Photo courtesy of the newborn and infant critical care unit at Children's Hospital Los Angeles, winner of the 2013 Design Citation Award.

What will the ICU of the Future look like?

Clinicians and architects share thoughts on informatics, life support systems, design trends, and use of design guidelines in renovation and new construction projects.

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Life Support Systems

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The ICU of the future will require a robust life support system that organizes information (e.g., multifunction physiologic monitor), delivers medical gas utilities and electrical capacity, and allows platforms or baskets to be attached for convenience items, such as sphygmomanometers, otoscopes, or useful supplies. Today's ICUs utilize three basic formats with some variation: headwalls, power columns, and overhead booms. In the future, these systems will be more advanced and wirelessly integrated with improved documentation and communication systems.

It is tempting to say the overhead boom offers the greatest flexibility and immediate access to the patient's head and airway during a code situation – but it not realistic to predict that all ICUs will adopt the most flexible and elaborate system, for reasons of clinician preference, patient acuity, or cost. It is possible, however, to imagine a rational hierarchical distribution of acuity levels, similar to that used in emergency and trauma centers.

Perhaps a community hospital with the lowest expected acuity, designated as level 3, would most often utilize an improved version of the headwall life support system. Large urban and teaching hospitals might have a level 2 ICU that utilizes an advanced power column. The level 1 ICU designation might be limited to tertiary and quaternary institutions or major trauma centers, and these facilities would likely need all the flexibility an overhead boom system could provide. Life support technology selection likely will be based on acuity.

## A (Slightly Provocative) Description of Architecture

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As an architect specializing in healthcare for 30 years, and having studied and judged entries to the ICU Design Citation for 10 years, I've observed trends in ICU design that I believe will become the norms of future ICU programs and designs. Not all will apply to every ICU; large academic centers are fundamentally different than small, general community hospitals. Indeed, one shoe does not fit all – but a shoe is still a shoe. Here are my predictions:

1) Larger Units – Expect more ICU beds per unit, and larger unit size per bed. Support space will increase as units become more operationally independent.
2) Patient Room – All-private rooms will remain the standard, with a stable room size of about 250 square feet. Family, toilet and possibly shower space will be added to this square footage.
3) Family Zone – Designated and meaningful family and visitor space amenities will be included in the ICU and patient rooms.
4) Technology and Life Support Systems – Ceiling-mounted life support systems will become the norm in critical care units. See Kirk Hamilton's "Life Support Systems" for additional considerations.
5) Design for Interdisciplinary Teams – ICU teams will become more comprehensive, especially as the units become larger and include more specialties. A balance of centralized and decentralized work stations will be included.
6) Proximity to Diagnostic and Treatment Technology – More units will include diagnostic and treatment technologies, either adjacent to or within the unit. Improved mobile technology will be part of this trend.
7) Administrative and Related Spaces – Locating administrative, educational and research spaces within the ICU will be the norm.
8) Unit Geometry – ICUs will continue to adapt to surrounding conditions. Large units will be subdivided into smaller, manageable groupings of beds.
9) Unit Circulation – Segregation of public/visitor and patient/support circulations, horizontally and vertically, will be expected.
10) Access to Nature – The importance of nature to patients, families and staff is fully recognized and will be incorporated, regardless of unit size.

Advanced Informatics
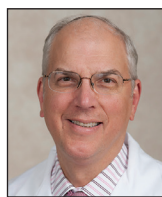
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The patient will be at the center of a vast computer system in the ICU of the future. Therefore, primary design goals will revolve around the electronic integration of the patient with all aspects of care (i.e., devices, data, supplies, caregivers, medical and administrative applications and the electronic medical record [EMR]), utilizing the data and monitoring of the ICU environment.

The first step in this process is the creation of a connectivity envelope around the patient that interfaces with ICU and hospital networks. The envelope is composed of wired and wireless data receivers, the placement of automatic identification tags on all data sources to facilitate tracking, and the attachment of adaptors/computers on the medical devices to transmit data and alarms. The second step is the installation of ICU middleware (servers and applications) on the ICU and hospital networks to perform the required tasks.

Three elements are critical to the success of advanced ICU informatics. The first is the association of all data sources and their output with the ICU patient. This is accomplished by either linking the data with the patient or with the patient's location. The second element is synchronizing time across all bedside devices and systems to achieve a stable electronic flow sheet and medical record. The third is achieving "interoperability" among data sources, middleware and the medical record. This process converts and aligns the proprietary data output of medical devices with industry standards (www.ihe.net), thereby allowing the middleware to recognize the data.

ICU middleware has the potential to perform many functions that advance both ICU care and management. Alarm systems capture alerts and convert them into actionable information by filtering and transmitting them to dedicated receivers and personnel. Intelligent alarm systems can even analyze raw device data and create personalized alarms. Data "sniffers" monitor ICU data and the EMR and profile patients at risk for clinical deterioration. Real-time locating systems/solutions (RTLS) can improve management and workflow by tracking or locating tagged assets, monitoring device utilization and controlling product inventory. RTLS can also be integrated with existing systems to improve personnel location, infection control and patient room management. Devices (e.g., all ventilators) can be monitored by middleware, thereby supporting global device viewing (i.e., local telemedicine), alarm transmission, report generation, and remote troubleshooting. Lastly, ICU middleware can create smart displays that merge data from bedside devices and the EMR and process these data through artificial intelligence algorithms.

Design Guidelines

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Guidelines have a role in the design and construction of the modern ICU. Two important sources of guidelines are the medical literature and the documents created by organizations like the Facilities Guidelines Institute (FGI).

The FGI Guidelines for the Design and Construction of Health Care Facilities are produced by a committee of about 120 professionals from various backgrounds, including physicians and nurses, infection control personnel, architects and designers, structural and mechanical engineers, and others with particular expertise in the design of healthcare facilities. Devised to meet minimum standards for design and construction, these guidelines are adopted throughout the United States and are used in other countries. In the United States, these are integrated into state regulations, either partially or in their entirety. The FGI guidelines also reflect and incorporate other subspecialty requirements, such as electrical, air handling, Americans with Disabilities, and Life Safety Codes. Because these are minimum standards, they can be exceeded but not reduced.

The second source, the medical literature, contains the SCCM's Guidelines for Intensive Care Design, created from a different perspective – as optimal evidence-based design. For instance, these guidelines recommend larger rooms and clearances. The combination of guideline perspectives is complimentary and will help achieve a design that fits the individual unit and the particular program, with the potential to adjust costs.

An important consideration in both the FGI and SCCM guidelines is adoption of these tools early in the design process by developing the functional program, an understanding of spaces needed to comprise the ICU. The use of design guidelines and standards enhances the finished environment, and ongoing revisions are necessary to keep pace with the changing nature of medical practice, technology and evidence-based studies. Find the SCCM guidelines at www.LearnICU.org/guidelines. ⏏

ProCCESs AWARE
Mayo Clinic
Rochester, Minnesota, USA

Brian Pickering, MD

Brian Pickering, MD, professor of anesthesiology and consultant in the division of critical care at the Mayo Clinic, estimates that the standard electronic medical record (EMR) displays an average of 2,000 data pieces per patient per day, spread multiple screens. "This is an overwhelming issue in the ICU – integrating data, managing information and processes of care," Pickering says. "And if you can't get to the answer you need in one or two steps, you are likely to be interrupted, increasing the possibility of errors." He and colleagues Ognjen Gajic, MD, FCCM, and Vitaly Herasevich, MD, PhD, want to corral this deluge of data by first studying how it is managed in the EMR and linked to care practices. To this end, they have spent the past two years developing and testing the Patient Centered Cloud-based Electronic System: Ambient Warning and Response Evaluation (ProCCEs AWARE),

an acute care information technology interface with built-in tools for error prevention, practice surveillance, decision support, and reporting. Pickering describes the system as a cloud-based "electronic intern" that runs clinical rules (i.e., the most important information relating to a patient's condition) on each case and pulls that prioritized information in the patient's EMR onto a single screen. Data are organized by organ systems and updated every few minutes. "We've reduced decision-making errors by half and task difficulty by two-thirds," Pickering says. "We found that providers were typically spending 20 minutes per patient gathering data to present on rounds. With AWARE, it's now five minutes – and that's 15 more minutes to connect with patients."

CC: Why is this EMR restructuring important?

Pickering: One of the biggest motives is data and alert fatigue. In the standard EMR, one in 10 alerts are actually useful, but in AWARE, one in three is useful; and once you act on the alert, it disappears. There is so much noise and distraction in the ICU – AWARE integrates

better into workflow. We've also built "smart checklists" that have a real-time context and switch off questions that aren't relevant to a particular case. [These electronic checklists] have 100% compliance, compared to paper checklists that have only 20% compliance.

CC: What are the biggest challenges to this work?

Pickering: Data integration, followed by workflow integration and implementation, are the first two hurdles. And you must measure outcomes or you are working in the dark.

CC: What advice would you give to hospital leaders and clinicians looking to implement this work?

Pickering: First, top-down development doesn't work. If you don't understand your users' needs, it will be a terrible system. Second, the patient has to move back to the center of the discussion. The discussion is vendor-centered now.

The Patient-Centered ICU
Brigham and Women's Hospital
Boston, Massachusetts, USA

With a dedication to promoting better safety and respectful engagement in patient care, leaders at Brigham and Women's Hospital are bringing what they call a "patient-satisfactive model" to the ICU. "Patients want to know what to expect in their care, and although doctors and nurses agree with that, they rarely ask about expectations or tell patients what will happen – and that gap creates a lot of problems," says David Westfall Bates, MD, chief quality officer and senior vice president. "This system is designed to improve concordance between patients and providers." In the ICU, those discussions should include patients' care partners as well, he adds. Bates and his colleagues are installing devices and software in ICU rooms that allow patients to view an electronic patient-centered care plan. They and their care partners can now follow their progress, see their medications and tests, and identify their care

team members. A "micro-blog" also lets patients and families ask questions and learn more about their care from anyone on the care team, and all communication is transparent. The model is still in its early phases, with a "go-live" date for one medical ICU and two oncology units scheduled for early next spring.

CC: Why is this new patient communication tool important?

Bates: The ICU is so complicated, and it's an enormous challenge to keep everyone on the same page. Patients and their families want to know about their progress, likely outcomes and who is caring for them. So many changes in care plans and decisions are made informally among providers during rounds. This model can improve care delivery by involving patients and care partners in more of these conversations.

CC: What are the biggest challenges to this work?

David Westfall Bates, MD

Bates: ICUs are already physically crammed with devices, and providers are already working very hard. There is some intervention fatigue, but our hope is that the model will ultimately increase efficiency. We also need to develop a coordinated response to the micro-blog, determining who should answer which patient and family questions.

CC: What advice would you give to hospital leaders and clinicians looking to implement this work?

Bates: It's helpful to have multiple disciplines come together to do this, and it's very much about treating patients with more dignity and respect, as well as providing consistent, real-time information about their care plan and how they are doing.


The ABCs of ICU Recovery
Vanderbilt University Medical Center
Nashville, Tennessee, USA

"The dilemma we face in the ICU is that the sickest patients come here and are cared for in a somewhat antiquated approach," says E. Wesley Ely, MD, FCCM. "It's hard for them to tolerate life-support systems that slam them into a coma. It's safer to be kept near-awake and alert." Ely and his fellow researchers have conducted multiple randomized controlled studies over the last 15 years to prove that point and their "ABCDE bundle" has since been implemented in hospitals worldwide. The bundle encompasses awakening, breathing coordination, delirium monitoring and management, and early mobility, and its goal is to take ICU patients off of mechanical ventilation, lighten their sedation and encourage some type of physical movement as quickly as safely possible. The reason: to prevent or minimize the effects of ICU delirium and physical weakness, which compromise mobility and create long-term, sometimes permanent

cognitive impairment. Although Ely says at least some elements of the evidence-based practice set are now prevalent in most up-to-date hospitals, he and his colleagues are continuing to prove the bundle's value. Next trials will focus on cognitive rehabilitation, determining what kinds of "brain exercises" can help rebuild portions of the brain that become disabled under ICU sedation.

E. Wesley Ely, MD, FCCM

CC: Why is this issue so important?

Ely: This is a global public health problem that patients and their families don't know about. Most critically ill patients are at risk of developing this dementia-like brain disease and these muscle and nerve problems during ICU recovery. But I think the Society of Critical Care Medicine's new pain, agitation and delirium clinical practice guidelines have been a great catalyst for change.
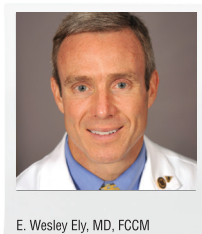
CC: What are the biggest challenges to this work?

Ely: The medical community is not ready to change. It's an "undoing" of 15 to 20 years of culture. The studies have had an impact, but it's a combination of the data and the full realization of how these "ICU diseases" have affected patients that will really create understanding and change.

CC: What advice would you give to hospital leaders and clinicians looking to implement this work?

Ely: You must have an interdisciplinary team of nurses, pharmacists and physicians at the table. And you have to say the ABCDE steps aloud during rounds to incorporate this new culture. Nurses are especially important, since they are involved so closely with drug management and getting patients out of bed. And physicians have to take their egos off the table; they have to be leaders of a team in which everyone has a role to play.

Getting to the Roots of ICU Harm
Beth Israel Deaconess Medical Center
Boston, Massachusetts, USA

Using systems engineering to analyze the root causes of harm in the ICU, Daniel Talmor, MD, FCCM, vice chair in the department of anesthesia, critical care and pain medicine, and Kenneth Sands, MD, vice president of quality and safety, are launching an initiative to look at the total "ICU ecosystem," as Talmor terms it. "We typically do individual root cause analyses to map out possible causes of harm and put in specific interventions to stop that harm," he says. "But looking at the burden of all harm may reveal many causes that have not yet been addressed." Checklists for such common ICU risks as central line infections or ventilator-associated events have been a start, but Talmor, Sands and their colleagues want to pull together all critical care checklists to learn more. "Context-sensitive" checklists that can assess the risk state of the entire ICU are the next step, Talmor says. "For example, we know that adverse events have been associated with using more travel nurses, unfamiliar new technologies, or caring for a higher-risk patient who takes attention from the patient next to him." Talmor and Sands will begin by analyzing in detail all 700 adverse ICU events that occurred in Beth Israel's medical ICU in 2012. Once they electronically capture the "burden of
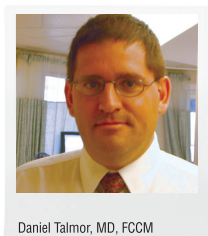
Daniel Talmor, MD, FCCM

harm," they plan to create a preliminary algorithm that will eventually become a "self-educating system" fed with risk data that can identify how adverse events happened.

CC: Why is this broader root cause analysis important?

Talmor: By identifying these larger risks, we can create applications and find interventions to decrease the risk state of the ICU, such as improving nurse-to-patient ratios or bringing in experts in new ICU technology. We think we will eventually be able to identify when the ICU is beginning to move into a risk state.

CC: What are the biggest challenges to this work?

Talmor: This is fairly avant-garde work. It requires a large team of physicians, nurses, social workers, patient advocates, information technology experts, and systems engineers. One of our major goals is to spread what we learn beyond academic medical centers.

CC: What advice would you give to hospital leaders and clinicians looking to implement this work?

Talmor: Never be happy with the current state. That's the real impetus behind this initiative.

Project Emerge
Johns Hopkins Medicine
Baltimore, Maryland, USA

Named for the processes and data needs that continue to emerge as researchers learn how to create a "system of systems" in the ICU, Project Emerge aims to create an integrated platform that pulls together all ICU monitors, devices and other data sources into a single tablet, allowing all components to "talk" to each other and operate in concert. The dual goal: to improve patient safety and clinician efficiency, and better engage patients and their families in their care. Peter Pronovost, MD, PhD, FCCM, senior vice president for safety and quality, and his research partner, Adam Sapirstein, MD, along with colleagues from 18 other disciplines at the university, soon will launch the project by feeding four questions into the tablet relative to seven possible harms in the ICU. "We are using the lens of harm prevention to tear down and rebuild the system," Sapirstein explains. The four questions – For which harms is the patient at risk? What therapies should he/she receive? Were therapies given in a timely manner? Did the patient get well? – should help prevent central line-associated bloodstream infections, ventilator-associated harms and infections, venous thromboembolism, decubitus ulcers, delirium, deconditioning. and care inconsistent with patient and family wishes and not aligned with patient care goals.

Peter Pronovost, MD, PhD, FCCM

CC: Why is this new overarching data system important?

Pronovost: Preventable harm is the third leading cause of death in the U.S. Our goal is to eliminate all harms, including patient disrespect.

CC: What are the biggest challenges to this work?

Pronovost: One of the most frustrating challenges is getting vendors, (especially EMR vendors), to open up their devices – called application program interfaces, or APIs – so that we can connect them and gain information to predict who is at risk for harm, recommend therapies, monitor if patients received those therapies, and learn what worked. Because vendors do not open their APIs, it takes a 100- to 1,000- fold more effort to get data out of these systems.

CC: What advice would you give to hospital leaders and clinicians looking to implement this work?

Pronovost: Healthcare organizations should require that, when they buy any health information technology, the contract states that patients, not vendors, own the data. They should also require that the vendor allow the device to connect to other devices and that they will publish the APIs. Healthcare providers need to reframe the conversation so that the technology serves their needs. ◬