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How to Build a Cath-Lab Operating Room

Johannes Bonatti,[1] Thomas Vassiliades,[2] Wiley Nifong,[3] Heinz Jakob,[4] Raimund Erbel,[4] Erik Fosse,[5] Kalervo Werkkala,[6] Zeljko Sutlic,[7] Thomas Bartel,[1] Guy Friedrich,[1] Bob Kiaii[8]

[1]Departments of Cardiac Surgery and Cardiology, Innsbruck Medical University, Innsbruck, Austria; [2]Department of Cardiac Surgery, Emory University, Atlanta, Georgia, USA; [3]Department of Cardiac Surgery, Brody School of Medicine, East Carolina University, Greenville, North Carolina, USA; [4]Department of Thoracic and Cardiovascular Surgery and Cardiology, West German Heart Center, University of Duisburg-Essen, Essen, Germany; [5]Interventional Centre Rikshospitalet, University of Oslo, Oslo Norway; [6]Department of Cardiac Surgery, University of Helsinki, Finland; [7]Department of Cardiac Surgery, University of Zagreb, Zagreb, Croatia; [8]Department of Thoracic and Cardiovascular Surgery, London Health Science Centre London ON, Canada

ABSTRACT

Recent developments in cardiac surgery and interventional cardiology have led to the installation of integrated operating rooms that allow both surgical and endovascular procedures. These units offer surgical as well as angiographic equipment and personnel and therefore require special planning and design. A variety of integrated procedures can be performed. Hybrid coronary revascularization, percutaneous valve repair, and aortic stent-graft placement are current developments that are ideally performed in a cath-lab operating room. This review by an international working group of cardiac surgeons and cardiologists outlines the challenges involved with implementation of an integrated operating suite and suggests general planning and construction guidelines.

INTRODUCTION

A cath-lab operating room (OR) is a facility in which both surgical and catheter-based cardiovascular interventions or operations can be performed. Recent developments in interventional cardiology and cardiac surgery have prompted increased interest in such units. At present, few cath-lab OR are installed worldwide and little information on how to build such a unit is available in the current literature. Standards as how to establish and organize cath-lab OR are completely lacking. It is the aim of this review to point out the necessities for implementing these high-tech facilities, to discuss the main challenges involved with planning and constructing them, and to provide a basic view on issues of organization and team management. Basis for the information provided are discussions at the first, second, and third Integrated Coronary Revascularization (ICR) Workshops for Interventional Cardiologists and Cardiac Surgeons, held at Innsbruck Medical University 2004, 2005, and 2006 (www.icrworkshop.at). The authors of this paper were actively involved in knowledge generation about the topic at these workshops and do have personal experience with planning or running a cath-lab OR. Views into integrated operating suites are shown in Figures 1-3.

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Correspondence: Johannes Bonatti, MD, FETCS, Associate Professor of Surgery, Innsbruck Medical University, Department of Cardiac Surgery, A-6020 Innsbruck; 43-512-504-80631 or 23806; fax: 43-512-504-22528 (e-mail: johannes.o.bonatti@i-med.ac.at).

Synonyms

Several terms have been suggested and the following are currently used to briefly describe a cath-lab OR: integrated OR, hybrid room, angiography-OR, and high-tech OR. We will use all these terms throughout the conduct of this review.

WHICH PROCEDURES SHOULD BE PERFORMED IN A CATH-LAB OR

The necessity for installation of integrated OR can be derived from 2 major trends: cardiac surgery is becoming less invasive, and interventional cardiology is becoming more invasive. Following these trends, cardiac surgery requires more sophisticated imaging modalities in the OR and complex procedures in interventional cardiology demand full and immediate backup of cardiac surgery and perfusion technology. Table 1 lists current procedures that should ideally be carried out in a hybrid room. Hybrid coronary revascularization [Barstad 1998; Bonatti 2005a, 2005b; Kiaii 2005; Friedrich 2005; Srivastava 2006; Bonatti 2007], thoracic aorta endograft [Krohg-Sørensen 2003; Eggebrecht 2005], and endovascular valve repair [Vassiliades 2005] are the procedures that have recently received special attention and are probably the clearest indications for cath-lab OR use.

BASIC PRINCIPLES FOR PLANNING A HYBRID ROOM

There is no doubt that an interdisciplinary team of heart surgeons, interventional cardiologists, anesthesiologists, and other associated specialists should plan and run such a facility. Heart centers with close proximity of cath-labs and heart surgery OR probably have better prerequisites than hospitals with the classic separation that placed interventional cardiology in the internal medicine building and cardiac surgery in the surgery building. For such a situation it was agreed at the ICR workshop discussions that the hybrid room should

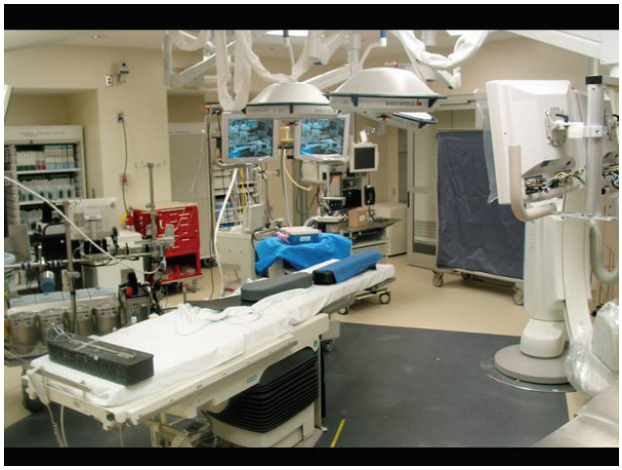

Figure 1. Cath-lab operating room at Emory University in Atlanta, Georgia, USA.

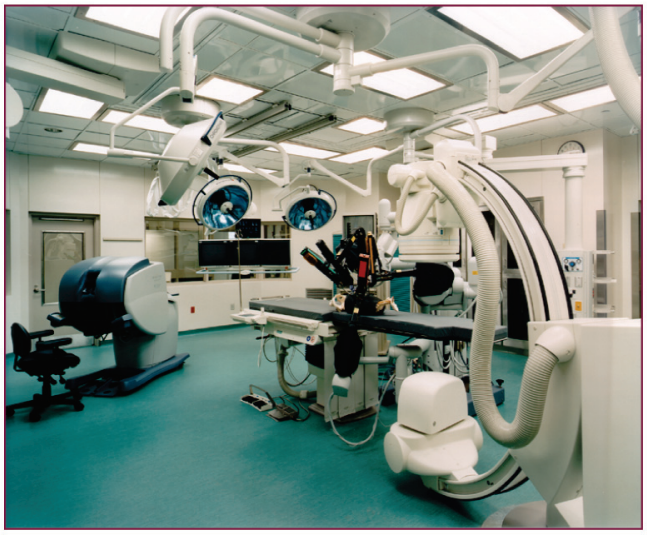

Figure 2. Cath-lab operating room at the London Health Sciences Center, London, Ontario, Canada.

be installed in the cardiac surgery wing. Two reasons speak for this: immediate availability of heart-lung machine and perfusionists, and availability of cardiac anesthesia and surgical intensive care. Reasonable proximity of the hybrid room to other imaging systems like computed tomography scanning or magnetic resonance imaging should be taken into consideration.

Size of a Cath-Lab OR

It is an obvious fact that a cath-lab OR should be larger than a standard OR [Fosse 2000]. The larger the better should be the basic principle for planning. At many hospitals, a standard size is used for construction of any OR irrespective of speciality involved. This is a major disadvantage for heart surgery, which is dependent on technologies such as sophisticated anesthesia equipment, heart-lung machine, transesophageal echocardiography, cell saver, consoles for atrial ablation, and flow measurement devices in coronary surgery. Minimally invasive procedures in cardiac surgery require thoracoscopy or even robotics with a demand for corresponding space. To integrate angiography into an already device-overloaded environment represents a highly significant challenge. In addition, contrast injectors and intravascular ultrasound are required. It needs special consideration which of these technologies need to be used simultaneously.

Mobile or Fixed Angiography Unit?

Simple integrated cardiovascular procedures can probably be handled with a mobile coronary angiography C-arm. Literature reports performance of hybrid coronary procedures [Bonatti 2005a, 2005b; Srivastava 2006; Bonatti 2007], valve interventions [Lichtenstein 2006], and thoracic aortic procedures [Zipfel 2007] with mobile C-arms. Discussants at the ICR workshops agreed that such mobile C-arms are probably underpowered for complex catheter-based interventions and fixed units should ideally be installed. Nevertheless, there was also agreement that a possibility to park the C-arm of a floor-mounted unit in a corner of the OR or in a side room would be ideal. See also Figures 3-5. Fixed angiography units offer the special advantage of isocentric imaging.

Monoplane or Biplane?

In an environment that is already filled with complexity, a monoplane angiography is probably sufficient. An exception would be a situation where complex work in electrophysiology is planned. For the current implantation technique of a

Table 1. Procedures that Should Ideally Be Performed in a Hybrid Operating Suite

(1) Coronary artery disease:
Hybrid coronary interventions
High-risk catheter-based coronary intervention (unprotected left main disease, other complex and high-risk morphology)
On-table angiography for quality control in coronary artery bypass grafting
(2) Valve disease:
Endovascular, catheter-based interventions on the heart valves
Aortic valve disease
Mitral valve disease
(3) Congenital heart disease:
Pulmonary valve disease
Integrated surgical and catheter-based procedures for atrial septal defect II, ventricular septal defect repair, and coarctation of the aorta
(4) Thoracic aortic disease:
Stenting or stent-graft placement to the thoracic aorta
(5) Heart failure/cardiac rhythm disturbances:
Cardiac pacemaker insertion
Automatic implantable cardiovascular defibrillator insertion
Insertion of devices for biventricular pacing
Hybrid procedures for treatment of atrial fibrillation
Endomyocardial biopsy
(6) Others
Fulminant pulmonary embolism

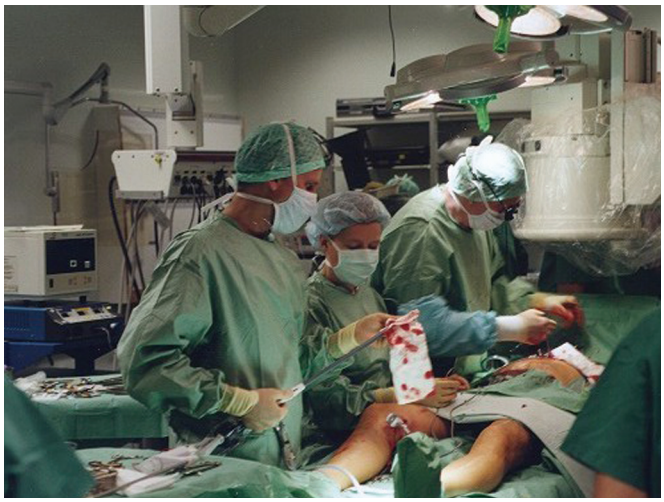

Figure 3. Cath-lab operating room at the Rikshospitalet Oslo 1. Coronary surgery in the first generation hybrid suite at Rikshospitalet, Oslo 1996-2000. Note that the C-arm was fixed at the head of the table; all communication between surgeon and anaesthesiologist had to be done through the C-arm. The table could be swiveled 90 degrees out of the C-arm, but during cardiac surgery the swiveling of the table was abandoned because of the risk of tearing out lines and endangering sterility (GE Advantix; GE, Milwaukee, WI, USA).

percutaneous pulmonary valve, biplane angiography units are recommended [P. Bonhoeffer personal communication].

Floor-Mounted or Ceiling-Mounted Units?

Ceiling-mounted angiography units are intriguing at first sight, but may cause discussions on hygiene because device rails could lie directly above the operating table.

Operating Table

The operating table should meet the expectations of both surgeons and interventional cardiologists. This fact is a special challenge. Tables that can be moved in a horizontal plane and can be tilted to allow vertical and lateral positioning of the patient are commercially available [ten Cate 2004]. Special care has to be taken that rails for mounting special surgical equipment like retractors or camera holders are available on the table. Placing the operating table in a diagonal position in the OR may gain space. A crucial element when selecting the radiological system and table is the possibility to have access to the patient all around and tilting of the table both head up and down and sidewise.

Anesthesia

Anesthesia technicians will have to modify position and work flow in an angio-OR. Integration of this subspeciality in unit planning is highly important. As the anesthesiologist at many cardiac surgery units operates transesophageal echocardiography, this person will play a significant role in integrated procedures. Anesthesiologists will have to adapt to a different position to the patient. The first generation of operating tables that serve the needs of both heart surgeons and interventionists can probably not be moved around. Induction of anesthesia therefore needs to take place in the OR. Ventilators have become space inefficient and heavy, and anesthesia operate transesophageal echocardiography machines, cell saver, and rapid transfusion devices. It should be a principle that all machines in such a hybrid room should be as small as possible. The spectrum of sizes available is probably wider in anesthesia than in robotic or angiography techniques and therefore these other devices provide more possibilities of space gain.

Monitors

In a standard cath-lab, the interventionist stands on the patient's right side and monitors are located on the patient's left side. This principle needs to be modified in a hybrid room. Surgeon/interventionist, assistant, anesthesiologist, and nurse, perfusionist should all have views of all major imaging and monitoring sources, including endoscopy. It was therefore suggested that a display of all these sources should be available in all 4 quadrants of an integrated room. A large number of ceiling-mounted flat screens is necessary. A quick switch between sources is of major importance. Care has to be taken that these ceiling-mounted flat screens do not collide with operating lights or other ceiling mounted equipment and that they are movable and flexible.

Control Room, Data Processing

In standard cardiology catheterization laboratories image and data processing is performed in a separate room outside the angiography unit. This would be ideal for the cath-lab OR as well but may be difficult to install in surgical OR floors without major rebuilding.

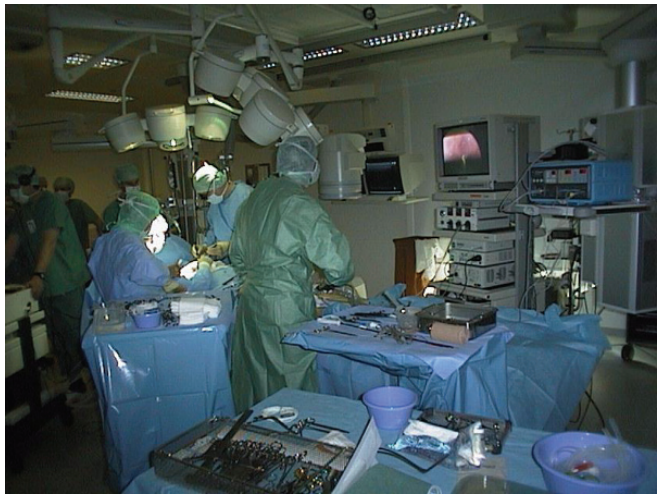

Figure 4. Cath-lab operating room at the Rikshospitalet Oslo 2. Coronary surgery in the second generation hybrid suite at Rikshospitalet, Oslo 2000-2007. The floor-mounted C-arm can be withdrawn from the table (Angiostar; Siemens, Erlangen Germany), giving access to the patient from all sides. Note the image enhancer behind the first assistant. The table developed especially for combined surgical and radiological procedures can be tilted head up and down and sidewise, while maintaining the floating tabletop function (Angiostar plus OR; Siemens).

Table 2. Devices in a Cath-Lab Operating Room

Device	Easy (E) /Difficult (D) to Remove
Operating table	D
Operating lamps	D
Ventilator	D
Electrocardiogram, pressure monitoring	D
Injectors for intravenous anesthesia and cardiovascular medication	D
Transesophageal echocardiography	D
Defibrillator	E
Aspirator	D
Cell saver	D
Surgical head lamp	E
Electrocautery	D
Flow measurement devices	E
Consoles for atrial fibrillation ablation	E
Heart lung machine	E
Surgical endoscopy unit and/or operating robot (including CO2 insufflator, video/DVD recorder)	E
Angiography unit	D
Contrast injector	E
Intravascular ultrasound console	E
NOGA mapping unit	E
Surgical instrument cart	E
Angiography/catheter cart	E
Warm water bath	E
Computers for imaging/data processing	D

Radiation

Standard surgical OR usually have lead covering of 0.5 mm, which is not sufficient for the radiation dose generated by fixed angiography units. Some OR suites that are suggested for a hybrid suite may therefore require completely new coverage in the range of 2 to 3 mm. In some countries, special training for the use of x-ray devices may be required.

Hygiene

There is a special issue of device as well as personnel overload. The significant number of devices may cause undesirable heat production, and ceiling mounting devices on rails above the operating table may cause discussions on potential contamination of the operative field. As compared to standard cath-labs, it is one of the main advantages of an integrated suite that all prerequisites concerning correctly sterile handling of surgical or endovascular implants are present.

General Supply with Disposables

It is clear that the hybrid suite needs additional supply rooms for surgical and catheter-based intervention–related material. These supply rooms need to be as close as possible. A reasonable number of catheters, guidewires, and implants needs to be available, as well as standard surgical equipment. Depending on the planned procedure, specific kits can be transported into the suite on carts. This could reduce the number of storage containers in the room and facilitate space gain. The principle should be to have a very lean number of different disposables so as to maintain overview in an already complex environment.

Device Placement and Use

Placing the different devices is a major challenge. All devices should be as small as possible but maintain required function. Three-dimensional placement may provide additional space. All different professionals working in the hybrid suite should be cooperative and willing to change position and habits.

In a room of 70-square meters or more it is possible to have all devices and personnel in the room at one time. Robotic and sophisticated videoscopic surgery have been performed in an angiographic OR of that size for the last 10 years [Fosse 2000]. Smaller rooms require more selective planning. It is then of utmost importance to position devices and personnel in virtual models on the computer or even train positioning with real devices or models in the room. Part of the procedures will be similar to a scene change in theater.

For the angiography-related procedure, it may help to move out machines, equipment (Table 2), and professionals that are not absolutely needed. This is also wise concerning radiation dose and general hygiene issues.

General Workflow and Organization

Coordination of the hybrid room function requires a dedicated team and a coordinator who directs the workflow. This coordinator may be chosen on a case-by-case basis or on a more stable, long-term basis. Team players will be more suitable for work in the cath-lab OR than individualists. The personnel profile should include open-minded attitude toward innovation, excellent communication skills, and the ability to think ahead. Not all of the personnel are necessary during the whole procedure (Table 3). Calling specialists in and targeting a "just-in-time concept" is a major issue. Integrated procedures, at least during learning curves, will require patience, persistence, and acceptance by the local established OR team. Organization of the cath-lab OR will require specific ways of dealing with hospital reimbursement and honoraria of the different subspecialties working in this environment.

Table 3. Maximum Number of Personnel in the Cath-Lab Operating Room

Anesthesiologist
Anesthesia nurse
Cardiac surgeon
Assistant #1
Assistant #2
Scrub nurse
Circulating nurse
Perfusionist
(Perfusionist #2)
Interventional cardiologist
Cath-lab nurse
Circulating cath-lab nurse
Radiology technician

Figure 5. Simultaneous integrated coronary artery revascularization in the cath-lab operating room at the London Health Sciences Center, London, Ontario, Canada. The floor-mounted C-arm (Axiom Artis; Siemens, Erlangen, Germany) can be moved around as needed during the procedure to provide access to the patient.

Cost

When estimating costs it is important to consider both construction cost and equipment. Angiographic equipment with a table with both floating and tilting capabilities would today cost approximately 1.0 million to 1.5 million Euro in Europe. Construction costs will depend upon the need for a control room (recommended), the need for extra lead insulation of the walls and type of ventilation. Laminar airflow roof will reduce the number of particles in the room and may be advisable with the large number of staff in the room.

CONCLUSION

The integrated OR for cardiac interventions is becoming a reality. Only few such facilities are available worldwide, but because of the to current developments in minimally invasive treatment of coronary artery disease, valve disease, aortic disease, and other diseases the interest in building cath-lab OR is rising. A variety of procedures can be performed in such a unit. Construction of integrated operating suites requires specific planning that should include all professional groups who are projected to work there. Special planning issues include use of fixed, floor- or ceiling-mounted surgical or angiography devices as compared to mobile machines. Size of the room is a major issue and special strategies have to be developed that reduce space requirements. Specific work flow patterns will be necessary for adequate function of these units. Both the cardiac surgery and interventional cardiology community will have to address these challenges in order to achieve the common goal of integrated procedures. Future advancements in both fields will certainly happen in integrated high-tech operating suites.

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