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A Decade of Adult Intensive Care Unit Design:

A Study of the Physical Design Features of the Best-Practice Examples

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ABSTRACT

This paper reports a study of the physical design characteristics of a set of adult intensive care units (ICUs), built between 1993 and 2003. These ICUs were recognized as the best-practice examples by the Society of Critical Care Medicine (SCCM), the American Association of Critical Care Nurses (AACN) and the American Institute of Architects (AIA). This study is based on a systematic analysis of the materials found on these ICUs in the booklet and videos jointly published by the above organizations in 2005. The study finds that most of these examples of best-practice adult ICUs have the following negative characteristics: 1) they are built as renovation projects with more health and safety hazards during construction; 2) most of them are mixed-service units with more safety and staffing problems; 3) the overall layout and the layout of staff work areas in these ICUs do not have any common design solutions for improved patient and staff outcomes; and 4) in these ICUs, family space is often located outside the unit and family access to the patient room is restricted, even though family presence at the bedside may be important for improved patient outcomes. Some of these negative characteristics are offset by the following positive characteristics in most ICUs: 1) they have only private patient rooms for improved patient care, safety, privacy and comfort; 2) most patient beds are freestanding for easy access to patients from all sides; 3) they have handwashing sinks and waste disposal facilities in the patient room for improved safety; and 4) most patient rooms have natural light to help patients with circadian rhythms. The paper discusses, in detail, the implications of its findings, and the role of the ICU design community in a very complicated design context.

Key words related to intensive or critical care unit: design, planning, environment, design guidelines, best practices, best designs, layout, patient room, staff work area, family area

1. INTRODUCTION

The intensive care unit (ICU) or the critical care unit (CCU) in a hospital provides the care for patients with life-threatening illness or injury. Patient care in an ICU is generally provided by multidisciplinary teams of physicians, nurses, respiratory care technicians, pharmacists and other allied health professionals who use highly sophisticated equipment and the services of expert support personnel.

The importance of ICUs in today's healthcare system is enormous. In 1994, *Critical Care Medicine* reported that nearly 80% of all Americans will experience a critical illness or injury, either as the patient, family member or friend of a patient, and that ICUs occupy only 10% of inpatient beds, but they account for nearly 30% of acute care hospital costs (1, 2). It is very likely that the cost of ICU services has increased significantly since 1994.

With an aging U.S. population and more critical illnesses, the demand for critical care services is rising each year. At the same time, significant changes are occurring in ICU services due to changes in medical informatics, technology, and equipment. The 2001 and 2004 reports of the Institute of Medicine (IOM) and the 2002 report of the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) have added a few more reasons for these changes to occur (3-5). In the IOM reports, U.S. hospitals are recognized as dangerous and stressful places for patients, families and staff members. According to these reports, medical errors and hospital-acquired infections are among the leading causes of death in the United States, each killing more Americans than AIDS, breast cancer, or automobile accidents. According to the JCAHO report, hospitals perform poorly as workplaces. Consequently, registered nurses have an alarming turnover rate, averaging at 20 percent.

With so much at a stake, hospital administrators are looking for new methods to improve ICU services. In this regard, the physical design of ICUs may have some value. A very large body of research literature shows that the physical design of healthcare facilities can help improve patient safety, privacy, comfort, staff working conditions, and family integration with patient care (6). It is probably safe to assume that most ICUs are still being designed without taking into account the available research evidence. This study examines whether this assumption is true for the best-practice example ICUs.

This study will identify important physical design features of some of the best-practice example ICUs in the United States. General patterns and the advantages and disadvantages of these design features will be explained. This study will provide a better understanding of the forces that helped shape these designs. It will also open us a discussion of the role the of the ICU design community in improving ICU designs.

2. MATERIALS & METHODS

The study included nineteen adult ICUs built between 1993 and 2003. Each had received an ICU design award from the Society of Critical Care Medicine (SCCM), the American Association of Critical Care Nurses (AACN) and the American Institute of Architects (AIA), and was included in the ICU Design Award booklet and videos published by these organizations. The booklet and videos, last published in 2005, contained 5-7 minutes of video footage with narrative, a brief written description, and one or more drawings of the layout of each ICU. Some award-winning adult ICUs built during this period were excluded from the study, because the booklet and videos contained inadequate information on these ICUs.

The study focused on issues related to overall design, patient room design, staff work area design, and family area design in these adult ICUs. This focus required that several important ICU features such as medical informatics, technology and equipment were excluded from the study, even though they have significant impacts on physical design. Other design features such as environmental systems (heating, ventilation, and air conditioning), alarm systems, lighting, furniture and finishes were also excluded from the study. Design features such as ancillary service areas were not discussed independently but were mentioned in relation to other features, as these features were not as important as the ones discussed in this study.

3. OVERALL DESIGN ISSUES

Issues related to the overall ICU design affect all people and functions in ICUs. Some of these issues are construction processes, functional types, layout types, size, and circulation spaces of ICUs. Below, we discuss these issues in relation to the best-practice adult ICUs included in the study sample.

3.1. ICU construction processes

This study finds more renovated ICUs than newly built ICUs in the study sample. Out of 19 cases, 9 are renovated, 8 are new, and 2 are partly renovated or partly new (**Figure 1**). This is probably because most of the studied hospitals are located in urban areas. Therefore, it often makes more sense in terms of economy and convenience to renovate or upgrade an existing ICU than to build a new one. This often creates challenges for ICU design teams in terms of their expertise in infection control and their ability to work around design limitations posed by existing structures.

Every ICU design team should know that numerous infection control issues may impact the health and safety of patients and staff while ICUs are being constructed or renovated. Studies show an increased risk of nosocomial infection and death during the construction and/or renovation of healthcare facilities (7-10). Under the current *Guidelines for Design and Construction of Hospital and Healthcare Facilities* (used by the American Society for Healthcare Engineering (ASHE) and published by the American Institute of Architects (AIA)), an Infection Control Risk Assessment (ICRA) must be part of every health care construction project including ICUs.

Every ICU design team should also know that an ICRA for a renovation project is often more complicated when carcinogens are involved, which is the case in many old hospitals. Mercury and lead are also problems in many old hospitals. Control measures need to be taken to reduce exposures of hospitalized patients to airborne particulates and spores, and to reduce the increased risk of aspergillosis and other fungal infections associated with hospital construction projects. All required infection-control partitions must remain in place during the construction. Negative pressure within the construction area needs to be maintained. In order to resolve these and other infection control related issues, every ICU design team should require the participation of an infection control expert.

In addition to infection control problems, every ICU design team should also know that any old hospital facility can pose several design limitations for an ICU in terms of function, structure, dimension, environmental systems and utilities. For example, one of the ICUs included in the study was built in an existing space with 8' floor to ceiling height, 11'-6" floor to floor height, 20" structural depth, and less than 20" clear ceiling plenum. These are difficult limitations to work with, but the best-practice examples often show innovative ways to solve these design problems. If necessary, an ICU design team must be prepared to do additional research on those ICUs where similar design problems exist.

An ICU design team is responsible for finding ways to reduce several threats and inconveniences that construction processes may create for patients, staff and visitors in an existing facility. The design team is also responsible for ensuring the overall efficiency and effectiveness of an ICU using physical design even under extremely limiting physical conditions.

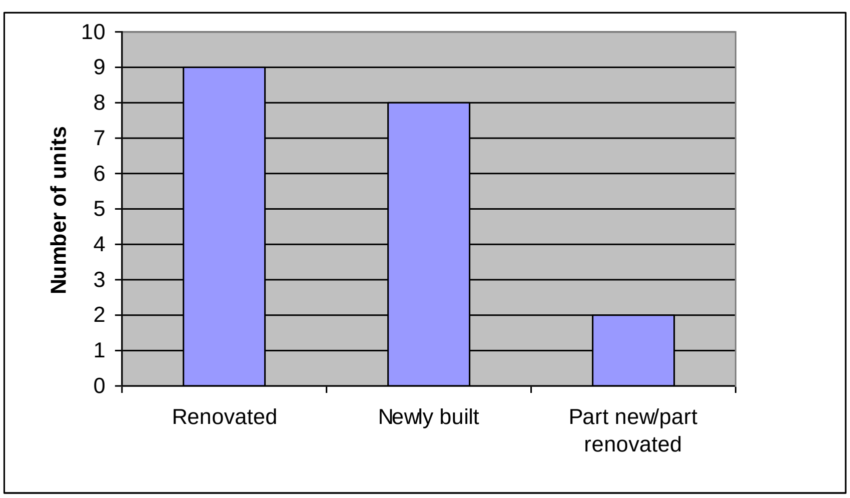


Figure 1: Categorization of best-practice example ICUs based on construction processes.

3.2. Functional types

A typology of adult ICUs, if based on services, may include the following: Medical Intensive Care Unit (MICU), Surgical Intensive Care Unit (SICU), Neuro Intensive Care Unit (Neuro-ICU), Coronary Care Unit (CCU), Respiratory ICU, Burn ICU, and Mixed-Service ICU. According to this survey, 12 out of 19 units provide mixed critical care services; three provide cardiac and thoracic cardiac services; three medical-surgical services; and one provides services to burn victims (**Figure 2**). In other words, only few ICUs of our sample provide specialized services. This is probably because the decision to build a specialized ICU is often driven by economy and patient volume.

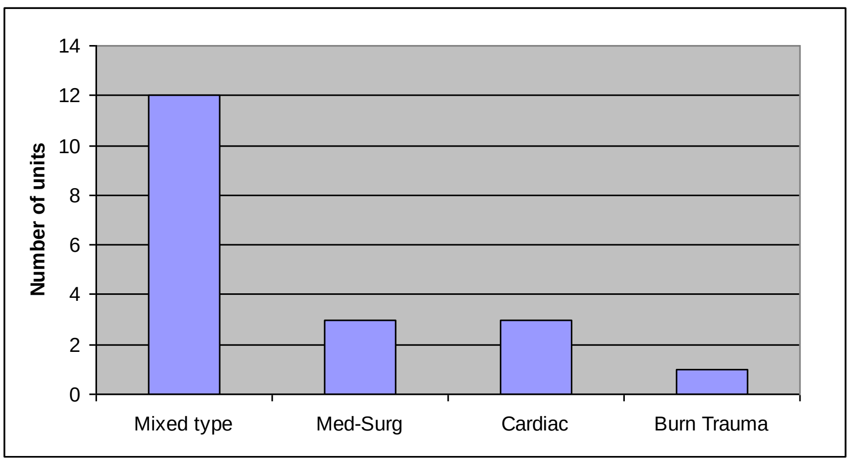


Figure 2: Categorization of best-practice example ICUs based on functional types.

In this context, it may be noted that ICUs providing mixed services generally have more problems to solve than the ones providing any one specialized service. For example, ICUs providing mixed services may require a larger body of clinical staff for the same number of patients. In such units, patient rooms may need more equipment, space and flexibility. Required clinical support services needed in a mixed unit may also be very different: a burn victim may need a hydrotherapy room, while a patient with brain trauma may need frequent CT or MRI. The length of stay for patients in a mixed unit varies significantly. Medical-surgical patients generally have shorter stays than patients with brain injury. There is a desperate need for empirical studies on the impacts of specialized and mixed-service adult ICUs on patients, staff, and visitors. In the absence of empirical evidence, the design team may need to consult more with experts and learn more about the best-practices of mixed-service adult ICUs for improving its own designs.

3.3. Unit layout types

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 condition and family integration. Layout determines the location and configuration of different spaces and/or functions within a unit. In doing so, it impacts how a function is performed, and how internal and external functions relate.

Over the years, designers have used different types of unit layout in order to solve various interface problems among patients, staff and visitors, as well as various kinds of circulation conflicts among clean supplies, dirty supplies and people. James and Tatton-Brown (11) have identified at least seven types of hospital unit layouts including - open or Nightingale type, corridor or continental type, duplex or Nuffield type, racetrack or double corridor type, courtyard type, cruciform or cluster type and radial type (**Figure 3**).

Using Brown's typology, the study finds out of 19 units, 12 are racetrack type. As shown in the figure, this type has service in the center and patient beds are on the perimeter with corridor in-between. Of these, some are simple, while the others are more complex. Only three units are modified open nightingale type (i.e., nurse station surrounded by patient room, and support services located next to the unit instead of inside the unit). Among the remaining three units, one is corridor or continental type, one is radial type, and two are mixed-type (i.e., they do not fall in any one particular type defined by James and Tatton-Brown) (**Figure 4**). Designers prefer the racetrack type layout because it maximizes the perimeter wall of a unit. As a result, more patient rooms can have natural light and outdoor views. Arguably, this type of layout also reduces nurse's walking distance, an issue that needs further investigation. Additionally, a racetrack type layout with beds around a central service core seems to be a very logical pattern to achieve a workable visual module, where nurses and patients are able to see each other.

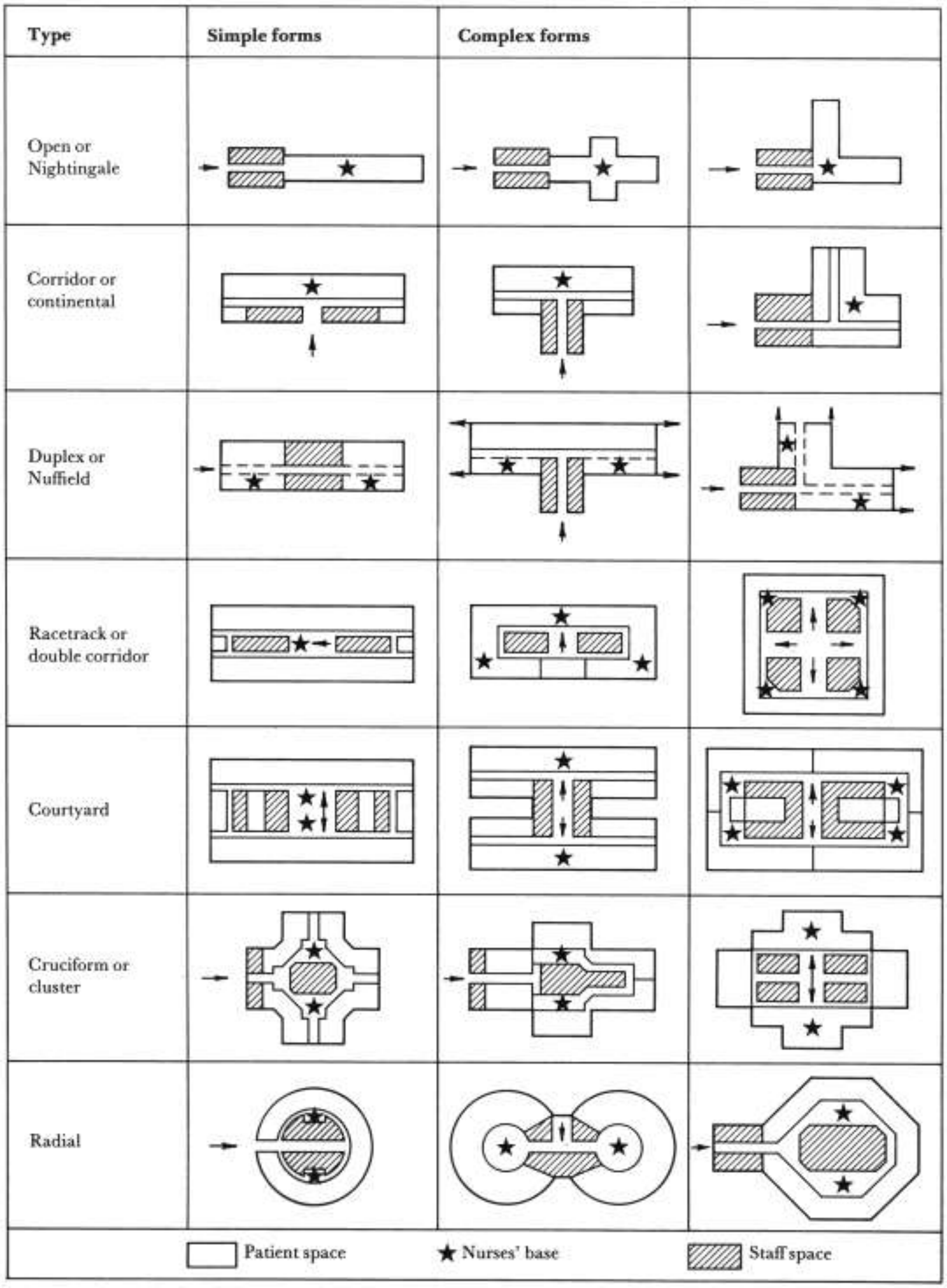


Figure 3: Layout types of hospital units (11).

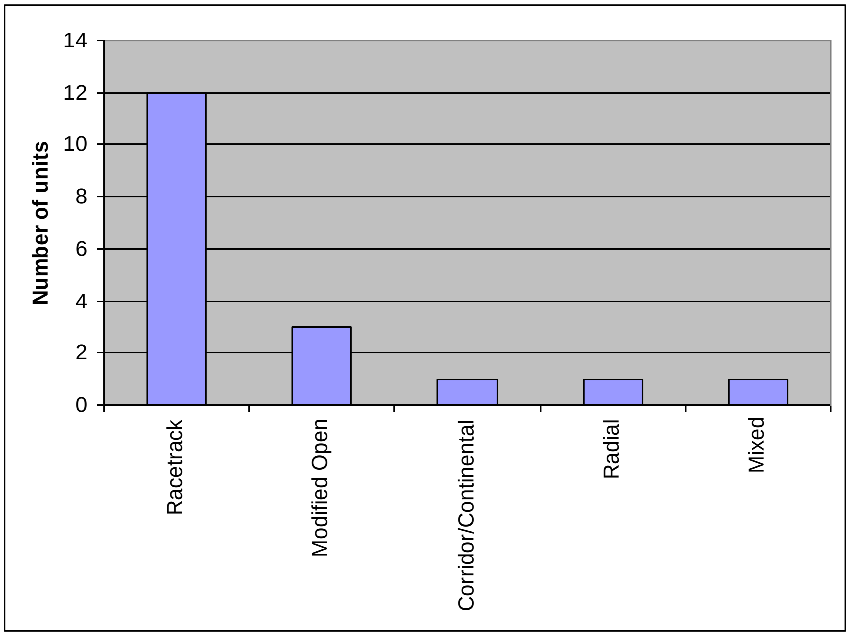


Figure 4: Categorization of best-practice example ICUs based on layout types

3.4. Unit size

Among other things, unit size, expressed as the number of patient beds, has shown to impact infection rates in ICUs. For example, in 1995, the European Prevalence of Infection Control in Intensive Care study reported that the ICUs with more beds have more infections (12). Unit size also impacts noise, crowding, privacy, traffic flow, staffing, and functional needs within a unit.

This study finds that the unit size of adult ICUs varies between 12 and 40 patient beds on a single floor with the average number of patient beds 22 (STDEV 6.74). The number of beds that occurs most frequently is 20. This number is much higher than that recommended by the *Guidelines for Intensive Care Unit Design* (henceforth, the *Guidelines*). The *Guidelines* stipulate, "Eight to twelve beds per unit are considered best from a functional perspective" (13-16). In a more recent survey, a group of ICU experts agrees with the *Guidelines* (17). According to this group of ICU experts, which included 10 physicians, 29 nurses, 37 architects, 7 interior designers and other multidisciplinary representatives, the ideal number of patient beds in an ICU should be 9 or 10, and no be less than 6.

The number of patient beds in an ICU does not seem to depend on the total number of patient beds in a hospital. That is because, the study finds no correlation between the two (**Figure 5**). In other words, a larger hospital may not always have a larger ICU. Rather, the size of an ICU may be a factor of economy and patient volume, among other things.

Of course, in most best-practice ICUs, designers use multiple pods in an attempt to improve patient-staff visibility and to take services closer to patients. The spatial, social and behavioral implications of a multiple-pod ICU layout are yet to be studied, but some observations follow. Firstly, pods may do very little to reduce congestion, crowding and noise at the critical locations in a unit. That is because most ICUs with multiple pods do not have separate entrances to these pods for reasons of privacy, control, and safety. As a result, like any other large units, the units with multiple pods are unable to distribute movement evenly. This causes the pods near the entrance to have more movement, crowding, and noise then those away from the entrance. This may also create a sense of disparity among patients and staff. Secondly, pods may break down the visual and social cohesiveness of a unit. As a result, clinical staff may begin to develop different social cliques, sometimes working against each other. Thirdly, an ICU with multiple pods may take more space, as each pod needs its own service/support areas to function efficiently and effectively. Finally, multiple pods may make movement of supplies more difficult in an ICU simply because they create more service stops.

In addition to having a large number of beds, the best-practice adult ICUs have widely different gross area per bed. According to this study, the gross area per bed varies between 1688 sq ft and 313 sq ft with the average gross area per bed 820 sq ft (STDEV 291.7). The findings point to a lack of consensus in the field regarding the amount of space needed for an adult ICU, even though space is a very expensive resource.

On a different note, the study finds a significant positive correlation between the number of patient beds and the total gross area of an ICU (**Figure 6**). The finding suggests that as the number of beds increases the total gross area of the unit also increases. Though the predictive power of the number of beds on the total gross area of an ICU is not so great (r^2=0.49), it can be safely argued that the need for space in an ICU may increase as the number of beds increases. This is a useful evidence for those ICU designers who are often given less than adequate space to design an ICU.

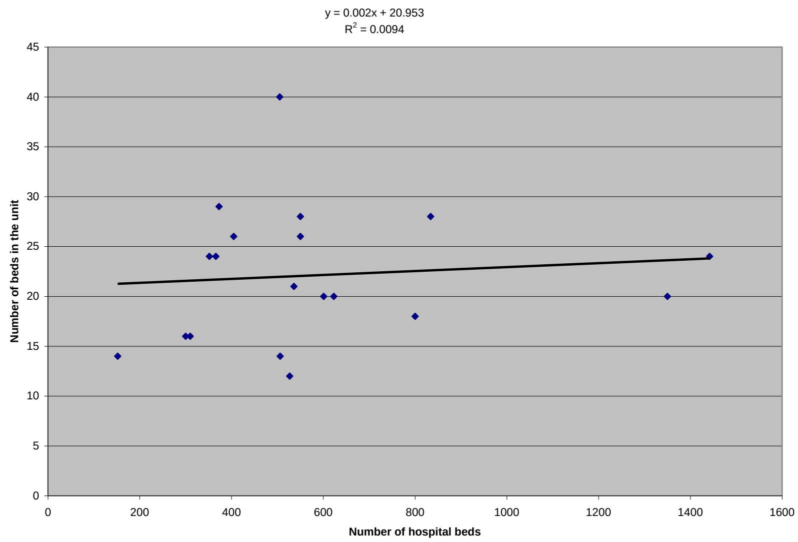


Figure 5: The scattergram shows no correlation between the number of patient beds in an ICU and the total number of hospital beds.

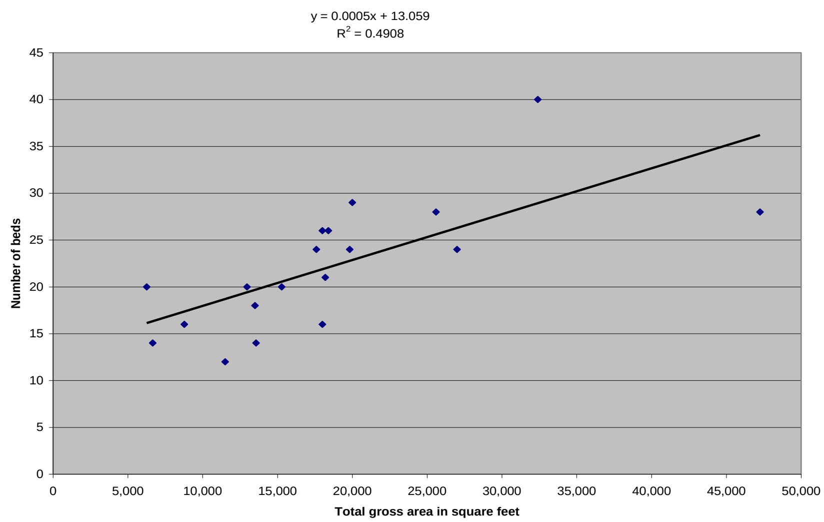


Figure 6: The scattergram shows a good positive correlation between the number of patient beds and the gross area of an ICU.

3.5. Circulation spaces

Circulation spaces within an ICU consist of internal hallways, corridors, and/or aisles used by all ICU users - patients, ICU staff, and visitors. They do not include private movement areas within any well-defined areas such as the nursing station and the patient room. They also do not include elevator cores, fire-stairs, and open lobby areas if identified as waiting spaces.

Circulation spaces are an important indicator of the square footage efficiency of an ICU layout. Like any other facility, an ICU may become inefficient if there is too much or too little of circulation spaces. Circulation spaces are also sociologically important, for they determine the interconnectedness of people and functions within a facility. A narrow corridor within an ICU can impede transfer of knowledge as much as it can impede the flow of goods and people. If this is true that the medical practice in ICUs depends largely on the tacit knowledge of care-givers, then properly designed circulation spaces may hold a great potential for enhancing the transfer of tacit knowledge through face-to-face social interactions.

Designers of the best-practice example ICUs do not sufficiently appreciate the importance of properly designed circulation spaces. Regarding spatial efficiency, the study finds that the amount of circulation spaces varies between 20% and 40% of the total area (i.e., the area within the external perimeter of the unit excluding any internal courtyards) for these ICUs. This is a rather wide range for circulation spaces in a facility where efficiency must be very important.

Very little empirical work has been done on the effects of circulation spaces on the social life of care-givers in ICUs. However, a visual survey of the layouts of these ICUs, as presented in our primary source documents, leaves little doubt that circulation spaces may not have consistent effects on the social life of caregivers across the study sample. Widely different geometric configurations of these ICUs may suggest that visual relations among care-givers, which an important precondition for social exchanges, may be very different in these layouts. Different configurations also suggest that these layouts may provide very different opportunities for work-related group interactions as well as social interactions - an issue that requires further investigation.

4. PATIENT ROOM DESIGN ISSUES

Patient room is the basic working module of an ICU. The design of the room directly impacts the care of a patient including her privacy, safety and comfort. The type and orientation of the bed, the amount of space available around the bed, the type of entrance door to the room, the type and location of handwashing sinks and toilets, the window and views out the window, the location of gas and air outlets and physiological monitoring devices, the artificial and natural lighting conditions, the furniture, fixture and finishes, the amount of work surface, cabinetry and storage space, and the visibility of a patient in the room from nursing stations - all can directly affect the care provided to the patient in the room.

Patient room design also impacts staff working conditions in an ICU. For example, nurses can save multiple trips to nursing stations or storage rooms if room module includes a space for charting or a storage space for supplies. A longer distance between the bed and the toilet can cause additional physical stress for a nurse who needs to help the patient to the toilet. Clinicians may not be able to provide much-needed services efficiently if the bed does not have a 360-degree access, or if the room does not have enough space for clinicians to work on the patient as a team when needed. A nurse may not be able to work on a patient's chart at the bedside if there is no work surface available. Additionally, room design may also impact the role of families in patient care. If there is a well-defined area within the room for families, families can be present not only for patient comfort but also to help clinicians in patient care. When ICU patients are unable to communicate, the patient's family can be an invaluable source of information for clinicians.

In order to respond to all three groups of users of a patient's room, Jastremski and Harvey suggest that an ideal room should have three zones: a patient zone, a family zone, and a caregiver zone (18). In this study, however, this framework is not used for evaluating patient rooms. Rather, some important design features that may simultaneously affect patient, staff and visitors in ICUs are discussed. These features include private rooms, isolation rooms, patient room size, utilities, patient room toilets, patient room entrance doors, windows and views out of them.

4.1. Private patient rooms

Private patient rooms provide several benefits. Most importantly, they provide dedicated space for individualized care without disturbing other patients. Studies have consistently shown that private rooms help reduce noise. They also help improve privacy, sleep quality, patient satisfaction, and staff-patient communication (18, 19). Additionally, studies show that patients may have lower nosocomial infection rates in ICUs with individual patient rooms, because of improved airflow, better ventilation, and more accessible handwashing facilities (20, 21). From an infection control viewpoint, the evidence may then suggest that there is no significant difference between open units and units with private rooms if both have properly designed and functioning environmental systems. This, however, may not be enough to make a case for open design ICUs. Though some degree of privacy can be obtained in open design ICUs through the use of curtains, the curtains are easily contaminated, must be removed frequently for laundering, provide little or no sound barrier, and are aesthetically unpleasant.

In private rooms, however, patient visibility is often at a stake. Patients need and deserve privacy, but are also afraid of being left alone. From a clinical viewpoint, it is even easier to make a case for open patient rooms in ICUs. These rooms allow easy visual monitoring of the patient by the clinical staff, thus increasing patient safety. Staffers often prefer a wide-open ICU to see everything that happens in the ICU, to readily seek help from others in a crisis, and to act on a patient immediately in groups without being bothered by the enclosing walls of a private patient room.

In general, the importance of private patient rooms with appropriate visibility and flexible space (i.e., an ability to open up the room when needed) has been recognized in the field. According to this study, most best-practice adult ICUs in the sample have only private patient rooms. On the average, this sample of case studies has 21 private rooms for every 22-bed unit. To be more precise, 17 out of 19 units have only private rooms. As we will discuss below, most of these rooms have glass breakaway doors to ensure both visibility and flexibility.

In one best-practice example, the ICU design team achieved the balance between patient privacy and visual monitoring in a unique manner. Instead of making all rooms private or open, the unit has 4 semi-enclosed observation beds and 16 private patient rooms. The observation beds are rapid recovery beds primarily for post anesthesia patients. They allow for intensive observation and concentrated technology. Once patients regain consciousness, generally within 24 hours, they are moved to private rooms. The inclusion of observation beds makes sense both in terms of staffing and economy: one staff can observe all four patients at the same time. Also, observation beds allow for close visual and physiological monitoring, which may be more important than privacy for an unconscious patient.

4.2. Isolation rooms

In addition to having negative/positive pressurized individual rooms, most ICUs also have isolation rooms, even though isolation rooms are more expensive and need more space. In the sample of best-practice adult ICUs, only 6 out of 19 units are without isolation rooms. In the others, the number of isolation rooms varies between 1 and 8.

The *Guidelines* recommend that each healthcare facility should consider the need for positive- and negative-pressure isolation rooms within the ICU, but makes no specific suggestions as to the minimum number of isolation rooms. The *Guidelines* maintain that this need will depend mainly upon patient population and State Department of Public Health requirements (13:2).

In light of the increasing incidence of resistant microbial strains and of recent terrorist attacks, and also in light of the fact that the available research evidence does not recommend going back and forth from positive to negative pressure rooms (20, 22-24), we can safely assume that the need for isolation rooms in ICUs will increase. Simple positive- or negative-pressure rooms may help reduce airborne infection, but they may be inadequate for critical situations where better air pressure control is required.

In order for ICU design teams to determine the correct number of isolation rooms for any ICU, more studies are needed to predict the percentage of future ICU patients who may need to be isolated as well as to understand how isolation may impact the rate of infection.

4.3. Patient room size

The demand for larger patient rooms is increasing in adult ICUs for several reasons. Firstly, many infection control experts recommend that each patient room have dedicated patient-care equipment in order to reduce cross-contamination with more resistant microbial strains that are difficult to diagnose and clean. Secondly, experts also recommend that each patient room have a dedicated family space with necessary amenities for improved family integration with patient care. Thirdly, as patient care technology improves more equipment is needed in patient rooms, which requires more space. Fourthly, the multidisciplinary nature of patient care in ICUs requires patient rooms to accommodate a large team of clinicians at any one time. For a research hospital, it is also true that more space may be needed in patient rooms for additional recording and monitoring devices. Finally, as the acuteness of illness of ICU patients increases, so does the number of possible interventions. Consequently, the need for space in ICUs increases.

Despite a growing demand for larger patient rooms, the response of the ICU design community has not changed over the last decade. The 1995 *Guidelines* stipulate, “Ward-type ICUs should allow at least 225 square feet of clear floor area per bed. ICUs with individual patient modules should allow at least 250 square feet per room (assuming one patient per room)…” (13:5). According to this study, the average size of a patient room in the best-practice adult ICUs has remained at 250 sq ft (STDEV 57) during the last decade. With one exception where the patient room size is 450 sq ft, the range varies between 300 sq ft and 187 sq ft, with no significant change in trend over a 10-yr period.

One primary reason why there has not been an increase in the patient room size may be that the idea of family integration with patient care has not yet become a standard practice. As a result, we see that a very large number of the best-practice example ICUs do not provide a designed family space within the patient room, an issue we further discuss below.

It is necessary to clarify that while an ICU design team should determine the size of an ICU patient room based on functional needs, the fact that the patient room size has not changed over the last decade should not alarm us for another reason. This is because, the study finds almost no correlation between the patient room size and the total gross area of a unit among the best-practice examples (**Figure 7**). In other words, for the same number of patient beds, units with smaller rooms do not have smaller gross areas. This can be attributed to the fact that various support/service spaces for primary care activities are also an important determinant of ICU gross areas. Consequently, ICUs with larger patient rooms may not always be better, for they may provide less support/service spaces.

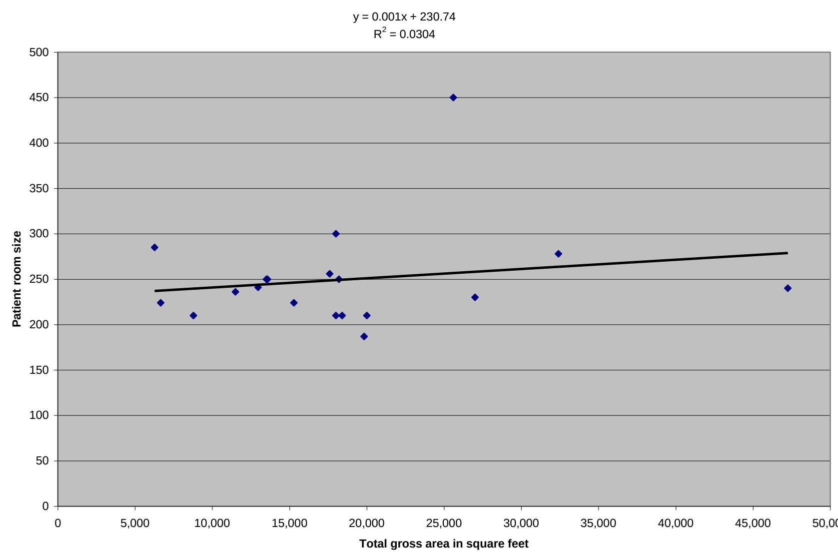


Figure 7: The scattergram shows no correlation between the patient room size and the gross area of an ICU.

4.4. Patient bed location and medical utilities

It is often crucial to maintain maximum access to the ICU patient. Access is greatly affected by two interrelated design factors: 1) the type of monitoring and power supply planned for patient care, and 2) placement of the patient's bed. The location and orientation of the bed generally depend on how the array of medical gas outlets (oxygen, medical air, and vacuum) together with electrical and data outlets are brought into the room. Traditionally, these devices have been clustered on a vertical surface at the head end of the patient bed, known as the “headwall” (**Figure 8**). Headwalls require patient beds to be put against the wall, thereby restricting movement and access to the patient’s head. A more recent trend is to have a ceiling-mounted, articulating-arm with all gas and electrical outlets and monitors, known as a “boom” (**Figure 9**). As the patient care space gets larger and the desire for flexibility within the space increases, the ceiling boom offers the desired flexibility to caregivers by allowing support services to be placed at a variety of locations around the patient. However, booms are very costly. An intermediate solution that offers flexibility as well as economy is the fixed or rotating “power column” (**Figure 10**). The power column is often equipped with multiple electrical, suction and oxygen outlets, as well as several supply baskets and stands for monitor/s. The power column requires very little space, and allows 360-degree access to the patient.

This study shows that ICU design teams generally recognize the need for easy patient access and flexible orientation of beds. In 14 out of 19 best-practice examples, the bed is free-standing. 11 out of these 14 units have power columns, and the other three have ceiling mounted arms. Only in 5 ICUs, the bed is centered on a head wall. It is clear that design teams prefer the power column over the ceiling mounted arm for economic reasons. In addition to the cost of the ceiling mounted arm itself, the arm is also a very heavy device often requiring costly structural modifications.

Figure 8: Headwall in a patient room.

Figure 9: Ceiling-mounted boom in a patient room.

Figure 10: Power column in a patient room.

4.5. Patient room door

Direct observation of patients and the surveillance of physiological monitors are among the most important functions in an ICU. In response to these needs, the *Guidelines* stipulate,

> Patients must be situated so that direct or indirect (e.g. by video monitor) visualization by healthcare providers is possible at all times… The preferred design is to allow a direct line of vision between the patient and the central nursing station. In ICUs with a modular design, patients should be visible from their respective nursing substations. Sliding glass doors and partitions facilitate this arrangement, and increase access to the room in emergency situations. (13:3)

Since most ICUs have only private patient rooms, the doors to these rooms are an important design element in relation to direct patient observation. They help maintain patient visibility as well as privacy. When shut, they help reduce noise in patient rooms. They also affect the movement of patients, equipment and supplies in and out of these rooms.

This study shows that 14 out of 19 best-practice ICUs use full-length sliding glass breakaway doors (**Figure 11)**, and the other 5 ICUs use double glass swing doors. ICU designers prefer breakaway glass doors, as they can be closed for privacy, noise reduction and infection control purposes while maintaining maximum visibility of patients and monitors. Breakaway glass doors also allow maximum clearance for moving patients in and out of the room. In an emergency situation when free access to a patient room is desired, breakaway glass doors allow the room to become more open than any other door types. Among the disadvantages of breakaway doors is that sometimes it is difficult to hear ventilator alarms when they are closed.

Figure 11: Patient room with a glass breakaway door.

4.6. Toilet and waste disposal in patient room

There are several reasons for every ICU patient room to have a private bathroom. First, private bathrooms may help reduce chances for the patient to get an infection. Second, an ICU patient may already have an infection long before the infection is diagnosed. As a result, the patient may infect others if sharing a bathroom. Third, private bathrooms eliminate the need for carrying patient waste through other areas. Fourth, in the absence of a private bathroom, care givers are likely to use bedside units, which may be portable or fixed into near-patient cabinets. These units may increase the patient's exposure to contaminated splash and/or aerosols (20). Finally, it is a frequently argued myth that the intensive care patient is too ill to use the toilet and, therefore, it is unnecessary to invest money and space for a toilet in each room. In order to debunk this myth, Rourke and his colleagues wrote as early as 1966, "Although this is true for most patients, a few may have bathroom privileges throughout their stay in the intensive care unit, and many more may have them during the final day or two before transfer to another unit. Therefore, unless hospital policy dictates retention of bedfast patients only, planning to include toilets…is worthwhile" (25).

In spite of these reasons, there is no firm statement in the *Guidelines* on the need for a private bathroom in each patient room. Rather, the *Guidelines* stipulate, "<u>When</u> a toilet is included in a patient module, it should be equipped with bedpan cleaning equipment, including hot and cold water supplies and a spray head with foot control" (underline added; 13:6). By including the term <u>when</u>, the *Guidelines* leave the decision to include individual toilets with individual ICU design team.

However, this survey shows that almost all the ICUs included in the study provide private toilets in patient rooms. In addition, they also provide bedside units in case the patient is unable to use the toilet. Thus, the findings suggest that ICU design teams often go beyond what is required by the *Guidelines* on the issues of private toilets and waste disposal for improved patient and staff outcomes.

It must be mentioned that several critical details of toilet design are not covered in this study. One such critical issue is the distance of a toilet from the patient bed. ICU patients often need to remain connected to monitoring leads and infusion pumps even when they use toilets. The distance between the patient bed and toilet is also related to the amount of physical labor required by a nurse to help the patient to the toilet: Greater distance translates into more physical labor. Another critical issue is the disposal method of bedpans, as toilets in patient rooms are generally used for dumping bedpans. There are several disposal methods, starting from the most hazardous bedpan washer spray nozzle, to the moderately safe "hopper" which is deep clinical sink, to the safest closed disposal system used in Europe. Finally, there is also a need for providing continuous patient support from the bed to the toilet in order to reduce possible patient falls and staff injuries (26). In sum, toilet design in an ICU is an issue that needs further study.

4.7. Natural light and views

An intensive care environment is very different from a patient's customary pre-hospitalization environment. Every attempt should be taken to synchronize the ICU environment with the endogenous biologic rhythms of a critically ill patient. For example, a patient's access to natural light is important, for it helps the patient's sensory orientation and circadian rhythm. Numerous studies show these and many other positive effects of natural light on patient's well-being (e.g., 27-29).

Like natural light, views from windows are also important for the patient's sensory orientation. If the patient can see out the window, s/he can visualize both the sky and the ground for better orientation. It also gives the patient an opportunity to see things both close and far, which is comforting to the eyes. Numerous studies show that views can act as a positive distraction reducing the patient's stress (e.g., 30-32). In recognition of the importance of natural light and view, the *Guidelines* recommend,

> Every effort should be made to provide an environment that minimizes stress to patients and staff. Therefore, design should consider natural illumination and view. Windows are an important aspect of sensory orientation, and as many rooms as possible should have windows to reinforce day/night orientation (33)…If windows cannot be provided in each room, an alternate option is to allow a remote view of an outside window or skylight. (13:5)

It appears that most ICU design teams take note of the research findings on the effects of natural light and view on patient's well-being, complying with the recommendations made in the *Guidelines*. In 13 out of 19 units, all patient rooms have direct natural light. In 5 units, some patient rooms have direct natural lights and the others have borrowed natural light. In one unit, all patient rooms have only borrowed light due to a corridor round the unit that provides family members easy access to patient rooms. It is often argued that the filtered light coming through the corridor into the patient room can be soothing for a bedfast patient. However, since the corridor is used by all family members, the staff is forced to keep the blinds down or to pull the curtain back on the windows in order to protect patient's privacy. Consequently, patients hardly get the natural light they deserve.

In addition to natural light, in most best-practice ICUs all patient rooms have windows with views. The average ratio of patient rooms with a view to the total number of patient rooms is 0.8. In other words, for every 10 ICU patient rooms, there are 8 patient rooms with views out the windows. For the purposes of this study, windows are considered to have views out if the views remain unobstructed by another building for a distance greater than that recommended by by-laws.

5. STAFF WORK AREA DESIGN ISSUES

Rarely is it noted that ICU staff work in an extremely difficult environment. The gap between concerns for patients vs. staff is great. The culture of ICUs has always encouraged improvements for patient care, but has not always attended to staff working conditions. As a result, ICUs are often very stressful places, endangering both the physical and mental health of the staff. When the staff is under stress, they become irritable, forget things, make more mistakes, suffer from burnout, and often quit. In the United States, there is not only a shortage of nursing staff, but the current staff is already older and has a high turnover rate. The turnover rate is likely to be higher in ICUs because of the stressful working conditions.

In this context, we must acknowledge that staff work areas are an important part of ICU design. ICU design can help relieve staff stress by reducing unnecessary physical labor, by providing amenities, and by including positive distractions for the physical and mental replenishments of the staff. Though the specific design of an ICU will largely depend on the function of a unit, all staff work areas must be laid out not solely to help facilitate patient visibility and monitoring, but also to help reduce the physical and mental stress of the staff.

5.1. Staff work area types and layout options

In older hospital units, a centralized nursing station is generally the main component of the staff work area. Including patients' records room, the central monitoring station, and staff workstations for patient charting and medical recording, it serves as the hub of all functions in the unit (**Figure 12**). A centralized nursing station generally has a centralized support/service area next to it that accommodates medical and supply storage, pharmacy, conference rooms, administrative offices and other ancillary functions. In older units, a centralized nursing station is the place where clinical management, staff interaction, mentoring and socialization occur. It is often argued that centralized nursing stations contribute to errors and inefficiency because of noise, crowding, and the considerable walking distance from patient rooms.

In more recent hospital units, the centralized nursing station is often replaced with several decentralized observation units, either just outside the room or just inside the room (**Figure 13**). Typical functions in these units include a work surface for patient charting, a computer to record and access patient information, and telecommunication services. Depending on the quality of the units, they may or may not include storage spaces for medication and supplies, handwashing facilities and image retrieval systems. It is often argued that the decentralized observation units increase efficiency at the cost of the social life of the staff.

Team workstations or nursing substations are something between centralized nursing stations and decentralized observation units (**Figure 13**). These substations often provide spaces for social functions, interdisciplinary teamwork, mentoring, and clinical management, which are not integral to the totally decentralized observations units. However, nursing substations cannot be more efficient than nursing observation units, as they are located further from patient rooms.

To summarize, the centralized nursing station, the nursing substation, and the nursing observation unit are three basic nursing unit types that make up the staff work area in a hospital unit. Altogether, seven different staff area configurations are possible using these three unit types (**Figure 14**). This study shows that the staff work area in the best-practice adult ICUs uses either any one of these three basic nursing units or some combination of them. 6 out of 19 cases have nursing observation units only. 5 cases have nursing substations only. Another 3 have a combination of nursing substations and observation units. Only 2 have centralized nursing stations. One has a centralized nursing station with more than one nursing substations. One has a centralized nursing unit with several nursing observation units. Finally, one has a centralized nursing unit, more than one nursing substations and several observation units (**Figure 15**).

The relation of the support or service area locations to the nursing units also differs in the best-practice adult ICUs (**Figure 16**). 9 out of 19 cases have the common service area surrounded by the nursing units. 3 cases have the common service area at the center of the unit with nursing stations on both ends. 2 cases have the common service area located away from the nursing units with some other functions between them. 2 cases have more than one common service areas close to the nursing stations. Finally, 2 cases have distributed service areas close to nursing observation units.

This study, thus, shows that the configuration of staff areas and the location of service areas in relation to them are not yet resolved in the best-practice example adult ICUs. On one hand, the study suggests that design innovation with regards to the staff area layout is still possible, which is always exciting. On the other hand, it also suggests that it is not yet know which configurations most effectively balance patient care with staff needs. While design innovations must be encouraged, it is important to encourage more empirical studies that would ultimately help establish a staff area configuration most favorable to both patients and staff.

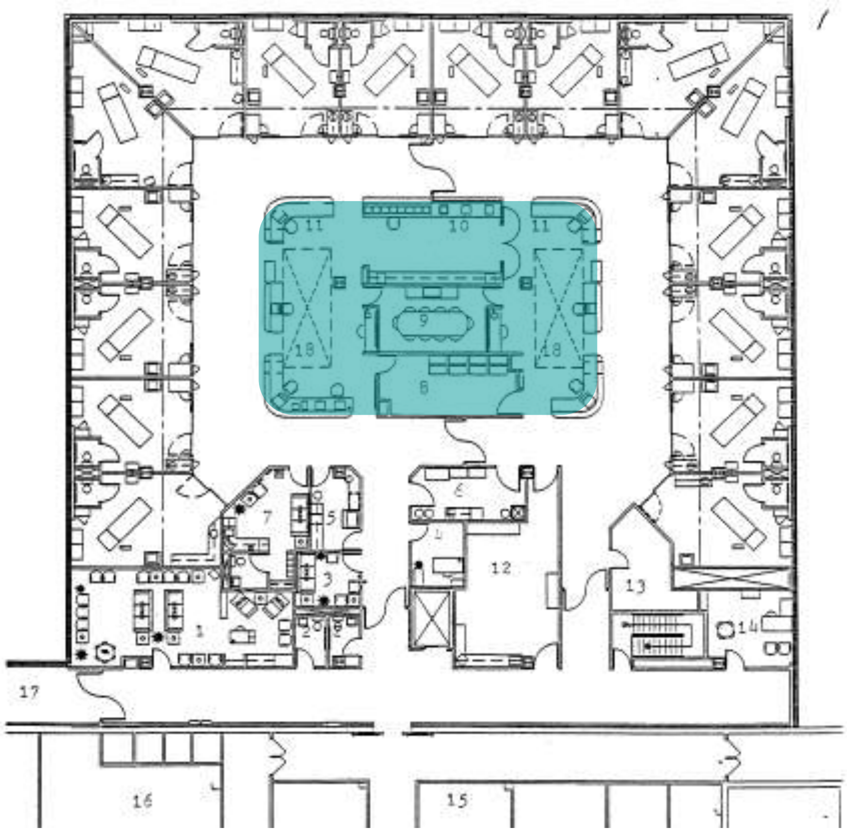


Figure 12: Centralized nursing station.

Figure 13: Nursing substations with observation units.

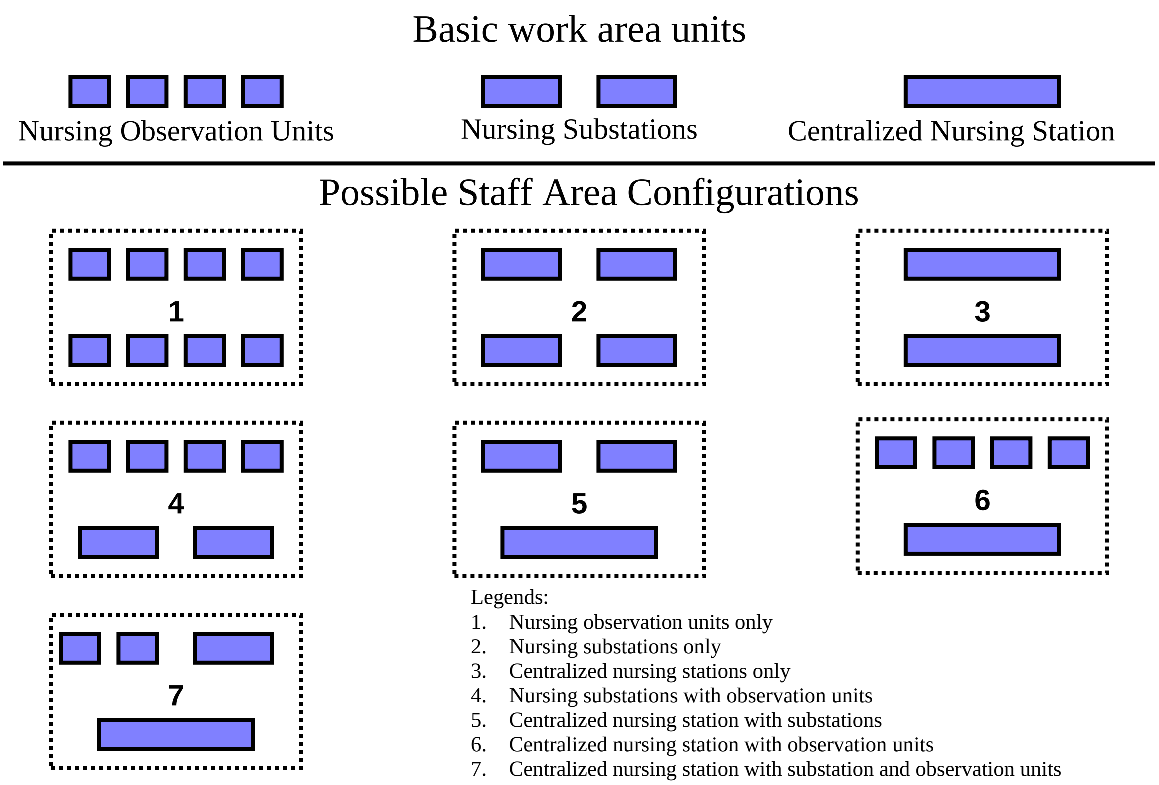


Figure 14: Seven possible staff area configurations using three basic nursing units.

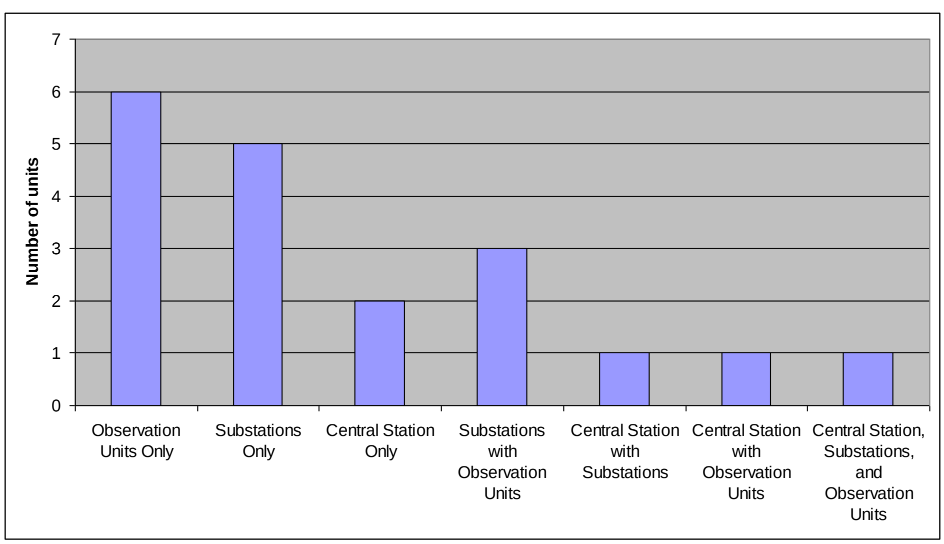


Figure 15: Categorization of best-practice example ICUs based on the staff work area layout.

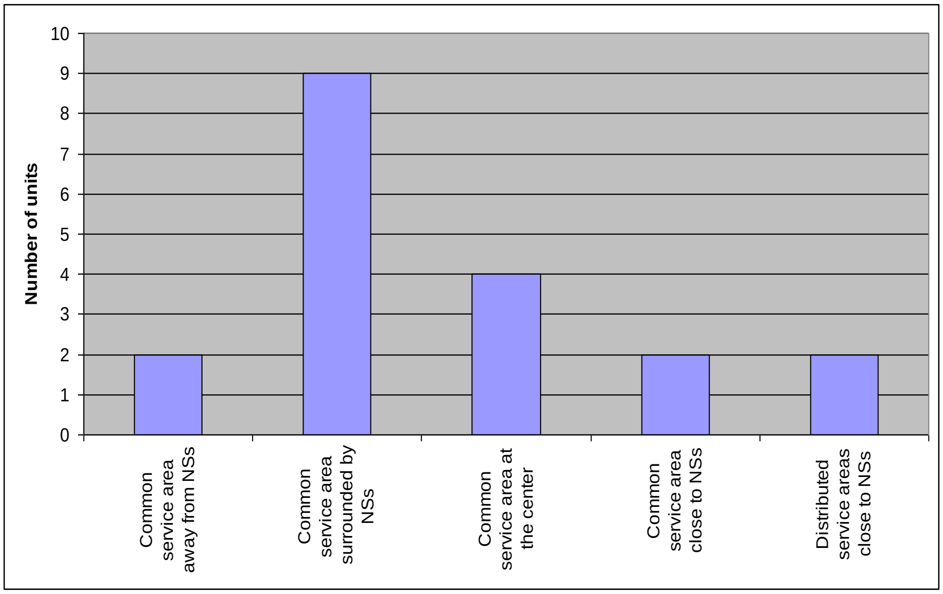


Figure 16: Categorization of best-practice example ICUs based on service area locations.

5.2. Patient charting locations

The recording of patient status and care information is another important function that an ICU design must facilitate. Studies show that nurses may spend from 15% to 25% of their time in charting (34-36). Several things can happen when charting is not done at or near the bedside. First, nurses may spend more time away from the bedside preparing and storing charts at other locations. Second, nurses may make more mistakes in charting because of memory lapses between the time of collecting the information at the bedside and putting it on the chart. Third, nurses may be required to walk further to places where charts are prepared and stored.

According to this study, most best-practice example adult ICUs use some sort of computerized charting system. The study finds that computer stations for patient charting are located at various places within the units. This includes in the nursing observation units next to the patient room; in the patient room; at fixed locations or on mobile carts; and at the central nursing stations away from the patient room.

In general, the best-practice examples recognize the importance of locating charting systems closer to the patient room. The study finds that in 14 out of 19 cases, charting occurs in or near the patient room. In 8 out of these 14 cases, charting occurs immediately outside the room at the nursing observation unit; in 3 cases, it occurs inside or immediately outside the room on mobile charting stations; and in 3 cases, it occurs at the bedside. Only in 5 out of 19 cases, does charting occur at the nursing stations away from the patient room (**Figure 17**).

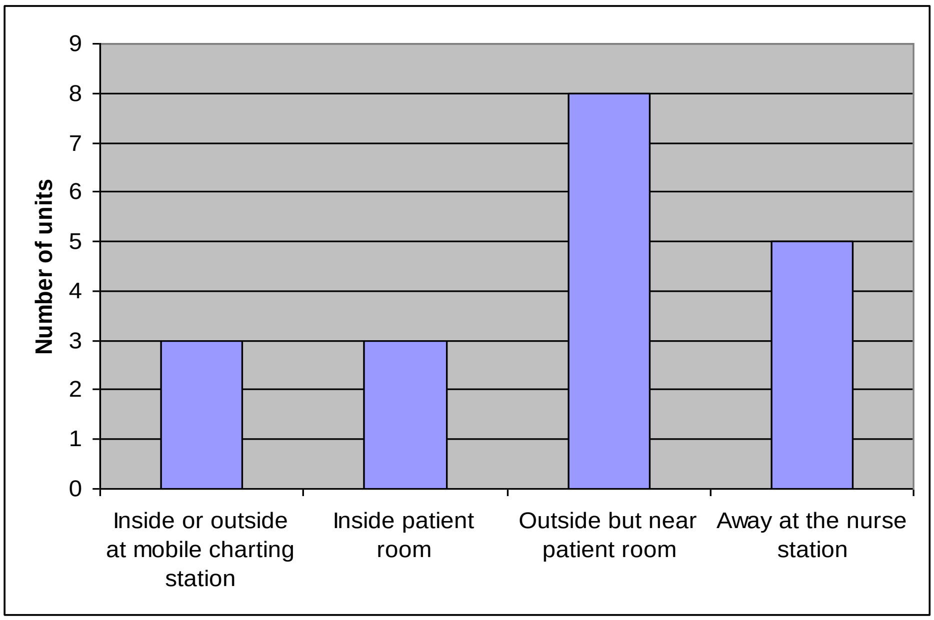
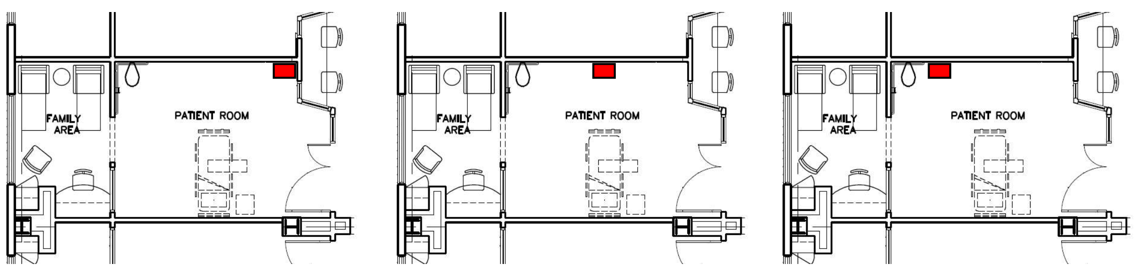


Figure 17: Categorization of best-practice example ICUs based on patient charting locations.

5.3. Handwashing sinks

Handwashing is the single most important infection prevention intervention (37-39). Studies show that the infection rate decreases as the number of handwashing sinks increases in healthcare settings (20, 40). Yet, the compliance rate is sub-optimal even in ICUs (41). This is partly due to inadequate number of basins, inaccessible locations, or poor design. The literature recommends that handwashing sinks should be located near the door to the patient room (20, 40, 42, 43). The *Guidelines* agree and stipulate, “Hand-washing sinks… must be available near the entrances to patient modules, or between every two patients in ward-type units” (13:6).

ICU designers, in general, have taken note of the research findings, endeavoring to follow the *Guidelines*. The findings are that 18 out of 19 ICUs studied have handwashing sink/s in the patient room, and at least 2 cases have handwashing sinks both inside and immediately outside the patient room. Within patient rooms, the sinks are located at the near-end, the middle, or the far-end of the sidewall in relation to the room entrance (**Figure 18)**. However, the near-end locations are most prevalent in the sample. In 9 cases, sinks are located at the near end of the sidewall, i.e., immediately next to the room entrance. In 3 cases, they are located at the far end of the sidewall. In the other 3, they are located at the middle of the sidewall.



Near-end of the sidewall Middle of the sidewall Far-end of the

Figure 18: Locations of handwashing sinks in patient rooms.

5.4. Staff lounge

The recommendations in the *Guidelines* regarding staff lounge is extensive:

> A staff lounge must be available on or near each ICU or ICU cluster to provide a private, comfortable, and relaxing environment. Secured locker facilities, showers and toilets should be present. The area should include comfortable seating and adequate nourishment storage and preparation facilities, including a refrigerator, a countertop stove and/or microwave oven. The

> lounge must be linked to the ICU by telephone or intercommunication system, and emergency cardiac arrest alarms should be audible within. (13: 4)

The study shows that designers of best-practice example ICUs have taken note of the recommendations. Each ICU included in the study has a staff lounge, and most have the basic service features including secured locker facilities, showers and toilets. However, the interpretations of the phrase, "a private, comfortable, and relaxing environment," have varied widely from one ICU to another. Based on numerous workplace studies showing benefits of natural light and outdoor views on workers (e.g., 44-46), staff lounges in some units have opted for windows, outdoor views, or access to nature. In other cases, they are limited to having comfortable chairs, sofas, and a television only.

6. FAMILY AREA DESIGN ISSUES

Families of patients need healing and comfortable spaces as much as the patients themselves do. Family integration with patient care begins with allocating sufficient spaces for families and visitors at appropriate places in ICUs. Such spaces may include different amenities for families in different zones. A relatively noisy zone may include a television and telephones. A quieter zone may include reclining chairs and sofas with pillows and blanket. The zone may also include one or more computer workstations with internet access, quieter recreational activities such as puzzles, board games, and reading materials. The family area may also include a service zone with lockers, washer and dryers, bathrooms with shower, and a small kitchenette. The amount of amenities to be included in family areas is greater if patients come from far away places and/or stay longer in ICUs.

6.1. Location of family areas

The location of family spaces is an important design issue, as it has the most impact on family-staff relations and the culture medical practice in ICUs. The location of family area can be a general indicator of the degree to which families are integrated with patient care in an ICU. Clearly, the nearest location to the patient in which a family space can be provided is the patient room. In this study, a patient room is considered to have a family area when the area shows distinct physical design demarcations (**Figures 19 & 20**). Most ICUs may claim that they have a family space within the patient room simply by the addition of one or two chairs. Such a move often does not make the same statement regarding family integration as does a properly designed family space within a patient room. A designed family space in the patient room suggests that care providers of the unit accept that families are important to patient care, and that they are eager to change the culture of medical practice, if necessary, in order for families to become a part of the practice. It suggests that family consultation can occur in the patient room, when appropriate. It also suggests that families can ask questions regarding patient care. Additionally, it suggests that care providers may get a few extra helping caring hands when needed. Several studies identify two primary needs of family members in ICUs: 1) to have adequate and timely information about the patient, and 2) to feel assured that their loved one is properly cared for (47-51). When families are put in the patient room, both these needs are immediately satisfied.

The next nearest location to a patient is inside the unit, without any physical control between the space and the clinical area of the unit (**Figure 21**). Like the earlier location, this location of family area also sends a clear message to families that they are welcome in the unit. It also cues care providers that they need to consider families as a part of the everyday medical practice. When family space are located in the unit, it is easier for families to find the care giver, and to monitor their loved ones. In other words, this layout easily meets the primary needs of a family, as mentioned above. However, to locate the family within the patient room is not the same as locating them within the unit. In the latter case, the family becomes somewhat distant from care givers and less integrated with the care process. It needs to be mentioned that the *Guidelines* do not include the provision for providing family spaces in the patient room or within the unit. The *Guidelines* simply mention, “A visitors' lounge or waiting area should be provided near each ICU or ICU cluster. Visitor access should be controlled from the receptionist area.” (13: 4)

The third nearest location for a family space is just outside the unit. Most often, there is some physical control between this family space and the clinical area of the unit (**Figure 22**), as recommended by the *Guidelines*. At this location, families become separated from their loved ones, and feel alienated. As a consequence, none of the above two primary needs of families can be met spatially. Families may not see a care giver unless the care giver goes to the family room for consultation, and they may not be assured that their loved one is being cared for by competent and caring people. They are often escorted to the patient during visiting hours. When families are at this location, family integration with patient care becomes minimal.

The farthest location for family space is when the space is away from the unit with some other space (e.g., elevator lobby) between the family space and the unit (**Figure 23**). It is at this location families may begin to feel helpless, having the least knowledge about patients and their care givers. When patient families are at this location, care givers are most protected and least bothered, and the idea of family integration with patient care becomes irrelevant, at least, in terms of space.

Finally, there are those ICUs where family spaces are provided both in and outside the unit (**Figure 24**). There are at least two possible interpretations for having multiple locations for patient families. On one hand, it can be argued that having a family area outside the unit is beneficial for family members. They may want to use the space to make phone calls, to take a shower, or to cook for the patient. If properly designed, family spaces can help relieve family stress. On the other hand, it can be argued that when family spaces are provided both in and outside the unit, family's role in patient care is yet undecided in the unit. Such an argument can be made when the family space outside does not provide necessary amenities, and is used only to push families out of the unit at the convenience of care givers.

This study finds that only 3 out of 19 ICUs have designated family space within the patient room. However, all 19 ICUs have some kind of family space: 12 out of 19 units have family space immediately outside the unit, as recommended by the *Guidelines*; 2 units have family space inside the unit; 4 units have family space both inside and outside the units; and one has family space away from the unit (**Figure**

25). In other words, family has been rarely integrated with patient care in the best-practice example adult ICUs from the perspective of design.

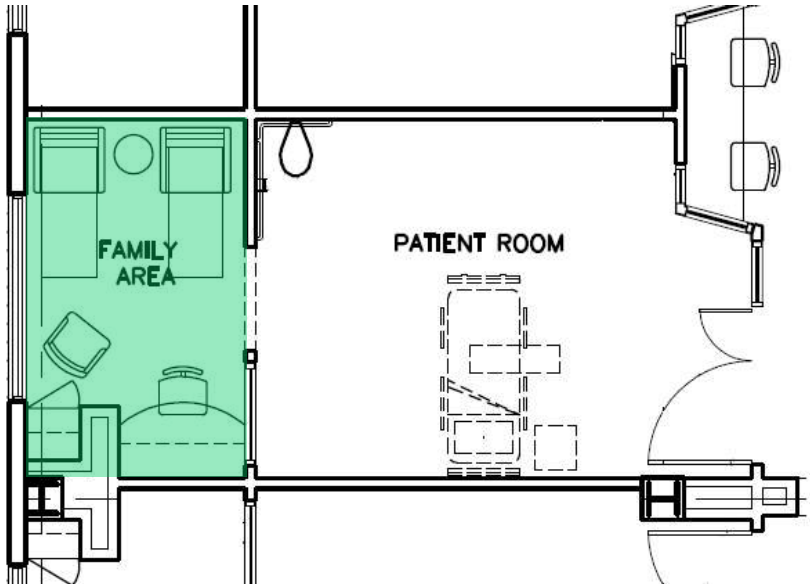


Figure 19: A designated family area within a patient room.

Figure 20: Example of a properly designated family area in a patient room.

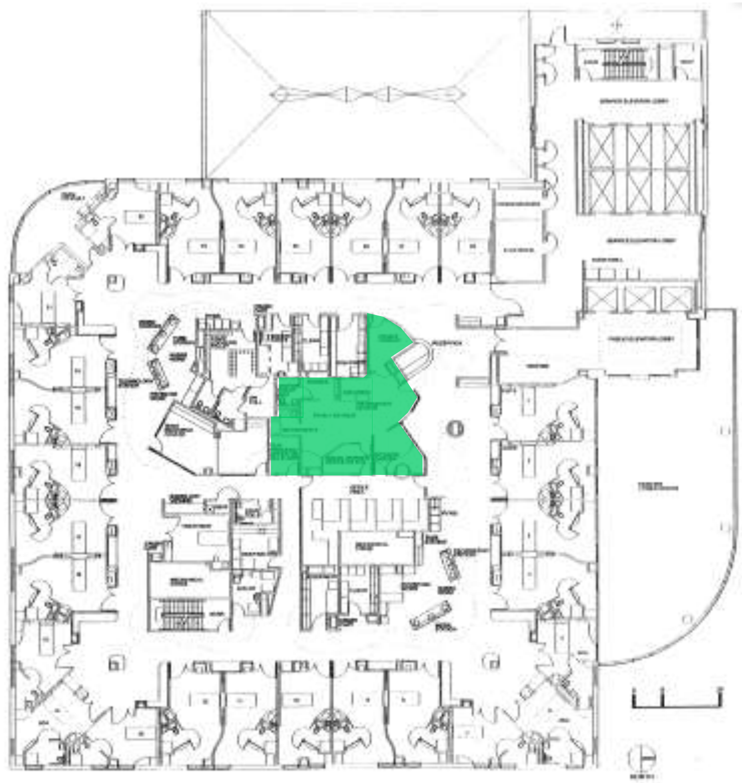


Figure 21: Family area inside ICU.

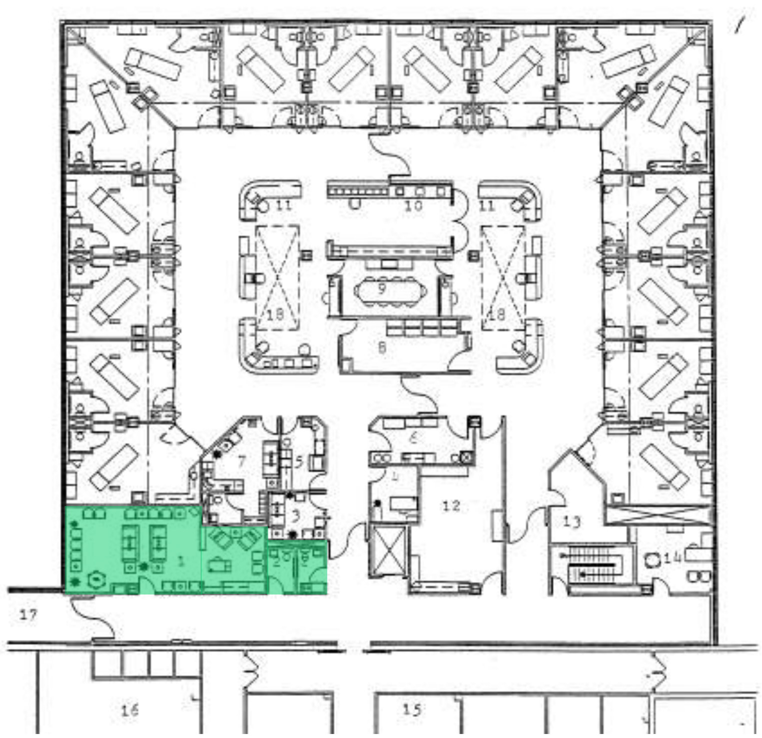


Figure 22: Family area outside ICU.

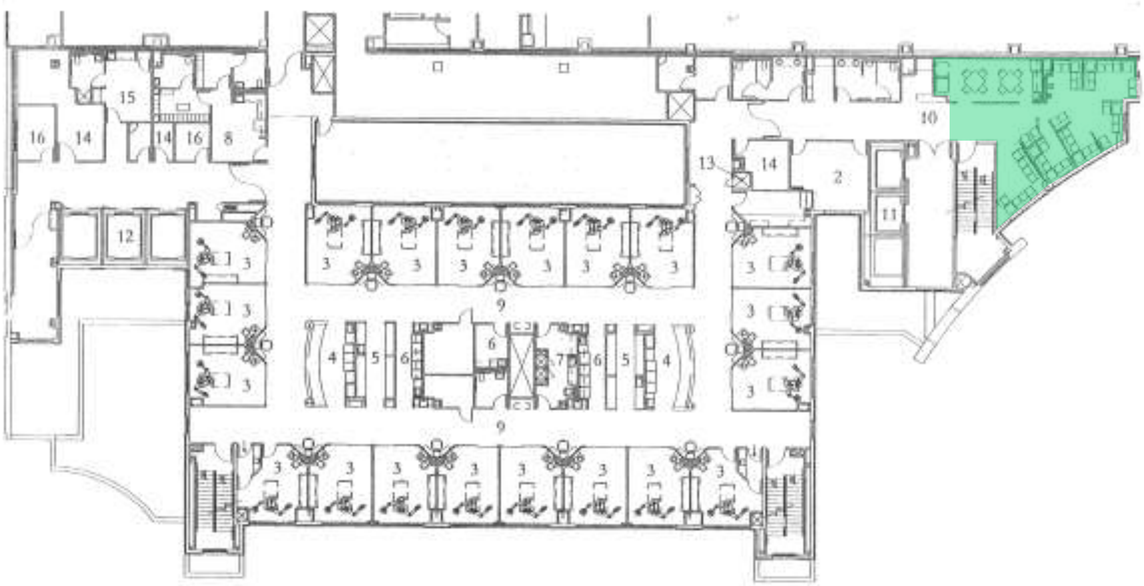


Figure 23: Family area away from ICU.

Figure 24: Family area both inside and outside ICU.

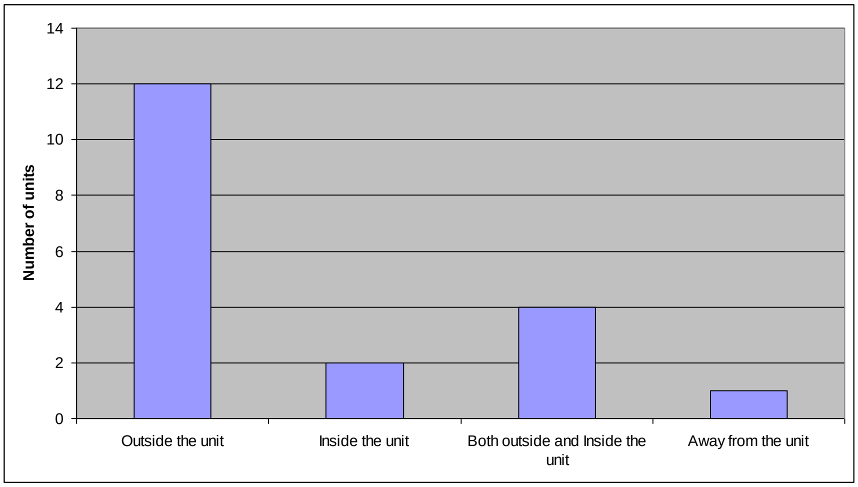


Figure 25: Categorization of best-practice example ICUs based on family area locations.

6.2. Family consultation room

Another important requirement for families in ICUs is the family consultation room. In ICUs, "A separate family consultation room is strongly recommended," suggest the *Guidelines* (13: 4). Because of HIPPA regulations, there is a greater need for family consultation rooms. Clinicians can no longer go to a common waiting area to talk with families regarding patient-related matters. Additionally, private and/or enclosed consultation rooms are likely to improve family-staff interaction. As noted earlier, studies show that the quality, frequency, and the length of interactions generally increase in more private spaces. The study finds that every best-practice example ICU has one or more family consultation rooms, though the exact number of these rooms is not known. Generally, the number of family consultation rooms should depend on the number of beds in an ICU. Every consultation room should provide adequate privacy. Each should also have a telephone line and/or interactive video conferencing facilities.

7. CONCLUSION

Despite limited information and scope, the study reported several important findings about the best-practice example ICUs in each of the four areas of study. A summary of the findings in each area is provided below.

In the general design area, the study reported the following findings:

- a significant number of best-practice examples were renovated units, even though renovation posed greater threat to health and safety;
- most best-practice examples provided mixed services, even though these units might have more problems to solve than a specialized ICU;
- the average number of patient beds in these units was 22, a number much larger than that recommended by the *Guidelines* or by experts;
- the average gross area per patient bed varied significantly in the best-practice examples;
- the most popular type of unit layout was the racetrack or double corridor type, even though there was no empirical study supporting its advantages over the other layout types; and
- the geometry and amount of circulation spaces vary widely in these ICUs, providing no benchmark for an efficient and socially-favorable ICU design.

Regarding patient room design, the study reported the following findings:

- most patient rooms in most units were private rooms;
- most ICUs had one or more isolation rooms;
- the average size of a patient room in the best-practice examples was 250 square feet, as recommended by the Guidelines;
- the size of a patient room did not change over the last ten years even though the need for larger rooms had increased;
- most patient rooms had free-standing beds with utilities provided by power columns;
- most patient rooms had natural light and views;

- most patient rooms had glass breakaway doors to increase patient visibility and to facilitate patient care and transfer; and
- most units had private toilets and/or waste disposal facilities within patient rooms.

Regarding staff work area design, the study reported the following findings:

- there were three basic units of staff work area: nursing observation units, substations, and central stations;
- most units had staff work areas composed of observation units;
- in most cases, observation units were distributed around central service areas;
- most patient rooms had handwashing sinks as an important infection prevention intervention;
- the majority of these sinks were located at the near-end of the side wall for ease of use;
- most units had charting in or near the patient room to reduce nurses' time and energy spent on this function; and
- each unit had a staff lounge area to help physical and mental restoration of the medical staff.

Regarding family area design, the study reported the following findings:

- all units had family areas but most units did not have a designated family space in the patient room;
- in most cases, family space was located outside the unit,
- in most cases, family access to the patient area was controlled, as recommended by the *Guidelines*; and
- each unit had one or more family consultation rooms.

In general, ICU design teams of the best-practice examples followed the *Guidelines*, making many design decisions based on economy and patient volume. For example, that most ICUs were renovated rather than newly built, and that medical utilities were brought in the patient room using power columns instead of ceiling mounted booms were probably driven by economy. That most ICUs had many more beds than the number recommended by ICU experts and the *Guidelines*, and that most ICUs provided mixed services were probably due to both economy and patient volume. That the patient room size floated around 250 square feet for the last ten years, and that most patient rooms had windows were probably due to the recommendations in the *Guidelines*.

In some cases, however, the best-practice examples went beyond the *Guidelines* and economy to follow the empirical research evidence. For example, that most patient rooms in the these ICUs were private, contained more isolation rooms than that recommended in the *Guidelines*, had private toilets and/or waste disposal facilities, and that some had family space in the patient room or unit, were not required by the *Guidelines* or dictated by economy. If anything, these features added to the cost of construction and maintenance of these units.

In some other cases, the findings were somewhat disparaging. For example, there were several types of unit layouts and staff work area layouts, and the gross area per bed varied significantly in the best-practice example ICUs. These findings suggest that the ICU design community has not yet resolved some of the more fundamental design issues that impact many other ICU design decisions.

In summary, the study identified the *Guidelines*, economy, patient volume, and the available research evidence as the four primary forces shaping the physical design of adult ICUs. According to the findings of the study, the effects of economy and patient volume on ICU design were not always in the best interests of patient, staff or family. The effects of the *Guidelines* were positive in some areas of design, because they ensured that the basic needs of patients, staff, and families/visitors were met in ICUs. However, in other areas the *Guidelines* had negative effects, because the design community became fixated with its recommendations, against its better judgment. Finally, the effects of available research evidence on ICU design were limited but positive. The research evidence allowed the community to push the boundaries defined by the *Guidelines* and to use better design features than those suggested in the *Guidelines.* Since economy and patient volume are beyond control, the ICU design community would serve its purpose well by conducting more empirical research aimed at resolving basic ICU design questions and updating the *ICU design guidelines* more frequently based on that research.

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