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WHAT'S NEW IN INTENSIVE CARE

ICU design in 2050: looking into the crystal ball!

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Some questions, but no answers yet: will illnesses, diagnostics and therapies be very different in 2050 than today? Will acute or chronic organ failure, immune or genetic problems, or sepsis be addressed with supportive care or bioartificial organ replacements, primary organ regeneration or other interventions at the genetic, cellular or immunologic levels? What will technology, connectivity and informatics advances look like? The answers to these questions will all ultimately impact intensive care unit (ICU) design going forward.

Advances in ICU design

We believe that at the generic level, ICU design will continue to be inextricably linked to patient, family and staff needs, hospital design concepts, space distribution, informatics capabilities, approaches to ICU care and unit management, technical achievements in the areas of diagnostics, therapeutics, and infection control, local and societal resources and regulatory mandates. The most dramatic changes in future ICU design will occur primarily in newly constructed hospitals and ICUs. Existing ICUs with an approximate 20–30 year lifespan will continue to have occasional technology and cosmetic upgrades. However, the technology of 2050 may also allow for ICU spaces to be created virtually anywhere within or outside the hospital in very short time periods; thus, our current concept of a clearly demarcated and long-term ICU space may evolve. For simplicity of our 2050 ICU design speculations, this article will focus on the future of traditional well-delineated and hospital-based ICU spaces.

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Hospital and ICU spaces

Currently, we think about hospital and ICU space distribution as the percent of hospital beds used by ICUs. The larger hospitals maintain the highest ICU bed percentages and the greatest number of specialty ICUs. We anticipate that ICU diagnostic and therapeutic technologies will lend themselves to supporting all types of ICU patients in the future. If so, ICU design and staffing will be simplified, as specialized ICUs will be less necessary and ICU beds can be efficiently located within a large area with broad-based supportive services, sustained by an efficient power and informatics infrastructure.

ICU rooms and beds

We foresee two ICU design approaches depending on ICU space and resource constraints. The first is one patient per room with actual walls composed of LCD glass (enabled for privacy or disabled look through). The second is multiple patients in one open space with virtual walls (providing virtual privacy and real infection control).

The ICU patient room environment will be adaptive to the patient, visitors and staff, and programmed to monitor and automatically control temperature, light, sound and air. Beyond the use of surfaces that actively prevent infectious colonization, automated surveillance systems will provide warnings of the presence of airborne-, device-, furniture- or skin-based pathological microbes and will activate targeted air and surface decontamination and purification systems. Large displays with diurnal, seasonal and calming graphics and sounds with digitally imported family or home pictures will provide serenity and familiarity as well as entertainment.

ICU beds

ICU bed design has improved over the years with the integration of enhanced mattresses, electronic controls, monitors, connectivity and low-level mobility support.

We speculate that the modifications going forward will continue to be a mixture of iterative improvements and transformative changes. The most dramatic advance may be the transition from an open ICU bed into a fully enclosed environmentally controlled patient biosphere capsule (Fig. 1). Operationally, the capsule will function either fully closed or open at various degrees to expose the patient to the ambient environment, local medical personnel and visitors.

The "mattress" will prevent integument breakdown by a mixture of a supportive bed and air suspension therapies. On-board exoskeleton systems will allow for mobility and exercise both within and external to the capsule. The mattress and exoskeletons will be "reprinted or refabricated" internally as necessary to adapt to patient needs using local 3D computing and printing systems. Both the interior and exterior of the biosphere as well as the patient's skin and any invasive devices will be monitored for infectious colonization and on-board systems will cleanse the colonized areas during and in-between patient occupancy using non-toxic processes. Automated waste removal systems that feed directly into closed evacuation or elimination systems will be included.

Advanced cameras and holographic systems with full human touch capabilities will allow virtual personal contact by family members and staff even without the visitors and staff being physically present when the capsule is fully closed. A patient helmet/visor will provide neurological and psychological analytical and translational systems that convert or transform patient emotions and thoughts into avatar-based expressions and communications as needed. Conversely, the visor will also bring images and sounds of home to the patient to intensely personalize the ICU experience and improve orientation and decrease delirium.

Monitoring, diagnostics, therapeutics, and informatics

Organ- and system-based diagnostics, imaging, therapeutics, environment and "holographic" telemedicine

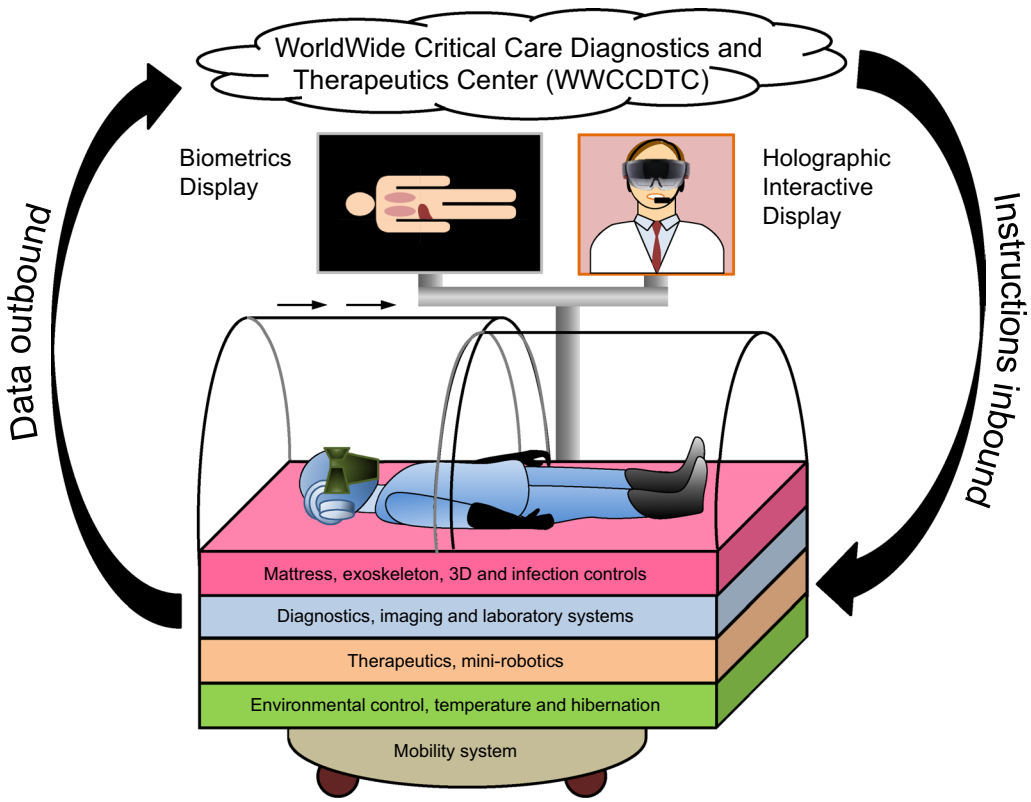

Fig. 1 ICU biosphere capsule. The ICU bed of the future will render care within a capsule that opens and closes and provides environmental monitoring and control, as well as ongoing biometrics display using noninvasive sensing technologies. Diagnostics and therapeutics will be rendered through a mix of on-board systems, local personnel and mini-robots, holographic intensivists and consultants all directed by an advanced informatics systems linked to the WorldWide Critical Care Diagnostics and Therapeutics Center (WWCCDTC). Mobility will be achieved using in-line exercise systems and exoskeletons to enable a full range of motion. Neurological and psychological analytics, patient communication and entertainment, and family interactions will be enabled through a virtual reality visor. Suspended hibernation systems will be available in the capsule for those patients who cannot achieve a successful clinical outcome

will be integrated within the capsule. The patient will wear a customized outfit with embedded sensors that will provide continuous noninvasive surface and deep organ monitoring. The capsule will also house miniaturized and integrated dynamic physiological imaging devices as well as monitors that track the body at the blood, organ system, cellular, plasma, and genetic levels.

The diagnostic imagers will provide a virtual conduit for the clinician to travel through the body visualizing all vessels, airways, gastrointestinal tract, etc. The clinician will be able to "virtually" sample tissue and fluids for immediate analysis by visualizing the integral components (i.e. DNA, tissue structure) of the fluids or tissues, followed by computerized reconstruction obviating the need to physically obtain samples. The therapeutic modules will also be integrated with 3D printers to generate individualized stents and other implantable devices and organ support. At the direction of the intensivists, mini-robots will handle diagnostics and therapeutics that cannot be addressed virtually.

The ICU bed biosphere will contain a multi-modality therapeutic platform (i.e. oxygenation and ventilation, natural or bioartificial organ support, renal replacement therapy, cytokine adjustment and medications). The therapeutics system will automatically combine or seamlessly transition care from one modality to another. Devices will be loop-controlled with direct feedback systems from the patient's monitored data. Additionally, the on-board neurological module will implant psychological therapies to counteract the potential of delirium and post ICU distress syndromes.

The bed systems will be managed by the artificial intelligence (AI) oversight program of the WorldWide Critical Care Diagnostics and Therapeutics Center (WWCCDTC), a massive dataset of critical care medicine cases, experiences, the most current research and care algorithms; this system is fully autonomous and capable of deep learning and analytics. The WWCCDTC contains the patient's medical history and psychological constitution, and determines and tracks in real time the patient's clinical conditions and changes, and guides diagnostics and oversees therapeutic delivery of care. Data will be displayed in a variety of customizable formats on the bedside display and remotely. The AI systems will simultaneously notify the critical care team of major clinical problems and automated corrective actions, and will also alert the CCM team when new research dictates a change in protocol. Alarms, quietly delivered, will no longer play as prominent a role as today, as the WWCCDTC and the bed's internal informatics, diagnostics and corrective systems will efficiently and expeditiously address most conditions.

Providers

With the adoption and integration of these advanced technologies, the approach to ICU providers will evolve. A local cadre of highly trained critical care nurses and informatics staff will be needed. However, the capsule biosphere and the WWCCDTC system, with its holographic intensivists and consultants, programmed to communicate with the patient, family members and staff simultaneously adjusting to their intellectual, clinical and emotional requirements, will alter the need for local intensivists. Clinicians and academic experts in all areas will support care, but remotely and as needed, as core ICU care will rely upon bedside technologies, virtual evaluation and supervision, and the mini-robots.

Conclusion

It is quite challenging to peer into the crystal ball and visualize what may be coming our way down the road. We hope that this speculative and intriguing read gives our readers a glimpse into a potential future. If the ICU capsule system becomes a reality and multiple capsules exist in one large controlled ICU space, this multi-patient environment would be similar to the setting used in the 1950s to care for polio patients with respiratory failure who were enclosed in ventilator capsules known then as iron lungs. What an interesting irony, a return to the past to achieve the future!

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Compliance with ethical standards

Conflicts of interest

Neil Halpern is a consultant to Bernoulli Health, Airstrip, Pronia Medical and Instrumentation Laboratory. Jozef Kesecioglu has received lecture honoraria from BD and QXV Communications Ltd. Diana Anderson declares that no conflicts exist.