Preoperative Planning and Designing of a Fluorocompatible Endourology Operating Room

Ravindra B. Sabnis, M.D., Shashikant Mishra, M.D., Rajan Sharma, M.D., and Mahesh R. Desai, M.D., FRCS (Eng), FRCS (Edin)

Abstract

Background and Purpose: A dedicated fluoroscopic-compatible operating room (OR) for endourologic procedures, such as percutaneous nephrolithotomy and ureteroscopy, is structurally and functionally different from the general OR. Publications with practical details are scarce, imposing a challenge in construction of such an OR. We outline a practical approach for the design and construction of a modern fluorocompatible endourology OR.

Methods: There were no publications related to a dedicated endourology OR in Medline. A search was then performed for English language articles on OR designing, fluoroscopy in the OR, data archiving, and data relay. We also surveyed the existing endourology OR in different hospitals and analyzed the available technology for audiovisual capture and relay in surgery. This article was then prepared, covering the relevant areas on designing a dedicated fluorocompatible endourology OR.

Results: Close cooperation and interaction between an architect and expert construction manager for designing, development, and construction of an OR are necessary. Strategic equipment placement with booms is essential to increase the efficiency and safety within the surgical space. Distinct features of an endourology OR are thickness of the walls for radiation protection, wide OR gate, central floor water exit drain, fluorocompatible rotatable OR table, C-arm unit, minimum three hanging thin-film transistor (TFT) screen monitors, and endoscopic equipments supported on a boom. The anesthetic boom should be retractable and movable from one end of the OR table to other. The OR should have an electronic workstation strategically located at one corner for data capture, archiving, and telementoring. Data relay of the OR procedure is facilitated by a control room located in the vicinity of the OR.

Conclusion: Designing the layout of the OR is extremely important, necessitating thoughtful planning to provide hassle-free movement, comfort to the surgeon, and efficient data archiving and transmission during a surgical workshop.

Introduction

Adapting the modern operating room (OR) for endourology is a challenge that begins with the more general problem of designing the OR. There is a need for safety, convenience, and economy in planning of a dedicated endourology fluorocompatible OR complex. It is necessary that planning is perfect, keeping in mind future needs, because subsequent changes or renovations are tedious and pose considerable economic burden. Scarcity of publications and guidelines in this regard results in inadequacies that are realized later. This article elaborates the planning necessary for an endourology fluorocompatible OR to carry out procedures such as percutaneous nephrolithotomy (PCNL) and ureteroscopy (URS).

Designing and Planning a Dedicated OR

The design and layout of the OR are extremely important. State-of-the-art design enables hassle-free movement of
equipment, the ability of the surgeon to view multiple screens, efficient data archiving, and management of the relay system. It is necessary to anticipate the average number of procedures that will be carried out and to plan for possible growth over the next 10 years. Meeting these challenges requires a multidisciplinary team and a well-planned process that addresses all aspects from long-term goals to exacting details.

Design and construction firms apply experience and expertise to handle the intricacies of the dedicated OR. Select an architect and construction manager with considerable healthcare experience, including surgical suites and ORs, and a track record of delivering complex projects on time and within budget. Architect, engineer, equipment planner, construction manager, and key equipment vendors should all be included in the team.

Strategic equipment placement is essential to increase efficiency and safety within the surgical space. Equipment booms and other ceiling-supported equipment are used increasingly in ORs because of the advantages they offer. Equipment booms are ceiling-mounted, articulating arms that support equipment, such as lithotripters, light source, endocamera, electrocautery, anesthetic gas connections, and electric plug points. The booms significantly reduce clutter and interconnect equipment by using the space above the false ceiling, thereby enhancing sterile setup and less maintenance as a result of cable breakage. Booms, however, need a significant amount of structural support that must be coordinated with the lighting, mechanical, and electrical systems above the false ceiling.

General Design for a Fluoroscopy-Compatible Endoscopic OR

Size

The size of a general OR is 20 \( \times \) 20 \( \times \) 10 feet. Because endourologic procedures need multiple large pieces of equipment, such as the C-arm, laser, ultrasound machine and the workstation, the recommended size would be 23 \( \times \) 23 \( \times \) 12 feet.

Ceiling

The height should be approximately 12 feet at the false-ceiling level. The overall height of the OR should be approximately 14 feet to compensate for the over-ceiling space of 2 feet. The over-ceiling plan is an important feature. This space includes:

1. Cables for various multiple equipment booms, such as oxygen, nitrous oxide, compressed air, vacuum, electrical wires for different equipment.
2. Air conditioning pipelines.
3. Data relay wires in various hanging arms.

Floor

There should be a central drain outlet from the floor centered underneath the OR table. The floor should have a slight tilt from all the walls converging at the water drain outlet. The surface of flooring must be slip resistant, strong, and impervious with minimum joints—e.g., mosaic with copper plates for antistatic effect or jointless conductive tiles/terrazzo, linoleum, etc. The recommended minimum conductivity is 1 m ohm and maximum 10 m ohms.

Walls

The radiation protection of a general purpose fluoroscopy suite necessitates a wall thickness in all directions equivalent to 2 mm of lead. While lead is always accepted as the standard material for radiation protection, ordinary building materials may be equally suitable, provided that they are thick enough. For wall building, 15 cm of concrete or 25 cm of brick with plaster are approximately equivalent to 2 mm of lead. On the walls, laminated polyester or smooth paint provides a seamless wall; tiles can break, and epoxy paint can chip out. Light color (off white, light blue, or green) washable paint will be ideal for walls. There should be a provision for a radiograph illuminator, wall-mounted camera, plasma screen, and drawers for endoscopic disposables recessed into the wall. The surface/flooring must be slip resistant, strong, and impervious with minimum joints.

Main door

The main door to the OR has to be of adequate width (1.2–1.5 m) to facilitate smooth patient trolley, laser, C-arm unit, and ultrasonography machine entry and exit. Sliding doors are preferred so no air currents are generated.

Electricity

The following criteria are ideal with respect to electricity in the OR:

1. Use of circuit breakers/interrupters is desirable if there is an overload or ground fault.
2. Power line (as per country specification).
3. Suspended ceiling outlets should have locking plugs to avoid accidental disconnection.
4. Insulation around ceiling electrical power sources should withstand frequent bendings and flexings.
5. OR electrical networks need to be connected to the emergency generators with automatic two-way changeover facility.

Grounding. This is an important feature but often neglected. All electrical equipment in the OR needs proper grounding. It should be common for all equipments and should come from a main source (like uninterrupted power supply). Grounding offers protection from macroshock. The grounding of the OR, control room, auditorium, or wherever transmission is going to be relayed should be at one single place. If every place has its own grounding, then the picture quality of the transmission becomes unclear and shaky. Many times this fact is neglected or not realized, resulting in much trouble later on.

Lighting

Different levels of lighting are necessary in the OR. The flat TFT monitor display in front for endocamera vision requires the installation of dimmable lighting to create optimum light levels. Color-corrected fluorescent lamps to produce even illumination of at least 500 lux at working height, with minimal
glare, are preferred. Means of dimming may be needed during endoscopic surgeries. In the operating area, the overhead light should be shadowless and give 25,000–125,000 lux of light (50,000 to 100,000 lux at the center and at least 15,000 lux at the periphery), as in a general OR. Light-emitting diode (LED) light provides unique multicolor temperature facility, which proves helpful during open surgery. This may be necessary for emergency exploration of an endoscopic procedure complication. LED light has the advantage of lower heat generation, adjustable light characteristics, and unlimited life span. Lights should be freely movable both in horizontal and vertical ranges. Equipment booms for lighting are mostly preferred.

**OR table**

The OR should have a mobile, modular operating table with electronically controlled hydraulic drive, battery, and mains operation. It should have a stable base construction, rotatable top, and large twin disk casters for easy travel and maneuvering. The operating tabletop is subdivided into multiple sections: Head plate, upper back plate, lower back plate, seat plate, and leg plates for the lithotomy position. The entire tabletop should be without crossbars for it to be compatible with fluoroscopy. Provision for kidney bridge elevation is helpful if open exploration is needed. There should be multilayered radiolucent foam padding for patient comfort and safety. The width and weightbearing capacity should be adequate.

**C-arm**

A mobile C-arm unit is a must for a urology-dedicated OR. It should have balanced and graduated movements in any angle. It should have a high quality image for quick and precise diagnosis and monitor brightness (image quality should not affect in changing lighting environments). The image intensifier should have Digital Imaging and Communications in Medicine imaging capabilities, last image hold memory, image processing, text/graphics, and other functions. Image display should be on a high resolution TFT monitor. The data output from the C-arm may also be connected to one of the hanging screen monitors to ease the vision to the operating surgeon.

**Sterilization**

There should be a separate room for cleaning and disinfection of endoscopic instruments. This area should have adequate ventilation to exhaust toxic vapors and airborne pathogens. The area must also be large enough to accommodate the cleaning and rinsing of endoscopes and accessories. Automated processing disinfection machines for endoscopic instruments are desirable. There should also be a provision for manual rinsing and cleaning, however. Endoscopic procedures need many delicate and expensive pieces of equipment, such as a telescope, flexible ureteroscope, or flexible nephroscope. Rapid sterilization is necessary if many procedures are to be performed in a day. We recommend that the OR have a nearby facility with a hydrogen peroxide sterilization system (for example, Sterrad, Johnson & Johnson) that provides a high level of sterilization within a processing time of half an hour.

**OR Configuration for Endourologic Procedures**

This aspect of an endourology OR is different from that of the general OR. The OR equipment has to be strategically located in the OR. This minimizes procedural time by means

---

**FIG. 1.** Surface view of a dedicated fluoroscopy-compatible endourology operating room. See Figure 2 for key to numbers.

of intuitive control and provides shorter changeover times because equipment settings can be freely defined and activated. The OR should integrate cameras, lights, videoconferencing units, endoscopic and anesthetic equipment, C-arm, and the operating table to be operated from the sterile area.

The anesthetic trolley should be movable on a mobile cart supported with an anesthetist equipment boom. It should change the location on the cephalad end of the patient as per the side of the procedure. There should be a minimum of three hanging display screen monitors supported by the boom to be placed on the front end of the surgeon (Figs. 1 and 2). The display monitors should be interconnected with changeable viewing. The display on the screen should include fluoroscopic image, endovision image, ultrasonographic image, and hospital information management system (HIMS) image. The hanging screens should be movable on the boom in all directions.

Quite often, surgery is needed on both sides, with the patient under the same anesthesia. This can be done in two ways. In the first case, the C-arm unit remains fixed while the anesthesia boom and table rotate by 180 degrees. In the second case, the anesthesia trolley and table remain fixed while the surgeon’s position changes. Display screens also change directions accordingly. C-arm position, surgeon position, and, accordingly, display screens change directions. The light cable source, lithotripsy device, endocamera cable, and irrigation tubing are attached to the equipment boom on the right side behind the surgeon. Figure 2 shows the essentials of strategic equipment placement in a case of left PCNL.

**Modular operating theater**

The prefabricated modular operating theater offers the advantage of speedy construction combined with design, future expansion, and development in surgical technique while simultaneously providing a structure of the highest quality and standards. The standard package includes an operating table, operating lights, endoscopy equipment, and a range of monitors that surround the patient. Currently, two endourology-dedicated modular ORs are available from Karl-Storz, Tuttingen, Germany, and Richard Wolf, Knittlingen, Germany; they can be installed on demand by the respective technical teams.

**Data Archiving**

In the current era of information technology, audio visual (AV) capture, archival and relay have become a frequently used teaching and training aid in surgery. Customized OR software can be designed for individual needs. The following

---

**FIG. 3.** Data archive through operating room workstation. AV = audio visual; USG = ultrasonography; OR = operating room; ISDN = integrated services digital network; DVD = digital versatile disc.
is the outline to provide the data management system that includes OR workstation and data capturing units.

**Workstation**

In the modern OR, there should be an electronic workstation located in one corner. The workstation (Fig. 3) has inputs via cables that are connected to the surface cameras, C-arm, ultrasonographic machine, and endovision camera. The cable input enters the OR panel where the composite AV signal is converted to S-video signal. The S-video output can be transmitted to any of the hanging display monitors (TFT screens) in front of the surgeon. Each screen has multiple cables; hence, any image (fluoro/endovision/HIMS) can be viewed on any screen. The workstation also has a video processor with digital video (DV) output. High-definition video is thus captured and recorded on digital versatile disc (DVD) for archiving and future editing.

The OR panel is also connected via two-way circuit to the HIMS. The necessary information, including the history, examination, radiographs, CT images can be relayed to the hanging display monitor in front of the surgeon during the operation. At the same time, the OR details can also be fed to the HIMS for data archiving. The workstation has three integrated digital network (ISDN) line connections.

**AV data capture**

Endovision camera. Three-chip systems provide better overall image quality than one-chip systems. The use of high-definition cameras and monitors during minimally invasive procedures can provide the surgeon and operating team with...
more than twice the resolution of standard definition systems. If a high-definition camera is selected, it is imperative to invest in computer hardware and software capable of editing and outputting high-definition video. A signal can be taken directly from the line out plug of the endocamera processing unit and inputted directly into an OR panel on the workstation.

Surface camera. There are many options for providing good quality video capture in viewing endourologic procedures on the body surface. At least three surface cameras should be present in the OR for video capturing. One camera is on the tabletop; it may be mounted on a light source or can be kept separate on a hanging boom. The second should be wall mounted at a height near the ceiling, which will give an overview of the full OR. This camera can be zoomed in or out by remote control as needed. The third camera should be on one of the TFT screens. The advantage of this position is that during videoconferencing, the surgeon, while performing the procedure, can watch the screen and simultaneously talk to the audience in the auditorium. The surface camera located at this position captures his face for transmission and gives the impression in the auditorium as if the surgeon is facing them and talking.

These cameras are available from any number of consumer electronics outlets and in a variety of formats. Although it is possible to obtain reasonable quality video recordings by using the automatic exposure settings on most cameras, this often necessitates diversion of the operating light away from the operative field to avoid overexposure of the image.

Fluoroscopic and ultrasonographic image. Most C-arm units and ultrasonographic machines have a coaxial output jack on the back of the device. To arrange for data transfer, the coaxial jacks need to be connected with a coaxial cable and connected to the OR panel.

OR Data Relay

Most surgical meetings at present devote a major session to the live operative workshop. Many times, live transmissions are performed by erecting temporary facilities, which involves high cost without providing optimal quality. If the transmission facilities are frequently used either for conference workshops or teaching, then it makes sense to install these facilities during construction of the OR. Once the cabling is done, it avoids recurrent cost and, in the long run, proves economical.

There are various components that need consideration for the state-of-the-art transmission relay system. Preliminary knowledge of the individual component of the relay system is essential for optimum utilization.

Control room

A small control room in the vicinity of the OR is helpful for a data relay system. The control room receives cable connections from all of the data capturing components. This control room has the capability to route voice, video, and data to and from the surgical suite. Information is not only distributed within the OR but also to remote locations, such as image archiving systems, class room, and auditorium. One such electrical circuitry is shown in Figure 4.

To channel transmit OR proceedings to remote places, the composite AV signal from the OR is first relayed via cables to the control room. Here the signal is passed through the modulator, combiner, and video mixer. The emerging radio-frequency (RF) signal is thus transmitted to remote places. One such signal can also be seen in the OR on the plasma screen recessed on the wall. The operating surgeon through the microphone can interact with observers at remote places in a similar way.

There are advanced video transmission features that can be incorporated in the relay system. Here the AV signal is relayed to the video mixer for picture-in-picture (PIP) and channel preview support. The PIP zoom function allows the personal computer image as the main screen with a video subscreen inserted. The video subscreen can vary in three sizes from 1/4, 1/9, and 1/16 of the main screen and can be relocated to anywhere on the computer screen.

Similarly, signals can be relayed from remote places to the OR, and this is depicted in Figure 5. For example, the AV signal from the auditorium is sent to the modulator in the auditorium, and the emerging RF signal is then relayed to the control room. The signal is then sent to the modulator, combiner, and audio mixer. The final amplified RF signal can be relocated to any remote place, including transmission into the plasma screen in the OR other location.

For teleconferencing to distant places and countries, an ISDN network facility should be available and connected to the computer in the workstation in the OR (Figure 6). Just like a regular telephone line, ISDN enables the OR transmission to be dialed to any ISDN location anywhere in the world. Through the B channel, ISDN line can support simultaneous two-way communication for two devices, such as a computer and a telephone, or a computer and a video camera for teleconferencing. With the help of the ISDN line, the data can be sent to remote locations and at the same time the data can be received in the computer on workstation and then can be sent to the control room and then transmitted everywhere.

Conclusion

The dedicated OR design is an essential tool requirement for a urologic hospital for efficient state-of-the-art care in the modern information technology world. The older cart-based paradigm restricts the ergonomic configuration of the OR and creates potential mechanical, electrical, and biologic hazards to the patient and OR staff. To decrease clutter, ease personnel movement, improve ergonomics, maintain the sterile field, and facilitate the use of advanced imaging, an appropriately designed OR is essential. These design elements may prove to be critical to the next generation of dedicated fluoroscopy-compatible endourology suites and will facilitate further advanced procedures. The data archiving, management, and relay system enables efficient cost-effective transmission of data. Every operation can be recorded on DVD or in HIMS. Organizing a live operative workshop is immensely easy if this system is already installed during construction of the OR.

Disclosure Statement

No competing financial interests exist.
References

2. Gehrki B. Key decisions in designing a new OR. OR Manager 2002;18:15–18.

Abbreviations Used

DV = digital video
DVD = digital versatile disc
HIMS = health information management system
ISDN = integrated services digital network
LED = light-emitting diode
OR = operating room
PCNL = percutaneous nephrolithotomy
PIP = picture-in-picture
RF = radiofrequency
TFT = thin-film transistor
URS = ureteroscopy

Address correspondence to:
Ravindra B. Sabnis, M.D.
Department of Urology
Muljibhai Patel Urological Hospital
Nadiad, 387001
Gujarat
India
E-mail: rbsabnis@gmail.com