Hybrid atrial fibrillation ablations and the increasing importance of the hybrid cardiovascular laboratory operating room

Substantial advancements continue to transform the treatment of cardiovascular diseases. Minimally invasive procedures performed by interventional cardiologists and electrophysiologists continue to expand the spectrum of cardiovascular conditions that can be treated outside of the operating room, creating new opportunities for cardiovascular anesthesiology. Recent developments in percutaneous cardiac procedures, however, have become collaborations with the surgical and anesthesia team, rather than independent of the surgeons. Newly developed procedures requiring cooperation between surgical teams and cardiologists include percutaneous valve implantation, high-risk revascularization, high flow hemodynamic support, left atrial appendage exclusion/occlusion, cardiac implantable electronic device implantation and extraction, and specialized electrophysiologic ablations. Some procedures, such as cardiac implantable electronic device extraction, have such an inherent risk of complications that they are recommended to be performed with perfusion and cardiovascular surgery backup immediately available.\[1\]

Historically, the separation of medical cardiology from cardiac surgery has resulted in the development of catheterization and electrophysiology laboratories separate from the operating rooms. This separation is both spatial (location in the hospital), as well as administrative. Different resources are available in each location. Catheterization laboratories have high-quality fluoroscopy and are well-stocked with catheters, wires, sheaths, and support equipment, but may not have adequate room for anesthesia equipment, perfusionists, operating room personnel, and the other equipment common in the cardiac operating room. Conversely, the operating room is well-equipped for initiating cardiopulmonary bypass, but if fluoroscopy is needed, an unwieldy mobile C-arm is required. Percutaneous valve implantation, cardiac implantable electronic device extractions, and other advanced procedures not only require the cooperation of cardiologists, cardiac surgeons, and cardiac anesthesiologists; they also require all the combined resources of the operating room and the catheterization or electrophysiology laboratory.

One solution is to develop a hybrid laboratory, a combination cardiovascular operating room with all the equipment found in a catheterization laboratory or electrophysiology laboratory. The advantages to this are many. There is good quality fluoroscopy, wires, catheters, sheaths, and percutaneous support devices that are found in the catheterization laboratory. The capability for electrophysiologic mapping and catheter ablation can allow electrophysiologic procedures to be performed in concert with surgical approaches to arrhythmia treatment. The ability for cardiac anesthesia to provide specialized support is

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Cite this article as: Schleifer WJ, Beshai JF, Ramakrishna H. Hybrid atrial fibrillation ablations and the increasing importance of the hybrid cardiovascular laboratory operating room. Ann Card Anaesth 2015;18:286-9.
enhanced by a more operating-room like environment. There is adequate room for surgical instruments, perfusion, transesophageal echocardiography, and any other needed resource during the case. The combined expertise of medical and surgical specialists working together as a heart team improves the likelihood that any difficulty or complication can be quickly recognized and addressed.

In particular, atrial fibrillation ablations demonstrate the advantages of the hybrid approach. The surgical approach to atrial fibrillation ablation, the Cox-Maze procedure, results in a number of atriotomy scars that heal to block conduction and isolate areas of atrial fibrillation. The procedure, however, is technically challenging and is rarely performed in the absence of another indication for cardiac surgery. Bipolar radiofrequency energy appears to be the most effective nonincisional method of creating lesions during surgical ablation, but obtaining transmural lesions is difficult. A recent study of surgical atrial fibrillation ablation confirms that permanent conduction block is difficult to achieve, as patients were routinely brought back 2–3 months after the ablation for planned endocardial catheter mapping and ablation. Bipolar radiofrequency energy was used for pulmonary vein isolation, left atrial roof line, atrial trigone line, and ligament of Marshall ablation and epicardial conduction block was confirmed intraoperatively in 98%. On follow-up, endocardial mapping showed pulmonary vein isolation was maintained in only 24%. The catheter-based approach of pulmonary vein isolation works well for paroxysmal atrial fibrillation, where the trigger is most commonly located in the pulmonary veins. However, to succeed in persistent atrial fibrillation, multiple linear lesions are often required, but a recurrence of atrial fibrillation or left atrial flutters after this ablation approach is quite common.

A successful hybrid procedure involves bilateral thoracoscopic, with epicardial ablation lines applied to isolate the pulmonary veins and create a left atrial roof and inferior lines and an atrial trigone line. Cavotricuspid isthmus and mitral isthmus lines are best made by a catheter-based endocardial approach, because of the technical challenges in creating a complete lesion down to the annulus from the epicardium. Moreover, endocardial catheters can check for the completeness of the epicardial lesions and potentially identify gaps, which can then be addressed with endocardial radiofrequency ablation. A similar approach has been performed using a transdiaphragmatic insertion of catheters with pericardioscopy rather than thoracoscopy. The hybrid approach (combined endocardial and epicardial ablation) has been validated, and has a 1-year atrial arrhythmia-free, antiarrhythmic-drug-free success rate of 79–94% in persistent and longstanding persistent atrial fibrillation, with somewhat lower success rates with a transdiaphragmatic pericardioscopic approach. Other facets of ablation, such as targeting vagal ganglionated plexus areas, are of uncertain value, particularly as success rate appears similar regardless of whether or not ganglionated plexus ablation is performed.

General anesthesia is required for a hybrid atrial fibrillation ablation. A few studies have evaluated whether general anesthesia affects outcomes compared to conscious sedation. General anesthesia does not reduce the identification of triggers of atrial fibrillation compared with conscious sedation. In addition, general anesthesia appears to increase the success of endocardial ablation lesions compared with conscious sedation, possibly because of increased catheter stability. One additional requirement for a thoracoscopic hybrid procedure is endotracheal intubation and one-lung ventilation with a dual lumen endotracheal tube so that one lung can be deflated during ablation on the ipsilateral side. One potential difficulty may occur if left atrial appendage exclusion is planned following the ablation lesion. Because atrial fibrillation with irrigated catheters results in significant intravenous fluid administration, single lung ventilation becomes more difficult after endocardial ablation. Anesthetic management for these procedures can, therefore, be challenging, similar to the issues posed by transcatheter aortic valve replacement. Increasingly, institutions are training dedicated “heart teams” that focus almost exclusively on procedures performed in hybrid rooms or specially equipped catheterization laboratories such as percutaneous aortic and mitral valve replacements along with complex electrophysiologic procedures like thoracoscopic ablations.

With so many advantages, what prevents the widespread adoption of the hybrid approach? The cost of building a hybrid operating room is a formidable obstacle. The costs have many dimensions. The mere monetary cost of each of the necessary components is significant. Beyond that, there are few limits defining what the necessary components are. The laboratory resources,
and thus the cost, will vary significantly depending on the type of procedures. For cardiac implantable electronic device extraction alone, the following is the minimum requirement: High-quality fluoroscopy and a wide selection of surgical instruments, extraction tools, extraction snare, and pacing lead implantation tools. In addition, general anesthesia, pericardiectomy, chest tubes, cardiopulmonary bypass, and transthoracic and transesophageal echocardiography must be immediately available. Ablations will require equipment for radiofrequency ablation, cryoablation, and electroanatomic mapping, with high-resolution display monitors. Additional imaging with biplane fluoroscopy, computed tomography, or magnetic resonance imaging adds substantially to costs and significantly affects logistics during the case. Non-electrophysiologic procedures are also very likely to be performed in a hybrid laboratory. These will require the availability of additional catheters, wires, and support devices. The list of potential procedures that such a laboratory could see is potentially endless, including valvular interventions (transcatheter aortic and mitral valve replacements), vascular interventions (thoracic and abdominal aortic aneurysm endovascular repairs and peripheral arterial interventions), complex coronary interventions requiring hemodynamic support, placement of percutaneous hemodynamic support, and a host of interventions for congenital heart disease. As there is no limit to what could be performed in a hybrid laboratory, there is also no limit to the potential cost. The cost issue will be further hampered by the multiple departments that would potentially be using the hybrid laboratory, including interventional cardiology, electrophysiology, cardiac and thoracic surgery, and vascular surgery. Coordinating cases among all parties will also be challenging, but progress in this area is driven by the heart team concept. The cost also includes the difficulty in finding space in the hospital, and the size of the room itself is dependent on the procedures that will be performed in it.

Despite the potential costs, it is our opinion that the advantages of having a unified team involved in the care of a cardiac patient outweigh any costs. This unified team approach should be carried forward even to the extent that specific rooms are designed to merge the cardiac operating room and the cardiac catheterization laboratory. These hybrid rooms will reduce complications, increase effectiveness, and facilitate the best care of patients. In the specific instance of atrial fibrillation ablations, there is a substantial amount of evidence regarding improved outcomes, particularly for persistent and longstanding persistent atrial fibrillation. From the standpoint of patient safety in cardiac anesthesia and electrophysiology, successful patient management is critically dependent upon teamwork and communication, both of which are enhanced by dedicated hybrid rooms, as well as specially trained cardiovascular teams, for these complex patients.

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Financial support and sponsorship
Nil.

Conflict of interest
There are no conflict of interest.

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