Contemporary ICU Design

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Introduction

The design of an intensive care unit (ICU) is a complex process and requires a multidisciplinary group of professionals. In 2010, there were approximately 6,100 ICUs with over 104,000 beds in the 3,100 acute care hospitals in the United States [1]. ICU design itself is continuously evolving as new guidelines and regulatory standards are developed, clinical models are changing, and medical technologies are advancing. It is highly probable that hospital-based intensivist leaders will be asked at some point in their careers to participate in efforts to design new ICUs or renovate existing ones. This chapter provides an overview to a wide array of design issues and is divided into three sections: an overview of ICU design, configuring the ICU space, and future trends in ICU design.

Overview of ICUs and ICU Design

The ICU provides care for the hospital's most critically ill patients and is a necessary resource for an acute care hospital. The average number of ICU beds per unit has increased between 1993 and 2012 [2]. Adult ICUs are now bigger by almost six beds, or 29 % [3]. In large hospitals, there are usually a high percentage of hospital beds dedicated to critical care through multiple-specialty ICUs (i.e., medical ICU, surgical ICU, coronary care unit, cardiothoracic ICU, neurosurgical ICU, burn ICU, pediatric ICU, and neonatal unit) [2]. In many of the smaller community hospitals, fewer beds are allocated to critical care, and there are fewer specialty ICUs; commonly one large multipurpose adult ICU handles all types of critically ill patients.

Four core principles should guide ICU-specific design. First, designing an ICU is a complex and time-consuming process. Second, an ICU is a semiautonomous mini-hospital. Third, the design requires balance between innovation and functionality, space and physical limitations, and desire and cost. Last, the design should combine technology, security, with a healing environment.

These design principles should operate in concert with the growing field of evidence-based design (EBD), a process of basing decisions about the built environment on credible research to achieve the best possible design and deliver positive clinical outcomes [4, 5]. EBD innovations optimize patient safety, quality, and satisfaction, as well as improve workforce safety, satisfaction, and productivity, with the additional benefits of operational cost savings and energy efficiencies [6, 7].

ICU Design Team

ICU design succeeds when the critical care medicine team and the hospital administration share common goals to design an "impressive" ICU, and the hospital, provides adequate space, and funding [8]. ICU design projects ideally are guided by an interdisciplinary design team which generally includes a variety of disciplines including hospital administration, the clinical team (a multidisciplinary group made up of physicians, nurses, pharmacists, infection control specialists, and other ancillary staff members), and the design team (made up of architects, engineers, and other specialists including equipment and information technology experts). Ideally, architects and engineers with a prior track record of excellent ICU design experience should be engaged.

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The Vision

Design-specific deliberations can only begin after basic ICU issues are addressed and a vision for the new ICU has been articulated [8, 9]. Issues include the location and purpose of the unit, the planned number of beds, the apportionment of space between patient and supportive areas, the logistics of unit function (centralized or decentralized), and whether a step-down unit will be associated with the ICU. The vision of the new ICU should reflect the big picture and focus on the desired atmosphere and feel, approaches to patient and family care, workflow, technology, environment, and the ICU's physical and logistical relationships with the remainder of the hospital.

Design Guidelines

The design process should be initiated by utilizing existing evidence-based guidelines, recommendations, and expert opinions to gather core knowledge of ICU design [8–14]. A primary source is the *Guidelines for Design and Construction of Hospitals and Outpatient Facilities*, published by the Facility Guidelines Institute (FGI) [15]. These guidelines (updated on average every 4 years by a multidisciplinary team of designers and clinicians) recommend minimum program, space, risk assessment, infection prevention, architectural detail, surface and furnishing needs for clinical and support areas, as well as minimum engineering design criteria for plumbing, electrical, and heating, ventilation, and air-conditioning (HVAC) systems. The FGI document is designed to meet minimum standards for design and construction and has been adopted by most states in the United States, in addition to being used in other countries.

Another fundamental resource is the Society of Critical Care Medicine (SCCM)'s *Guidelines for Intensive Care Unit Design*, which describes universal functions that should be accommodated in the modern ICU [10]. SCCM also maintains a digest of the ICU design award winners and includes architectural design drawings, pictures, and videos of outstanding ICUs from throughout the world [16]. This digest can also be used to provide benchmarks for the new ICU design.

One of the important considerations in using both the FGI and SCCM guidelines is the adoption of these tools early on in the design process by developing what is termed the "functional program" – an understanding of spaces needed to comprise the ICU. The use of design guidelines and standards enhances the built environment, and ongoing updates and revisions are necessary to keep these tools current alongside the changing nature of medical practice, technology, and evidence-based studies.

Design Timeline

The ICU design team must recognize that from design origination to occupancy may take several years [8]. Design committee meetings should occur regularly, and provision of continuously updated schematics and computerized renderings of the various design concepts to the design team speed the process along. Full-scale prototypes or "mock-ups" of the patient rooms are now standard practice in the design process, as they allow for an experiential rather than an observational experience. Mock-ups allow the staff to gain a sense of how the space and size of the room will accommodate patient care workflow in the future. Mock-ups can range from simple tape on the floor to indicate room outlines and components, to the use of cardboard walls and spaces outfitted with devices and finishings [4, 17]. Tours of existing ICUs may also be helpful in validating design ideas and identifying unanticipated problems.

Renovation Versus New Construction

Renovations of existing ICUs are usually limited in scope and may range from a cosmetic upgrade to a total overhaul. Renovations are often more complicated than new builds because of the restrictions of building in an older space (i.e., existing floor-to-ceiling heights, structural depths, and locations of elevators and staircases). Renovations also require the updating of existing space to current building codes. In new space, however, the design begins with a clean slate, and new construction is built to current code. If multiple ICUs are being built within a new facility, the hospital must carefully assess the ICU placements and core supporting spaces in order to maximize workflow and efficiencies. ICU design must also account for long-term functionality [14].

ICU Technologies

Medical devices today are actually informatics platforms [14]. For example, the purchase of infusion pumps or mechanical ventilators should include the costs of software licenses and updates. Additionally, connectivity and interactions with existing hospital systems should be considered. Optimally, the selection and deployment of new technologies should be preceded by testing in a simulation environment. A well-disciplined testing approach will reveal technologic gaps between current and new systems, thus guiding purchases and preventing avoidable errors.

ICU technologies should be standardized across the entire enterprise of critical care beds. Standardization permits efficiencies in education and assignment, device maintenance, and purchasing.

Advanced Informatics

Advanced ICU informatics systems transform patient-related data into actionable and well-displayed information using smart technologies [14]. The smart ICU coordinates the products of multiple vendors into one functional informatics platform that will meet clearly delineated ICU needs and be fully synchronized with hospital systems.

The first step to designing the “smart ICU” is the development of a connectivity envelope in each patient room which electronically integrates the patient with all aspects of care. The envelope infrastructure is composed of wired and wireless hardware that connects and communicates with data sources (i.e., medical devices, caregivers, medications), automatic identification tags on data sources for tracking purposes (real-time locating systems), and data transmission units attached to medical devices (to transmit their data to the network). The second step is the placement of middleware (the software that connects medical devices with the hospital’s operating systems and provides specialized applications) on the hospital network to achieve the goals of the smart ICU.

Core properties of ICU and hospital middleware include the association of the patient with the medical devices and data, interoperability (coordination of computer languages) between the medical devices and the medical record, and time synchronization across all data and data sources. Middleware facilitates personnel and device maintenance and communication, alarm management and transmission, and data displays both locally and remotely. Middleware also provides portals for remote device diagnostics and software upgrades.

Occupancy, Post-occupancy Evaluation, and Do-Overs

Preoccupancy preparations can diminish moving day angst and can include move simulation. Non-ICU staff and the family members of current ICU patients should be made aware of the moving date in order to minimize their anxiety as well. A post-occupancy evaluation (POE) process has been developed to identify major issues and plan for short- and long-term fixes as unanticipated problems are recognized. When implemented in healthcare design, research findings demonstrate that POEs can positively impact patient and visitor experiences and satisfaction, create supportive work environments for staff and caregivers, and help achieve organizational objectives [18].

Configuring the ICU Space

The ICU consists of distinct zones, each designed to incorporate a primary function and end user, in addition to supporting interrelated functions between areas. Zones include patient care and clinical and family areas, in addition to overall unit support. Clinical zones support direct patient care, such as nursing stations and the patient room, while support areas include spaces such as administration, materials management, and staff support functions [10].

Overall ICU Layout

The layout of an ICU is arguably the most important design feature affecting all aspects of intensive care services including patient privacy, comfort and safety, staff working conditions, throughput, logistical support and family integration [19, 20]. Layout determines the location and configuration of different spaces and/or functions within an ICU, the relationship of internal and external spaces, and how their functions relate. ICU designers have applied various types and combinations of layouts (Fig. 49.1) to solve throughput challenges of patients, staff and visitors, circulation between clean and used supplies, equipment, and the end users [3]. The choices are usually dictated by the physical layout of the facility and the location of fixed hospital components such as windows, staircases, elevators, and plumbing. Layout decisions may also be guided by considerations that address safety versus efficiency, supportive versus functional environments, revenue-generating ICU patient rooms versus central supply and logistical spaces [3]. The racetrack type of layout (“racetrack” implies patient beds around the perimeter with services in the center and a loop corridor space in between) appears to be the most dominant unit type among award-winning adult ICUs [3].

Patient care, especially in specialty surgical ICUs, may require a large amount of space to allow for acute resuscitation efforts especially following trauma. Thus procedure rooms, resuscitation bays, and access to helipads may be required. The design of the specialty surgical ICU may also necessitate ready access to large transport elevators capable of accommodating the patient bed, staff and other supportive devices. Advanced care of the perioperative surgical patient may require that the elevators be equipped with utility panels that provide power, oxygen, and suction. Additionally, some emergency centers are incorporating intensive care unit type rooms into their departments.

The Patient Room

The core of the ICU experience is the patient room [9–13, 17]. Current guidelines recommend the use of single patient rooms rather than multiple occupancy rooms to enhance privacy and infection control [10, 15]. Each room should additionally provide a healing environment and have access to outdoor views through windows. Each room should be similarly

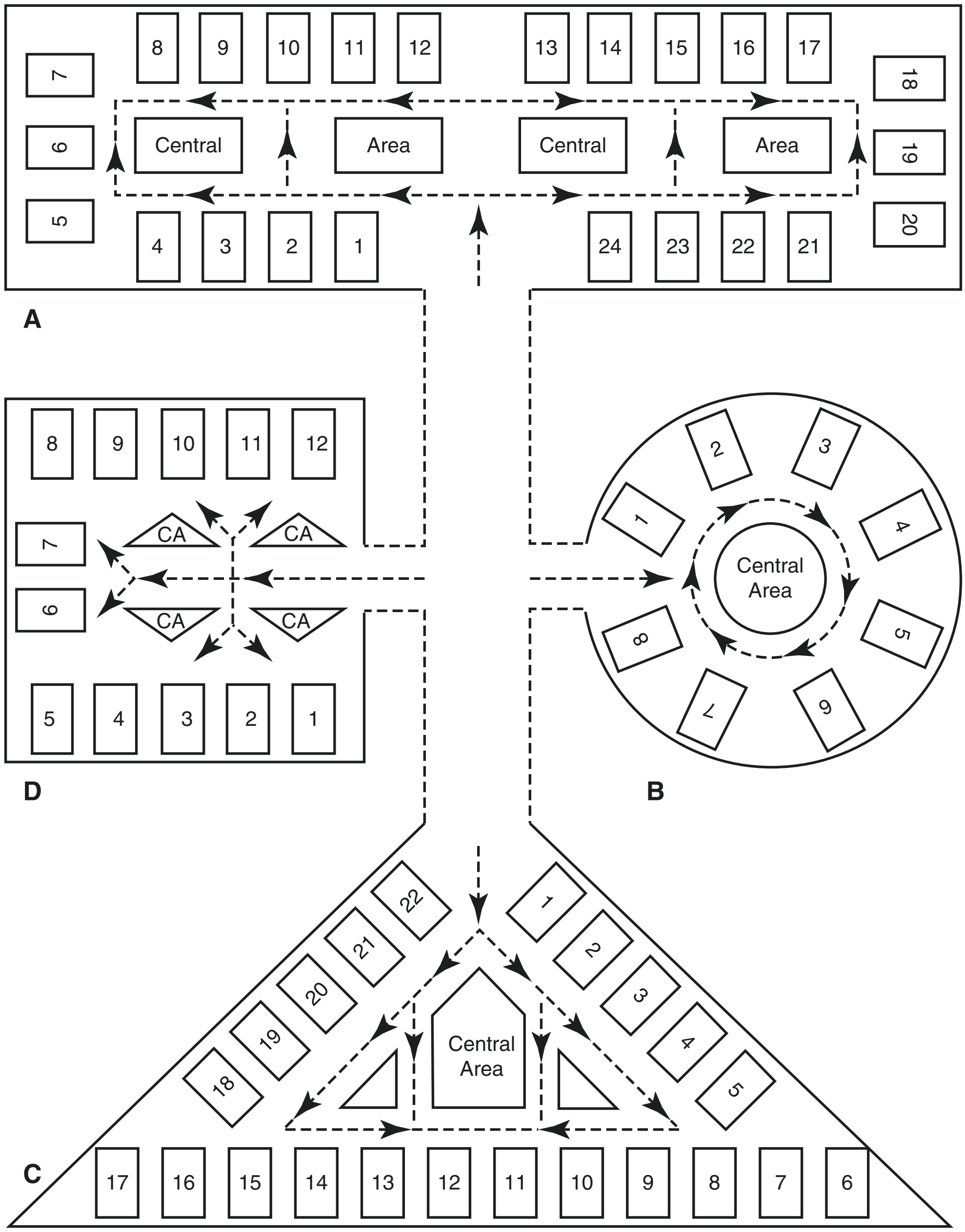

Fig. 49.1 ICUs can be planned in many configurations: rectangular (**A**), circular (**B**), triangular (**C**), and square (**D**). The "racetrack" with patient beds around the perimeter and nursing stations and supportive services in the center area (CA) is most common in current ICUs. Corridors that cut through the central areas facilitate staff movement. Modified with permission from CHEST [13].

designed and equipped to function as an autonomous area. Concomitantly, the rooms should be fully interwoven into the ICU and hospital fabric.

Patient Room Infrastructure

Much of the patient room's infrastructure involves components not usually familiar to clinicians. These include HVAC systems, electrical, plumbing, lighting, flooring, connectivity and communications, bathrooms and sinks, etc. The primary decision that guides the room's utilization involves the selection of the medical utility distribution systems. The choices are divided between fixed headwalls or floor-mounted columns versus mobile-articulating columns (booms) mounted to the ceilings or walls (Fig. 49.2, panel 1). The medical utility distribution system brings the hospital's supportive infrastructure (medical gases, vacuum, plumbing, electrical and data jacks) to the patient. Additionally, the medical utility distribution system provides the venue for installing medical devices (physiologic monitors, mechanical ventilators, infusion pumps), and communications and entertainment systems. The stationary utility systems are less expensive than the mobile ones; however, the mobile booms offer greater flexibility, patient access, and bed movement [21]. Regardless of the system selected, careful thought and even full-scale mock-ups should be considered for positioning the outlets and medical devices.

Bedside Medical Technologies

Core ICU room medical devices optimally include the ICU bed, physiologic monitor, mechanical ventilator, infusion and feeding pumps, pneumatic compression devices, patient lift, computers, chairs for patient and visitors, overbed tables, laboratory-specimen label printer, nurse-call intercom station, webcam, entertainment system, storage areas, and waste disposal bins. The design team should also address point-of-care testing (POCT) and ultrasonography and whether these devices should be placed in each room or stored centrally.

Patient Room Zones

Conceptually, each ICU room can be subdivided physically or virtually into three overall zones: patient, caregiver (work), and family (visitor) (Fig. 49.3) [10, 13]. While the room's

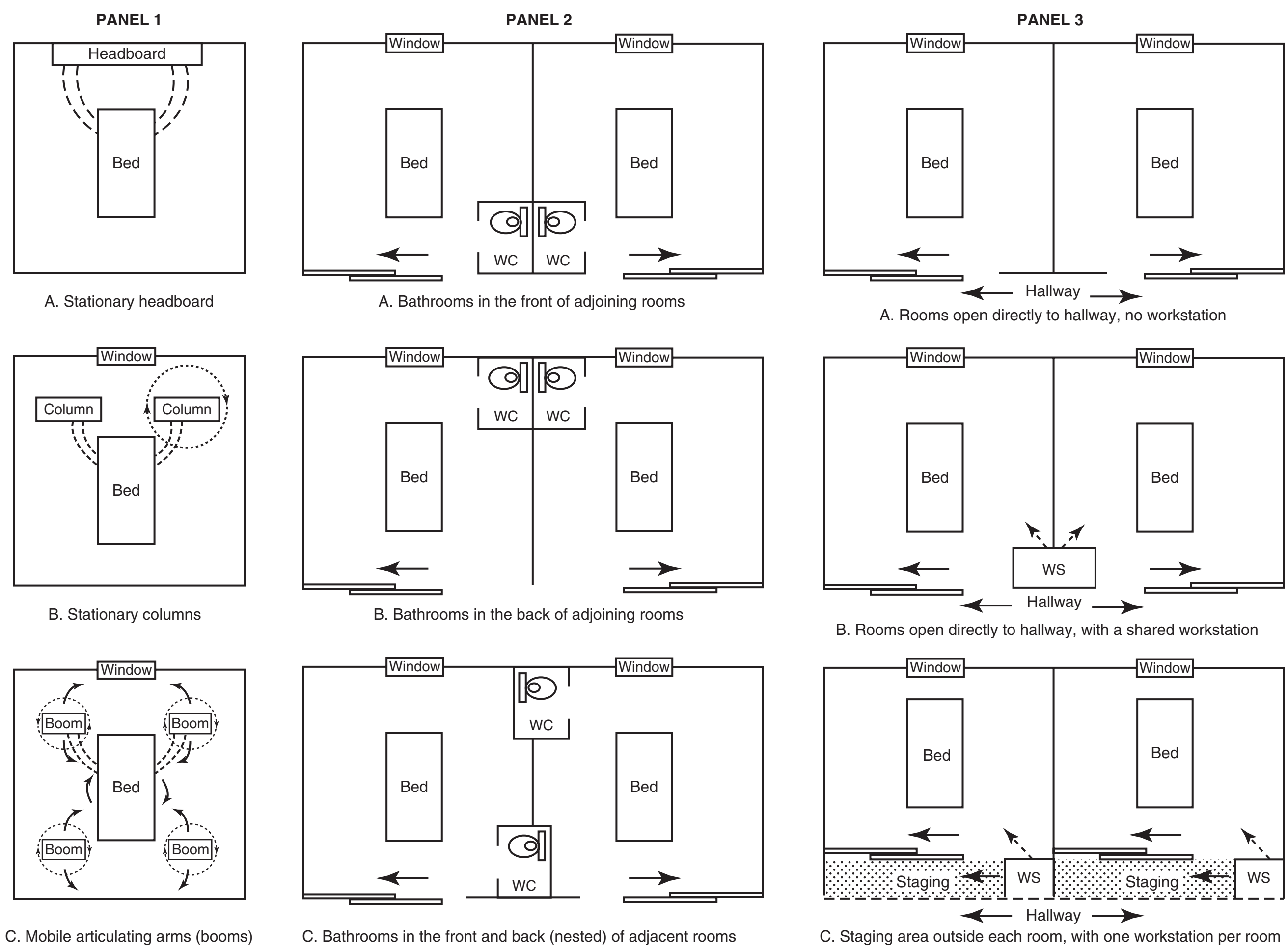

Fig. 49.2 ICU utilities and equipment (panel 1) are mounted on a stationary headboard (**A**), stationary (*left side*) or rotating (*right side*) columns (**B**), or mobile-articulating columns (booms) (**C**). The booms can be attached to the walls or ceiling, at any corner of the bed and swivel and move horizontally or vertically. In panel 2, the ICU patient room bathroom (WC) can be located in front of the room ("inboard") (**A**), back of room ("outboard") (**B**), and in the front of one room and the back of the adjacent room ("nested") (**C**) [22]. Although these decisions may be based upon the availability of plumbing, the impact on patient visualization from the hallway, window availability, and workflow should be considered by the design team. Panel 3 shows that patient rooms may open directly into the hallway without any workstations (WS) (**A**) or with a shared workstation for the two rooms (**B**). Alternatively, the rooms can be set back to provide a staging area in front of each room with one workstation per room (**C**). Modified with permission from CHEST [13]

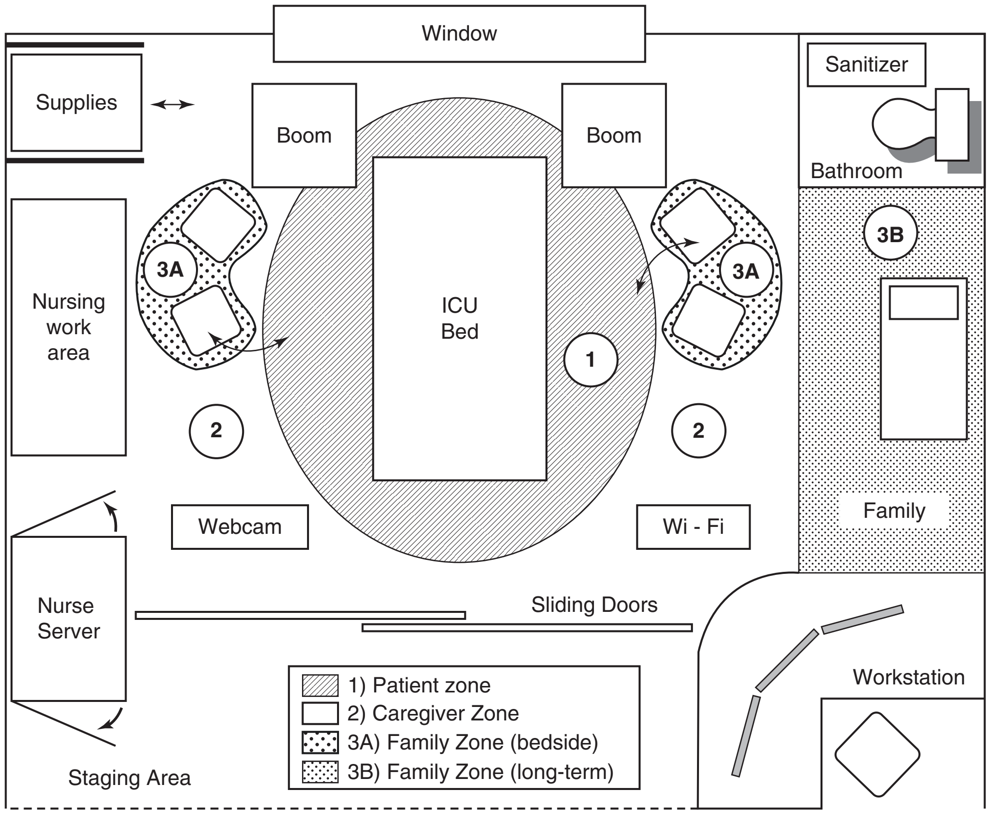

Fig. 49.3 The ICU patient room is divided into three zones: patient (1), caregiver (2), and family (bedside, 3A, or long term, 3B) zones. This figure also demonstrates a nurse server with bidirectional access, work area, supply space, booms, bathroom (outboard), webcam, Wi-Fi transmitter, and a workstation and staging area in front of the patient's room. Modified with permission from CHEST [13]

focal point is the patient bed, the patient rooms can be designed exactly the same (same-handed) or as mirror images of each other [22]. Installing all medical equipment on the medical utility distribution system clears the floor and facilitates ready access to the patient by family and staff. Elements of the caregiver zone include work areas for medication preparation, surface space, computers and displays, and storage areas. The family zone should incorporate comfortable chairs, electrical outlets, access to the hospital wireless communications systems and, if possible, long-term visiting necessities (chair-sofa-bed, table, light, sink, locker, and refrigerator).

Patient Room Logistics and Waste Management Systems

Adequate storage spaces for supplies, medications, linens, and waste management systems should be incorporated into each patient room. Storage is achieved through a mix of permanently based secured and nonsecured drawers, cabinets, and/or mobile carts. Permanent "nurse servers" (cabinets with bidirectional and secure access from both outside and inside the room) should also be considered (Fig. 49.3). The ability to access the nurse servers from outside the room improves privacy and infection control.

ICU patient rooms must now have direct access to separate enclosed bathrooms [15]. The design must determine the optimal bathroom location (i.e., front of room, back of room, or front and back of adjacent rooms) (Fig. 49.2, panel 2). Commonly these decisions may be based upon the availability of plumbing; nevertheless, the impact on patient visualization, window availability, or workflow is quite important.

Patient bathrooms should have either sanitizers to clean reusable bedpans or macerators to destroy single-use bed pans. Even with bathrooms, portable commodes are still necessary. Rolling carts or stationary containers should be available in each patient room for waste (standard, infectious, sharps) and soiled linens.

Room Environment

The physical environment affects the physiology, psychology, and social behaviors of all those who experience it [23]. Thus, the patient room environment must promote healing and serenity and address sound, light, temperature, visuals, and entertainment.

Studies suggest that sound control positively influences patient outcomes decreasing physiological stress and lowering the incidence of rehospitalization [24]. Acoustic control within the ICU is generally done through the integration of sound minimizers (sound-absorbent finishings and ceiling tiles, acoustic baffling in the walls, soundproofed windows, and sound attenuators in the HVAC system), patient level sound mitigaters (sound-canceling headphones or sound masking), and systems that control alarms and communications broadcasts. Pilot projects are now underway to transform stark device alarms to more calming sounds.

Natural light is essential to the well-being of patients and staff. Thus, ICU patient rooms are now all required to have windows [10, 15]. Windows should have antiglare glass and sunlight reducing shades, preferably with electronic controllers. The room itself should have multiple lighting arrangements to accommodate patient and staff needs.

ICU artwork can be mounted on the ICU walls, embedded in privacy curtains and ceiling tiles, electronically projected on video displays, or integrated into televisions or television/computers. Entertainment may also be provided through visor-based video displays. A "low-tech" white board should also be available in each room for the display of positive messages, get-well cards, and family pictures.

Electronic and computer-based integration of the environmental (light, shades, temperature, artwork) and entertainment systems facilitates efficient patient and staff-centered control of the room. Environmental profiles can then be tailored to day and night, procedural lighting requirements, and individual patient needs. Multiparameter sensors that monitor temperature, humidity, light, and sound and provide alerts for uncomfortable environmental circumstances also help track and maintain the healing environment.

Front of ICU Room

The front of the ICU patient room is the interface of the room with the ICU hallway. This space controls room entry, patient privacy, sound transmission, control of infection, and impedance of smoke and allows for patient observation and monitoring. The front-of-room options include curtains or framed glass doors with integrated privacy solutions (manually or electronically controlled integral blinds, electronic glass (LCD or e-glass), or curtains behind the glass doors. Curtains are more economical to install than glass systems; however, the efficacy of curtains in controlling sound, infection, or smoke is limited. The glass systems are easy to clean. Options for the electronic glass include glass color and dimmers for opacity adjustment.

Patient rooms may open directly onto the hallway, be set back, or have a hybrid design (Fig. 49.2, panel 3). Opening directly to the hall provides the largest possible room; however, setting the room back provides a staging area that incorporates handwashing systems, storage space, coat hangers, and identification systems. A hybrid design may provide the best of both worlds.

Patient observation and monitoring is facilitated by the incorporation of a clinical workstation (decentralized) in the front of the room. These spaces are generally designed as one per room or one per two rooms, and provide direct patient visibility and local patient monitoring (Fig. 49.2, panel 3). Such workstations should have access to bedside physiologic data (mirrored on displays or web-based) and the electronic medical record.

Central Areas

The central areas of the ICU bind all the patient rooms and other supportive areas together and foster overall unit cohesiveness. The goals of the central areas are to support bedside care, provide access to central (nursing) stations and logistical support areas, and offer a welcoming and warm atmosphere. Core (central area) design is commonly governed by the hospital's and ICU's approaches to centralized or decentralized care and logistics, and space availability.

Administrative, clinical and social interactions commonly occur at the central stations. In a small ICU, one centrally located station may suffice; in contrast, multiple central stations may be needed in a large ICU with several bed pods. The layout of these areas is primarily affected by the bed configurations (Figs. 49.1 and 49.2, panel 3). Optimally, unobstructed views of the ICU beds should be available from the central stations. Differences in patient room visibility may have important effects on clinical outcomes, and severely ill patients may experience higher mortality rates when assigned to ICU rooms that are poorly visualized by the staff [25, 26].

Many ICUs are incorporating decentralized care stations outside patient rooms in addition to central work areas. This configuration allows staff to be distributed around the unit and closer to the patient rather being in a single, central location (Fig. 49.2, Panel 3). Decentralization is driven by the notion that it provides greater visibility of the caregiver to the patient [27]. Regardless of the layout, bedside webcams, centrally based physiologic monitoring stations, or other data displays are strongly suggested. The composition of the central stations includes greeting desks, quiet work and conferencing areas, offices, and restrooms. Other technologies include nurse-call communication stations, telephones, grease boards, computers, high-definition image review stations, laboratory-specimen label printers, pneumatic tube stations, nourishment stations, emergency alerts, and cutoff switches for ICU utilities.

Corridors

ICU corridors provide pathways for transit around the ICU and promote physical and social unity (Fig. 49.1). However, physical barriers (staircases, elevators, supportive conduits, and closets) can limit optimal corridor design. If possible, separate and designated hallways for patients and supplies enhance patient privacy and minimize interactions with logistical support respectively.

The corridor finishings, artwork, sound control, and lighting set the emotional tone for the ICU. These considerations are very important as hallways are used to conduct rounds, impromptu clinical consultations, and family meetings and provide a track for patient mobilization. Some ICUs have also included large alcoves for devices and carts and respite areas for ICU visitors within the hallways.

ICU Storage Spaces, Supplies, and Medical Devices

Right-sizing the storage areas (central and bedside) requires a good understanding of the logistical approaches (centralized and/or decentralized) that the hospital and ICU will employ. Additionally, right-sizing requires correct assumptions of ICU supply utilization of consumables. Central storage spaces must also be able to handle supplementary medical devices (i.e., infusion pumps, ventilators, specialty monitoring or imaging devices).

Properly positioning the storage spaces in the ICU may prove challenging. Storage spaces should be accessible to transport or cargo elevators and be fairly close to the patient care areas. When space allocation and storage location are not handled well, ICU hallways are always cluttered.

Storage spaces may include traditional supply rooms (with stationary or track-based shelving, closed supply cabinets, or rolling exchange carts) as well as alcoves along the ICU hallways. Storage units and expensive supplies should be outfitted with electronic inventory management systems as part of real-time locating systems/solutions (RTLS).

The ICU design may also consider designation of ICU space for permanent imaging and procedural suites versus using the space for additional beds. This discussion is evolving as imaging technologies (i.e., mobile CT scanners) have currently become more economical and mobile than in prior years.

Pharmacy

Hospitals may have centralized or decentralized pharmacy and medication distribution systems and staffing models. The ICU pharmacy systems must be coordinated with the hospital's pharmacy and ICU bedsides. Options include a fully equipped satellite ICU pharmacy versus a pharmacy area with minimal resources. Both alternatives commonly utilize decentralized self-contained and secure automated medication-disposing units. Medications may also be stored in secured cabinets at the ICU bedside.

ICU Laboratory Testing and POCT

Both point-of-care testing (POCT) and centralized laboratory testing are usually required for the ICU. POCT focuses primarily on whole blood analyses using either large devices placed in defined ICU locations (ICU stat laboratories or central stations) or on carts, or smaller devices amenable for positioning at each ICU bedside. A combination of POCT modalities and locations may be used depending on the ICU workflow, necessary testing, and available space and resources. Pneumatic tube stations are still required to transport specimens to laboratories outside the ICU area as POCT is never a complete replacement for the central laboratory.

Staff Lounge and On-Call Suites

ICU clinicians regularly face extreme stress; thus, the ICU design must address the impact of space on staff efficiency, job satisfaction, and multidisciplinary teamwork. Well-designed staff lounges (break rooms) and on-call suites located within the ICU provide a place adjacent to patient care, for staff to relax and recharge. The lounges should be tastefully decorated with outside lighting, comfortable seating, televisions, as well as access to computers and ICU communications. Bathrooms, changing areas, lockers and scrub dispensers, napping alcoves, and nourishment stations complete the lounge furnishings. In ICUs that maintain 24/7 clinician availability, sleeping accommodations (on-call suites) with bathrooms and showers should also be provided.

Family Lounge (Visitor Waiting Room)

ICU visitors need a healing environment close to the ICU to recharge between visits with their loved ones. Soft lighting, warm colors, large windows, nature-themed artwork (either real or virtual), and quiet background entertainment set a serene tone. Privacy should be provided using small groups of comfortable chairs that are separated by dividers. Informatics support may include wireless Internet access, computers, and smartphone-charging stations. Nourishment areas as well as bathrooms, lockers, and coat hangers should be the norm. The inclusion of consultation rooms and social work offices helps promote family meetings and social support. Long-term sleeping accommodations, if possible, provide a space for visitors who prefer to remain nearby.

Conference Rooms

Staff meetings, educational programs, and family meetings are sustained through the construction of multipurpose conference rooms within the ICU space. The seating capacities of these rooms should be based upon predicted usage. Furnishings should include comfortable seating, conference tables with built-in informatics access, audio-visual-video systems, wireless access, smart boards, electronic attendance and scheduling systems, and food preparation and storage areas.

Infection Control and Prevention

Strategies for infection prevention rely upon infrastructure systems that provide clean air (air-cleansing systems, room-based air exchanges, and airborne infection isolation), clean water (plumbing for sinks inside and outside each patient room), waste sequestration and elimination in patient rooms, housekeeping, and environmental closets. Nonporous, well-sealed, and easy-to-clean surfaces and finishings, hand sanitizers, and fluid dispensers should be used throughout the ICU. Advanced modalities include electronic surveillance of handwashing stations, copper or silver "self-cleaning surfaces" in conjunction with surface surveillance monitors, and the use of environmental decontamination systems (i.e., ultraviolet light, hydrogen peroxide dispersion, and continuous air disinfection) [13].

Even in the setting of optimal infection control design measures, serious infections remain an ICU problem. Effective infection prevention also requires an ICU culture and workflow that promotes infection deterrence. Appropriate hand-hygiene products should be visible and accessible. Ultimately, the ICU may even include super-isolation zones that group highly infectious patients together with designated ICU traffic patterns.

Staff Communications

Telephones, smartphones, nurse-call intercom systems, pagers, and bidirectional transmitters are integral to ICU communications. These devices may all be integrated into one platform (i.e., within a nurse-call system, a primary communication platform, or an alarm system). Functionalities include point-to-point and global messaging, telephone and alarm communications, and real-time locating of staff. Even in these advanced settings, landline telephones and overhead speakers continue to be of value in providing reliable ICU communications.

Signage and Wayfinding

In addition to a well-designed ICU layout, good signage is necessary for efficient wayfinding. Directional signs should be clear in their message and easily visible, while destination signs should identify each room. Entranceway signs provide information about the ICU and can include the ICU designation (i.e., surgical ICU), management names (i.e., ICU director and nurse leader), and visiting hours.

Security, Fire, and Safety

The ICU design must address security and fire safety. Electronic identification card coded access should be used for staff at all secure doorways. The ICU "front door" optimally should be staffed by dedicated clerks. However, staffing limitations commonly preclude full-time greeters; therefore, other systems for visitor identification (i.e., closed-circuit televisions with electronic buzzers) should be installed at ICU entrances.

Beyond the basic fire safety devices (smoke detectors, automated sprinklers, fire extinguishers) and fire and smoke alerting systems (fire alarm pull stations, sound or light alerts, and overhead speakers), four design elements help ensure the safety of the ICU in the settings of fire and smoke. The first involves selection of products and furnishings with a low fire load and minimal release of heat and toxic smoke. The second addresses the construct of compartments that are fire- and smoke-rated. The third is the use of protective technologies within the HVAC systems to prevent the spread of smoke and other products of combustion from one area to another. The last is the integration of experienced fire safety officers into the ICU design process [13].

Future Trends in ICU Design

The impact of the built environment on the healing process, infection control practices, and patient safety is being increasingly studied in the context of ICU design and architectural layout. Through the integration of this growing body of evidence into the design process and by engaging expert consultants to collaborate with the end users, ICU design has the potential to impact future organizational performance, clinical outcomes, and cost of care delivery.

Larger Units

In our opinion, future ICU design trends will likely include even larger units with more ICU beds per unit. As hospitals may look for efficiencies in managing these large units, ICUs may be standardized in design, technologies, and general functions and be located near each other. Core areas that are adjacent to or within the units may include multiuse diagnostic and treatment technologies, administrative, educational and/or research spaces, and family areas. Larger units may also become multispecialty units utilizing a variety of unit geometries (so the unit can adapt to surrounding conditions) with larger units subdivided into smaller groupings of beds supported by a balance of centralized and decentralized workstations. Concomitantly, segregation of public/visitor and patient/support circulation types will be expected.

Patient Rooms

Single-patient rooms will also likely be larger and better able to accommodate family and bathroom space. Ceiling-mounted life support systems will replace fixed models, and devices throughout the room will become wirelessly integrated, allowing for improved documentation and communication.

Environment

Both the overall unit and the patient room will become more patient and visitor friendly. Thus, amenities that enhance the patient and visitor experiences will be expected to be included throughout the ICU. The importance of nature visibility and access for patients, families, and staff will become fully recognized and incorporated into all units.

Changing Practices

The ICU is an ever-changing and rapidly advancing environment. The next generation of ICUs must be planned for the long term and incorporate design decisions that allow for flexibility in order to accommodate changing care practices and information technology (power and data).

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