ICU that keep fire and smoke within the compartment where the condition originated. This safety feature permits staff, patients, and visitors to evacuate from a danger zone to a horizontal and adjacent compartment of refuge. The third is implementation of protective technologies within the heat, ventilation, and air-conditioning systems and ducts that prevent the spread of smoke and other products of combustion from one area to another. The fourth is the integration of experienced fire-safety officers into the ICU design process to assure that fire codes are met in the most practical and user-friendly fashion.

Core ICU fire safety devices include smoke detectors, automated sprinklers, and a variety of fire extinguishers. The ICU must also have fire alarm pull-stations to facilitate hospital-wide notice of ICU emergencies. Conversely, the ICU needs to have sound or light alerts and overhead speakers to notify the ICU staff of local or facility-wide fire and smoke situations.

Most deaths in ICUs occur because of suffocation rather than burns. Smoke spreads through the A/C ducts; therefore, as a rule AC ducting of ICUs should not be connected to any other facility ducts at all.

- There should be adequate fire fighting equipment inside ICU and protection from electrical defaults and accidents.
- The glass panels on ICU window should be breakable with hammers. Such hammers should be put and displayed in glass cupboards which can be easily obtained. Guide for methods to open the windows should be put up under each window in local language.
- Exit and escape routes signage should be displayed in local languages at prominent points near the ICU.
- There must be an emergency exit and staircase for ICU to rescue patients in times of internal disaster.
- There should be provision for some contingency room within the hospital where critically sick patients may be shifted temporarily. HDU may be the best place if beds are vacant.

ii) Floods

In India flood is common during rainy seasons in some areas, hence ICU should be located preferably on higher floor and provision for water drainage should be made. Such disasters have been earlier reported in India from ICUs.

iii) Oxygen Failure

There have been reports of multiple deaths in Indian ICUs because of central oxygen supply failure. This can be prevented by making provision of alternative supply line of oxygen using oxygen cylinders of different capacity as per requirement. Functional status of these cylinders must be checked periodically.

iv) Power Failure

Alternative power supply in the form of source UPS (24 × 7) for all beds, possibly whole ICU must be available

v) Air-conditioning Failure

Temperature control in ICU is also an important issue and need to be addressed. Alternative source of power supply in the form of generator must be available.

vi) Public Violence

Various factors are responsible for public violence in critical care settings and following measures may be taken to prevent the violence: – Good buffer zone may be created between public and ICU staff – Counsellor to address the issues – Frequent update on patient condition – Written and displayed hospital policy – No hidden agenda – Well-trained guards (24x7) to control the situation – Frequent interaction with relatives.

vii) Infection Prevention

- ICU is a vulnerable area for spread of Infections; therefore, it is imperative that all protocols and recommendation practices about infection control and prevention are observed and if there is a breakout then adequate steps must be taken to control this and disinfect the ICU if indicated.
- Infection control practices must be in top of the priority list of every ICU.
- All the Recommendations of State Pollution Control Boards and Biomedical Waste guidelines must be followed in letter and spirit.
- All beds must have 24x7 Hand rub solution bottles hanging by the bed foot end or around
- There should be one hand-wash basin with elbow operated water tap for at least 5 beds. A hand-wash basin for every bed may require lot of space and may lead to additional problems.

  Emergency Eyewash Station: Workers in the ICU are exposed to many hazardous fluids. Despite universal precautions, splashes of chemicals/ bodily fluids can occur. The institution will need to determine whether an emergency eyewash station may be used to address the issue. (7)

CONCLUSIONS

The ICU design team can optimise the experiences for patients, staff, and visitors by coordinating all aspects of the patient room, central areas, and universal support systems. This requires clarity of vision and purpose that emphasises functionality, healing, standardisation, and the thoughtful application of both existing guidelines and innovative approaches, keeping in mind evidence-based medical practices.

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