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The Next Generation of Operating Rooms

Abstract | ***Article***

Advancements in communication, information technology, digital imaging, and robotics have aided the development of new surgical techniques, allowing surgeons to perform procedures with better outcomes, such as enhanced patient safety, less pain, shorter recovery periods, and reduced system-wide costs. New surgical techniques such as minimally invasive surgery, image-guided computer-assisted surgery, and robotic-assisted surgery bring new technologies into the operating room (OR). It has been a challenge to accommodate new technologies, due to limited access for new wiring and lack of structural support in the conventional hard-ceiling construction of ORs. Often, ad-hoc solutions are found, such as placing new equipment on another cart, resulting in ORs that are crowded with carts, monitors, and electronic equipment with wires across the floor creating unsafe working conditions for the staff.

An increasing number and type of procedures are now being performed with minimally invasive techniques. A fresh approach is needed to integrate various technologies into the physical layout of the OR. Details of the OR design should facilitate optimal workflow for new surgical techniques, maintain a sterile environment, and provide flexibility to accommodate new technology over longer periods of time.

This article outlines specific design considerations and solutions for the next generation of ORs that provide the flexibility to accommodate current and emerging surgical techniques. Strategic location of doors, orientation of the OR table, and ancillary areas are suggested, along with a modular ceiling layout for support of ceiling-mounted utilities and booms.

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History and the Current State of the Art

Historically, surgeons have relied primarily on their direct vision of open surgical sites to perform procedures. Open-incision surgical procedures are generally followed by long recovery periods for patients. Dr. Kurst Semm, a German gynecologist, invented the automatic insufflator in 1960, which led to the development of minimally invasive surgical techniques in the 1980s. In 1987, Dr. Phillipe Mouret performed the first video-laparoscopic cholecystectomy in Lyons, France. By the 1990s, minimally invasive surgery was a common occurrence. An increasing number and type of procedures are now being performed with minimally invasive techniques with better outcomes, such as enhanced patient safety, less pain, shorter recovery periods, and reduced system-wide costs. Advancements in communication, information technology, digital imaging, and robotics have also aided the development of new surgical techniques, allowing surgeons to perform procedures with greater patient comfort, safety, and accuracy.

Following is a brief overview of current and anticipated surgical techniques that have an impact on the operating room (OR) design:

- ***Minimally invasive surgery (MIS). Surgeons perform a procedure by inserting surgical instruments, a light source, and an endoscopic video camera through keyhole incisions in the body near the surgical site and manipulating the instruments while viewing on the video monitors. MIS procedures require an ergonomic location of video monitors and electronic equipment in the OR (Figure 1) as well as the ability to control lighting for optimum viewing of the monitors.***

Figure 1. Minimally invasive OR at Parker Adventist Hospital
(Photo courtesy of HKS Inc.)

- ***Image-guided and computer-aided surgery. Modern computer-aided surgery techniques utilize radiography, fluoroscopy, computed tomography, sonography, and magnetic resonance imaging devices as navigation systems for greater accuracy. Three-dimensional image-guided systems are being utilized for neurosurgical procedures that require precision. Portable imaging systems generally used for these procedures require parking spaces in or adjacent to the OR.***
- ***Robotic-assisted surgery. Robotic surgery has two main components: the surgeon's console and a robotic arm above the patient table. The surgeon sits in a console and manipulates the master controls while looking into a viewer that displays images obtained from an endoscopic camera inside the patient's body. A slave robotic arm holds the surgical instruments inserted into the patient's body. This master–slave manipulator allows surgeons to perform more-precise surgical procedures than those possible with conventional endoscopic surgery. Future minimally invasive gene therapy may utilize a combination of surgical robots and navigation systems.***

Impact of New Surgical Techniques on Operating Room Design

New surgical techniques bring new technologies into the OR. This has been a challenge due to limited access for new wiring and lack of structural support in the conventional hard-ceiling construction of ORs. Often, ad-hoc solutions are found, such as placing new equipment on another cart, resulting in ORs that are crowded with carts, monitors, and electronic equipment with wires across the floor, creating unsafe working conditions for the staff.

A fresh approach is needed to integrate various technologies into the physical layout of the OR. Details of the OR design should facilitate optimal workflow to support new surgical techniques, maintain a sterile environment, and provide flexibility to accommodate new technology over longer periods of time. Specific design considerations for an OR are described in the following sections.

Operating Room Size

A typical response to equipment-crowded ORs is a request for increasingly larger ORs. However, experience has shown that the most valuable space in an OR is the space immediately surrounding the patient table. The prime space around a patient should be as free of carts as possible to provide work area for staff. Utilization of ceiling-supported utilities and equipment booms allows ergonomic organization of equipment around the patient. The space

along the walls can be utilized for parking supply carts. This frees up floor space and protects staff from the impact of wires, hoses, and carts on circulation, enhancing patient safety and workflow efficiency. An efficiently organized OR with an area of 600–650 square feet and a 24–25 foot width provides adequate space for most procedure types.

Operating Room Layout

The orientation of the patient table and the placement of doors is important for maintaining a sterile field and an efficient workflow in the OR. Figure 2 shows a layout of an OR to maintain the sterile work zone for surgeons and surgical staff. After evaluating various layouts, the best location for the equipment boom was found to be on the sterile core side. This arrangement allows the equipment boom to be placed anywhere along the OR table to facilitate procedures on any part of the patient's body. Placement of the equipment boom away from the OR door also minimizes disruption when the patient is brought into the OR. A workstation facing the OR table is needed in the OR for documentation as well as for management of various systems and components. The optimum location for the workstation is adjacent to the door between the OR and the sterile core. Space should also be designated in the inside corner of the OR for future robotic systems. In order to reduce medical errors and provide flexibility of use, all ORs should be identical in their layout (Figure 3).

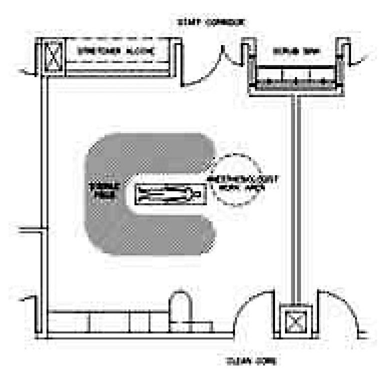

Figure 2. Sterile work zone layout

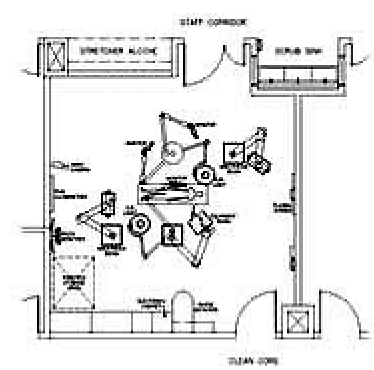

Figure 3. Typical OR layout

Ceiling Layout and Design

Ceiling design is critical to a functional OR and for flexibility to accommodate current and future needs for ceiling-mounted booms and utilities. Figure 4 shows a modular structural system with seven mounting locations to support utilities, monitors, and equipment. Each mounting location can support multiple arms for equipment, monitors,

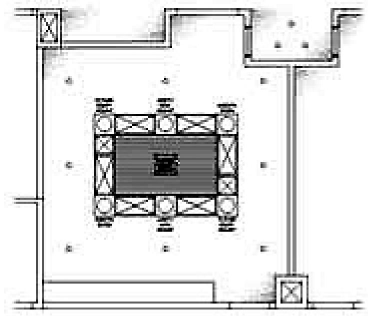

Figure 4. Modular layout for OR ceiling to support ceiling-mounted equipment and utilities.

and surgical lights. Removing the adjacent light fixtures provides access for maintenance of the ceiling-supported booms. Locating surgical lights and monitors along the centerline on either side of the patient table provides clearances for a portable c-arm unit. Additional mounting locations in the ceiling are intended to support future equipment and booms. The center mounting location above the patient is reserved for a future ceiling-mounted robotic arm.

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers recommends a vertical downdraft air-curtain system to reduce the risk of exposure to airborne impurities. HEPA-filtered air is supplied to the OR via diffuser panels located directly above the patient. The air is returned through vents near the floor, on the perimeter of each OR.

OR lighting should be designed to provide a wide range of lighting levels. A ring of fluorescent lights around the diffusers and an outer ring of dimmable down-lights provide flexibility of OR use. The fluorescent lights have one set of white lights and another of green lights that are switched separately. The green lights reduce glare for comfortable viewing of monitors during MIS procedures.

Accommodation of Imaging Technology

Placement of support rooms between ORs provides future flexibility. These adjoining rooms can be used as specialty supply or equipment storage for ortho, neuro, or cardiac procedures and can also be converted into control rooms or storage space for portable imaging devices. ORs should also be constructed with lead shielding to provide safety measures for current and future imaging technology. Picture archiving and communication systems (PACS) monitors mounted on the patient's foot-side wall can provide the ability to view high-quality digital images during procedures.

Data and Communication Systems

Many stand-alone data systems, communication, and voice-recognition technologies have been developed for ORs. Efforts are underway to develop an open-system infrastructure that will integrate all technologies in the OR.

Such a system would provide instant access to patient history, lab tests, and digital imaging with touch-screen, wireless, or voice-activated controls and would enhance operational efficiencies and patient safety. A dedicated equipment room within the surgery suite would be the connectivity hub for the various technologies.

A command center with interactive live audio-visual, two-way connectivity to each OR should also be provided for coordination of OR schedules, multidisciplinary collaboration, and teaching.

Conclusion

The next-generation OR will be based on successful integration of emerging technologies to provide an efficient and safe work environment for staff, better patient outcomes, and a reduction in overall costs. The Center for Integration of Medicine and Innovative Technology, based in Cambridge, Mass., is currently working on an Operating Room of the Future project. The project will examine the impact of individual technologies and systems integration on the safety and efficiency of patient care, with a year-2008 vision of delivering a new way to manage the surgical patient from check-in to discharge.

References

1 Mount Sinai Minimally Invasive Surgery Center, www.mssm.edu.

2 The Center for Integration of Medicine and Innovative Technology (CIMIT), www.cimit.org/orfuture.

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