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The Convergent Procedure: A Multidisciplinary Atrial Fibrillation Treatment

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ABSTRACT

Background: Persistent atrial fibrillation (AF) and long-standing persistent AF (LSPAF) are difficult to treat. Epicardial surgical and percutaneous catheter ablations have lower success rates in these patients. The convergent procedure, an endoscopic transdiaphragmatic ablation procedure with conventional percutaneous endocardial ablation, is examined.

Methods: Twenty-eight patients with persistent AF or LSPAF underwent the convergent procedure. All underwent combined surgical epicardial radiofrequency ablation and electrophysiological transseptal endocardial ablation to electrically isolate the 4 pulmonary veins, to exclude the posterior left atrium, to ablate the coronary sinus, and to confirm block at the cavotricuspid isthmus. Follow-up was with 24-hour Holter monitoring at 3 months, and 24-hour or 7-day monitoring at 6 and 12 months.

Results: The mean duration of the procedure was 187 minutes (102 surgical ablation minutes; 85 endocardial ablation minutes). The mean total fluoroscopy time was 35.1 minutes. Two patients developed symptomatic pericardial effusions requiring percutaneous drainage, and 1 patient has demonstrated phrenic nerve paresis. There were no deaths. At 3 months, 87% were in sinus rhythm, and 43% were free of AF and antiarrhythmic medications (AADs). At 6 months, 76% were free from AF and AADs.

Conclusion: The convergent procedure effectively combines surgical and electrophysiological AF expertise to provide a viable treatment option to patients with persistent AF or LSPAF. Long-term follow-up is under way.

INTRODUCTION

The surgical treatment of atrial fibrillation (AF) is based on the creation of an anatomical pattern of myocardial scar. The corridor procedure [Defauw 1992], the radial maze procedure [Nitta 1999], and the Cox maze I to III [Cox 1991; 1995] are anatomical patterns designed to disrupt the reentry circuits of AF by dividing the atria into nonconductive segments. Electrophysiologists, in comparison, use endocardial catheters and electrodes both to create a series of lesions that isolate specific areas of the left and right atrium and to identify triggers that may cause AF and then direct their treatments toward these foci of abnormal electrical activity. The individual success of these approaches, either surgical or endocardial, has been limited by technical complexity and/or less-than-desirable outcomes.

A truly successful and adoptable AF treatment has always seemed to be "just out of reach." The acclaimed "gold standard" cut-and-sew maze procedure has been reported to produce exceptional outcomes, but it remains a complex procedure that is rarely performed [Kosakai 2000; Prasad 2003]. The "mini-maze" [Wolf 2005] and pulmonary vein isolation [Edgerton 2008] reduce procedural complexity by decreasing the number of lesions and by eliminating cardiopulmonary bypass; however, both surgeons and electrophysiologists have demonstrated that when treatment is limited to the left atrium, especially when the patient has long-standing persistent AF (LSPAF) or left atrial enlargement, outcomes suffer as a consequence [Barnett 2006; Calo 2006]. The endocardial catheter-based AF ablations, not unlike the surgical procedures, remain long and technically difficult procedures that relatively few electrophysiologists perform. The high rate of repeat procedures and the less-than-desirable long-term outcomes have been disappointing [Cappato 2005]. Unfortunately, surgeons and electrophysiologists seldom collaborate in the development of new technologies and innovative approaches to overcome these individual procedural shortcomings.

A multidisciplinary team of electrophysiologists and cardiac surgeons have developed the convergent procedure to address existing procedural and communication barriers. The convergent procedure is the simultaneous creation of a surgeon's epicardial ablation pattern and an electrophysiologist's endocardial ablation pattern. The surgeon's ability to effectively create robust and visible epicardial ablation lines of 2 to 5 cm has greatly reduced the amount of endocardial tissue that must be ablated to complete pulmonary vein isolation, coronary sinus ablation, posterior left atrial ablation, and ablation of the cavotricuspid isthmus. The integration of

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a surgeon's anatomical approach to AF with the physiological approach of the electrophysiologist has led to the development of the convergent procedure.

METHODS

Patient Population

The electrophysiologists and cardiac surgeons evaluated patients with symptomatic persistent AF and LSPAF [Calkins 2007] who had failed medical management to determine their candidacy for the convergent procedure. All patients underwent a standard preprocedural evaluation that included documentation of AF, a medical history and physical evaluation, transthoracic and/or transesophageal echocardiography, cardiac catheterization, and a computed tomography angiographic evaluation of the left atrium for integration with endocardial navigation systems. Both the surgeon and the electrophysiologist obtained informed consent.

Description of the Convergent Procedure

During paracardioscopy, the patient is positioned supine under single-lumen, general endotracheal anesthesia.

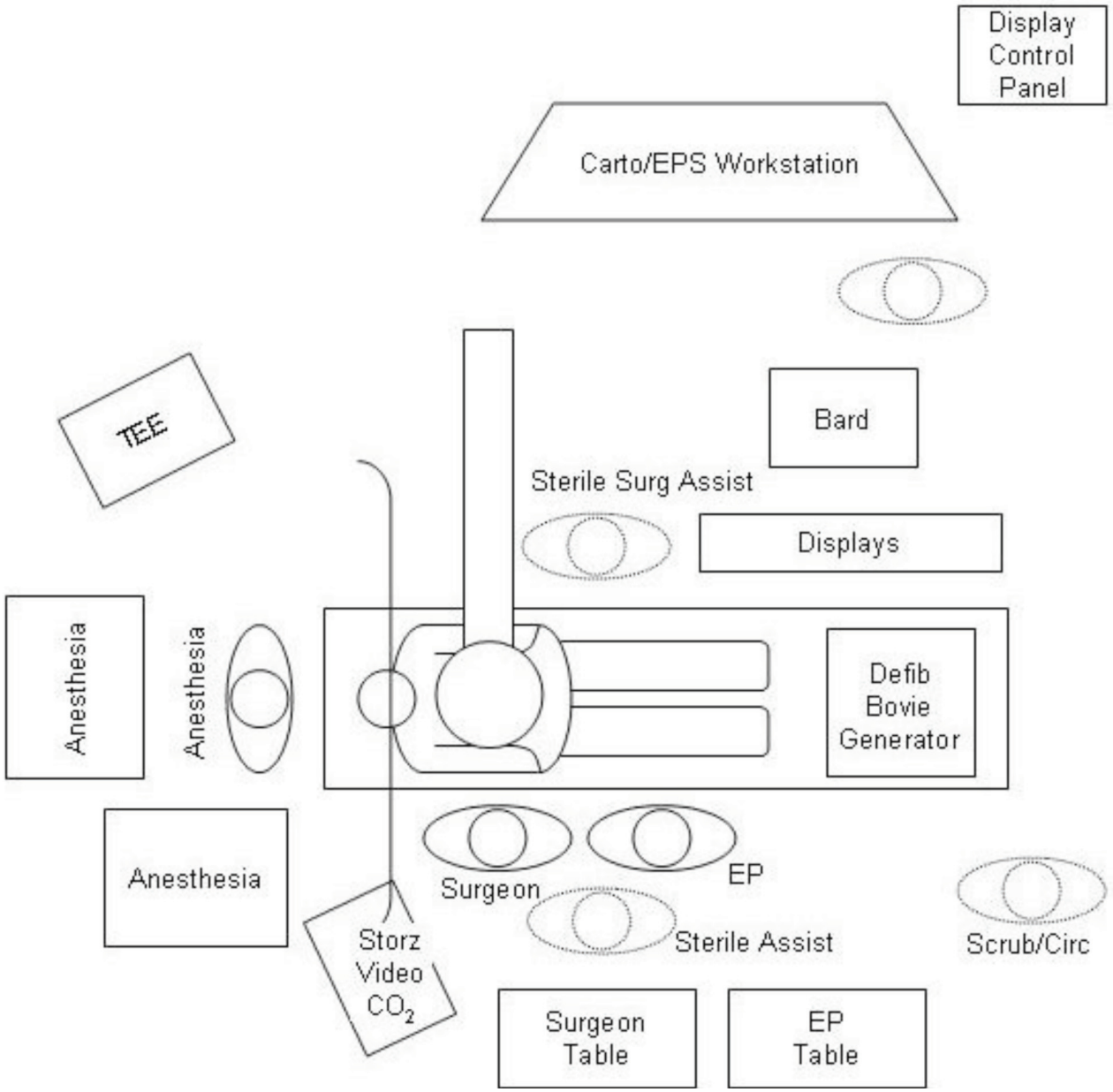

Figure 1. Hybrid suite schematic for the convergent procedure. EPS indicates electrophysiological study; TEE, transesophageal echocardiography; sterile surg assist, sterile surgical assistant; Bard, electrophysiology catheters and mapping system (Bard Electrophysiology, Lowell, MA, USA); Defib, defibrillator; Storz, Storz endoscope; EP, electrophysiologist; scrub/circ, scrub/circulating nurse.

Procedures were performed in either a "hybrid" operating theater or a "hybrid electrophysiology laboratory" with integrated fluoroscopy, endoscopy, general anesthesia, and CARTO™ mapping and imaging technologies (Biosense Webster, Diamond Bar, CA, USA) (Figure 1). A 2-cm incision is made 3 cm below the xiphoid process and extended into the peritoneum under direct visualization. Two 5-mm laparoscopic ports are placed in the left and right subcostal areas with the assistance of a finger inside the peritoneum. A 10-mm port is placed in the midline incision, and the abdomen is insufflated with CO_2 to 12 mm Hg. A 10-mm endoscope (Karl Storz Endoscopy, Tuttlingen, Germany) is used to identify the central fibrous region of the diaphragm anterior to the left lobe of the liver and left of the falciform ligament. With standard laparoscopic scissors and graspers in the 5-mm ports, the central diaphragmatic tendon is opened longitudinally 3 cm. The incision should be 1 to 2 cm anterior to the reflection of the hepatic ligament to allow later closure of the diaphragm if desired. The incision in the pericardium should be made directly behind the diaphragmatic incision. The pericardium is opened longitudinally as well to provide access to the posterior region of the heart. Once opened, the pericardium will be filled with CO_2 from the abdomen. The first direct view of the heart is at the acute margin of the right ventricle.

The paracardioscopic cannula provides direct access to the heart. The 10-mm port is removed, and the cannula is positioned through the midline incision. Once the abdomen is re-insufflated, the cannula is positioned through the defect in the diaphragm and into the pericardium under direct visualization via a 5-mm laparoscope in the left subcostal port. The abdominal insufflation is discontinued, and a rigid endoscope is inserted into the cannula to provide direct visualization and access to the left atrium, the coronary sinus, the superior and inferior vena cavae, the aorta, the right main pulmonary artery, the right and left pulmonary veins, the transverse sinus, the ligament of Marshall, and the left and right atrial appendages. Because the tip of the cannula is soft and flexible, it can be manipulated within the pericardium without injury to the epicardial surface of the heart. There is minimal compromise of cardiac function during paracardioscopy, unlike the hemodynamic compromises encountered during attempts to visualize the posterior left atrium via a subxiphoid approach.

A guidewire incorporated at the tip of the cannula provides a platform over which the VisiTrax™ (nContact Surgical, Morrisville, NC, USA) irrigated, unipolar radiofrequency ablation device can be positioned. Radiofrequency energy is delivered at 30 W for 90 seconds, with temporary decreases in power occurring during a rapid increase in impedance, as measured at the ablation electrode. Because these ablation lines are visible, a contiguous epicardial ablation pattern can be created (Figure 2). The cannula and the associated guidewire are used to create ablation lines from the atrial side of the coronary sinus to the left inferior pulmonary vein (2b in Figure 2), behind the left pulmonary veins cephalad toward the posterior pericardial reflection (2a), along the reflection from the left superior pulmonary vein to the right superior pulmonary vein (1a), along the posterior right pulmonary veins (3a), along the coronary sinus from the right to the left inferior pulmonary veins (1b), from the right inferior pulmonary vein onto the inferior vena cava (3b), and to the inferior right atrium near the Thebesian valve (7). The cannula is moved anteriorly over the inferior vena cava into the space between the right atrium and the right pericardium. In this location, an ablation line is created along the anterior surface of the right pulmonary veins from the top of the superior pulmonary vein to the oblique sinus (5 in Figure 2). A second line of ablation is created upon the fat in the Waterston groove (6). The cannula is repositioned behind the left atrium, where the left inferior pulmonary vein is again identified. From here, the cannula is directed along the anterior left pulmonary veins as far cephalad as possible in order to identify the base of the left atrial appendage and the ligament of Marshall. The ligament of Marshall is thoroughly ablated, and an ablation line is extended from the highest point on the left superior pulmonary vein along the antrum to the first ablation line on the inferior left pulmonary vein (4 in Figure 2). The cannula is then repositioned anterior to the inferior vena cava and then along the anterior right atrium to the superior vena cava. The cannula is then carefully positioned medial to the superior vena cava and into the transverse sinus until the left atrial appendage is visualized. A flexible guidewire is positioned through the cannula and the transverse sinus and behind the left atrial appendage to be in position along the anterior left pulmonary veins. The cannula is repositioned behind the left atrium; the wire is identified and pulled into the cannula, thus providing a platform for positioning the ablation device. Ablation at the anterior left pulmonary veins, along the ligament of Marshall, and across the dome of the left atrium in the transverse sinus is completed, and all ablation lines are reexamined to verify contiguity. On completion of the epicardial surgical portion of the procedure, the electrophysiologist begins the endocardial portion of the convergent procedure.

Femoral venous access is obtained percutaneously at both the right and left groins. After the transvenous placement of mapping catheters into the right atrium and coronary sinus, the electrophysiologist gains transeptal access to position circular mapping and ablation catheters into the left atrium. The

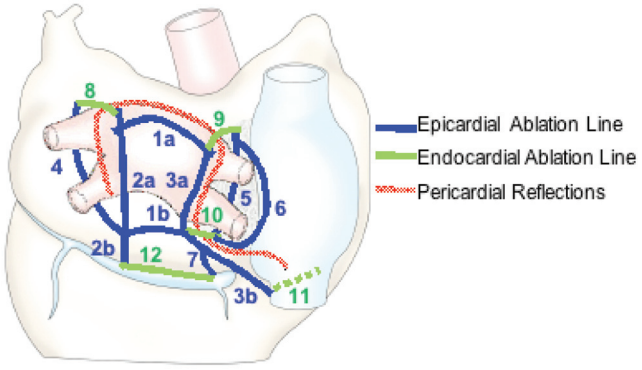

Figure 2. The epicardial and endocardial pattern for the convergent procedure. See text for details.

Early Clinical Results of the Convergent Procedure*

	3-Month Holter Monitoring	6-Month Holter/Telemonitoring
Patients free from AF	87% (20/23)	88% (23/25)
Patients in sinus rhythm	87% (20/23)	84% (21/25)
Patients free from AF and AADs	43% (10/23)	76% (19/25)

*AF indicates atrial fibrillation; AADs, antiarrhythmic medications.

patient is anticoagulated with unfractionated heparin, and the activated coagulation time is maintained at >350 seconds. Because of the pericardial reflections, the epicardial ablations may not be contiguous at the superior right (9 in Figure 2) and left (8) pulmonary veins and at the right inferior pulmonary veins (10). Each pulmonary vein is mapped with a multipolar circular catheter. The circular catheter has a series of electrodes that are used to map the pulmonary veins and the left atrial surface for residual high-frequency signals. Areas of activity identified in the pulmonary vein antrums are ablated endocardially until all of the pulmonary veins are electrically silent. Similarly, the posterior left atrium between the pulmonary veins is mapped, and electrical silence is confirmed. The coronary sinus is mapped, and if high-frequency electrical firing is demonstrated, a series of endocardial ablation lesions are applied in an effort to isolate the structure (12 in Figure 2). Finally, a line of ablation is created at the cavotricuspid isthmus with confirmation of a line of block (11). The metrics of procedural completion are electrical silence of the 4 pulmonary veins, electrical silence of the posterior left atrium, ablation of the coronary sinus with debulking or electrical isolation, and conduction block at the cavotricuspid isthmus. If sinus rhythm is not attained, the patient undergoes cardioversion, and further electrophysiological study with and without Isuprel® (Sanofi-Aventis, Bridgewater, NJ, USA) is performed with targeting of arrhythmias as indicated. Various mapping and visualization systems are used during the electrophysiologist's portion of the procedure. Fluoroscopy and ultrasound, either transesophageal or intracardiac, are used during transeptal puncture. Three-dimensional mapping systems are used with fluoroscopy during atrial mapping and endocardial ablation.

Upon completion of the endocardial portion of the convergent procedure, anticoagulation is corrected, and the venous sheaths are removed when the activated coagulation time is <200 seconds. A drain is placed in the pericardial space and routed through the left 5-mm incision, the midline fascia is closed securely with nonabsorbable interrupted suture, and the skin is closed in a routine manner. The patient is generally extubated in the operating room and is usually ready for discharge in 36 to 72 hours. With an enoxaparin (Sanofi-Aventis) bridge, warfarin (Bristol-Myers Squibb, New York, NY, USA) therapy is initiated the night of the procedure and continued for at least 3 months. Antiarrhythmic medications (AADs) are initiated at the discretion of the electrophysiologist but are discontinued by 3 months. The patients are evaluated at 1, 3, 6, and 12 months after the operation by routine electrocardiographic evaluation and with 24-hour Holter monitoring before the end of the first 3-month postoperative period. Monitoring for 7 days or longer is conducted at the 6- and 12-month visits and annually thereafter.

RESULTS

Twenty-eight patients (5 with persistent AF; 23 with LSPAF) have successfully undergone the convergent procedure. The mean AF duration was 8 years, and the mean size of the left atrium was 5.3 cm. The mean ablation time for the surgical portion was 102 minutes, and the mean endocardial ablation time was 85 minutes. The mean total fluoroscopy time was 35.1 minutes. One patient simultaneously underwent the convergent procedure and minimally invasive mitral valve repair via a 7-cm right submammary incision. This patient remains in sinus rhythm at 3 months postoperatively. Two patients developed a pericardial effusion 2 weeks after the procedure that required percutaneous drainage. Both patients recovered fully and remain in sinus rhythm at 3 months. No hemodynamically significant pericardial effusions have occurred since postprocedure drainage of the pericardium became standard. One patient has demonstrated temporary right phrenic nerve paresis at 3 months.

The Table summarizes the early clinical results. Twenty-three patients have reached the 3-month evaluation with 24-hour Holter monitoring. Of these patients, 87% were in sinus rhythm, but only 43% were free of AF and AADs. At 6 months, 84% were in sinus rhythm, and 76% were free of AF and AADs.

DISCUSSION

There have been many minimally invasive surgical approaches to treat AF, all based primarily on the original work by Cox and his maze procedure. Surgeons treating AF generally choose the technique, and thereby the device, that is most appropriate to their practice. This technique may be performed via thoracotomy, thoracoscopy, or paracardioscopy with a clamp, a pen, or an integrated device. Independent of the access or device, treatment must include pulmonary vein isolation, posterior left atrial exclusion, ablation of the coronary sinus, and a cavotricuspid isthmus ablation line for patients with persistent AF or LSPAF [Cox 2004]. Integrating cardiology with cardiac surgery in a "hybrid" AF treatment has allowed new procedural and perioperative standards to be established. The initial outcomes obtained with this multidisciplinary approach have been excellent, with patient satisfaction reflected by the growth in the volume of patients.

The success of any surgical treatment for persistent AF or LSPAF is dependent on the transmurality and contiguity of the ablation lines and the completeness of the lesion pattern. The inability to obtain a high degree of success with the current minimally invasive surgical approaches or with the percutaneous catheter approaches has led us to develop the convergent procedure. This multidisciplinary approach integrates the advantages of both cardiology and cardiac surgery. Without sternotomy or cardiopulmonary bypass, we are able to create and evaluate a comprehensive biatrial ablation pattern, which is important in the successful treatment of AF. The surgeon is able to access the epicardial space and effectively create wide, long ablation lines that significantly reduce the amount of endocardial ablation required to complete an endocardial AF ablation. The electrophysiologists are able to verify that the pulmonary veins are electrically silent and that the posterior left atrium is electrically isolated, and are able to successfully create lesions in the coronary sinus and at the cavotricuspid isthmus without cardiotomy. This collaboration of the surgeon and the electrophysiologist is an innovative way to provide patients with chronic AF a potentially new gold standard treatment. This convergence of technologies and expertise (1) allows the creation of a complete, biatrial, endocardial, and epicardial ablation pattern without a chest incision or cardiopulmonary bypass; (2) provides intraoperative metrics to confirm procedural success; (3) encourages integrated patient care by cardiology and cardiac surgery personnel; and (4) potentially decreases the length of hospital stay and the number of repeat ablation procedures.

Although the early results we have described are encouraging, the number of patients evaluated remains small. The development of symptomatic pericardial effusions, perhaps directly related to the degree of pericardial irritation combined with immediate anticoagulation, has been addressed successfully by draining the pericardium for 36 hours. We must, however, continue to evaluate these patients for procedure-related complications, such as phrenic nerve injury or intraoperative cardiac injury. Paracardioscopy with epicardial ablation is early in its development and thus requires appropriate initial training and guidance; however, it can be quickly mastered by surgeons with little experience in minimally invasive procedures. Careful evaluation of outcomes and procedural proficiency are crucial to the long-term success of this new hybrid approach to chronic AF.

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