elbow and gives off branches that supply the extensor muscle compartment of the forearm. Numerous anastomotic collaterals exist in the forearm that permit harvesting of the radial artery with little impunity.

**Compartment Syndrome After CABG**

Acute compartment syndrome occurs when the pressure within a contained fascial space exceeds capillary blood perfusion. If untreated, irreversible muscle damage with subsequent fibrosis and contracture occur. Compartment syndrome of the extremity is a recognized clinical condition associated with necrosis of the muscles and nerves within the involved compartment, which has significant morbidity. Although treatment options are available, reconstructive techniques are complex, not readily available at all centers, and functional return is never normal. Thus early diagnosis is important. It has long been taught that pulselessness, pallor, and paralysis led to the diagnosis; however, use of these clinical parameters can be misleading because loss of pulses and capillary refill and perfusion are late findings and they can be present in a patient with compartment syndrome [5]. During the early phase of the syndrome a palpable pulse may be present because the patient's systolic pressure may be greater than 30 mm Hg, which is an intra-compartmental pressure commonly associated with compartment syndrome [6].

In reliable patients, pain out of proportion to the injury, pain on stretching the involved compartment, paralysis, and paresthesia, hypoesthesia, or anesthesia can be reliable clinical findings suggestive of the diagnosis. If needed, measurement of the intra-compartment pressure can help with the diagnosis. In obtunded patients or in patients that are unreliable, measurement of compartment pressures can help diagnose the condition. The exact pressure that necessitates fasciotomy is presently being debated; thus a high index of clinical suspicion is important in the diagnosis.

Compartment syndrome after CABG has been previously reported in the lower extremity. The cause of lower extremity compartment syndrome after CABG involves vascular cannulation of the lower extremity. However, compartment syndrome of the upper extremity after coronary bypass surgery has been rare. Poullis and colleagues [7] reported one case of upper extremity compartment syndrome; however the cause was not stated.

Our patient had forearm pain and swelling during the immediate postoperative period. He subsequently went on to have anesthesia and paralysis in the radial nerve distribution develop, suggesting that he may have had an undiagnosed compartment syndrome. Postoperative pain medication and diuretics, which helped mask the pain and decrease compartment edema led to a delayed diagnosis. Because the normal circulation and collateral circulation were detectable on angiographic study, possible causes for this compartment syndrome include ischemia reperfusion injury, aberrant circulation to the dorsal forearm musculature, or generalized tissue trauma in the forearm leading to significant forearm muscle edema; because the volar compartment fascia was released with arterial harvesting, this compartment was spared. The posterior compartments were not entered, and thus these were not decompressed. However the definitive cause for the compartment syndrome in this patient is not known.

To prevent this complication in patients undergoing CABG with radial artery harvesting, close clinical vigilance is required with urgent compartment decompression as indicated.

In conclusion, coronary artery bypass surgery is an effective modality for treating coronary ischemia. The use of radial artery grafts for CABG has increased. Although compartment syndrome after CABG has been rare, vigilance is required because early diagnosis is critical in preventing significant morbidity.

**References**


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**Thoracoscopic Radiofrequency Pulmonary Vein Isolation and Atrial Appendage Occlusion**

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A 46-year-old woman with a 7-year history of profoundly symptomatic daily paroxysmal atrial fibrillation had undergone two percutaneous catheter ablations and multi-

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ple medication trials. With informed consent, bilateral pulmonary vein isolation and left atrial appendage occlusion as well as ablation of ganglionated plexi were performed by a totally thoracoscopic technique employing a bipolar radiofrequency device. She was discharged home on postoperative day 3 and had one brief episode of atrial fibrillation 1 week later, but had no further atrial fibrillation for more than 6 months since the procedure.


The cut-and-sew Cox-Maze III procedure has cured atrial fibrillation (AF) in more than 90% of cases, with follow-up beyond 5 years [1]. However, this procedure is technically challenging and invasive, resulting in infrequent adoption [2]. New techniques and technologies have facilitated surgical treatment of AF by creating atrial lesion sets that are simpler [2].

Bilateral pulmonary vein isolation (PVI) and amputation or occlusion of the left atrial appendage (LAA) has become the new minimal accepted lesion set for many surgeons. It may be accomplished from an epicardial approach with several different energy sources. Among these, bipolar radiofrequency ablation may create more reliably transmural lesions [3]. The least invasive procedure developed to date with bipolar radiofrequency devices has required bilateral minithoracotomies and bilateral thorascopy to achieve bilateral PVI and excision of the LAA [4]. Cardiologists may be reluctant to refer patients for bilateral thoracotomy procedures, however. In the laboratory, efforts were undertaken in animals and human cadavers to develop a totally thoracoscopic approach with commercially available instruments.

A 46-year-old woman with a 7-year history of symptomatic paroxysmal AF failed two catheter ablation procedures after multiple trials of medications. She reported that she was in AF approximately 50% of each day and complained of severe fatigue and malaise. An informed consent was obtained. Preoperative cardiac catheterization, transesophageal echocardiography (TEE), and cardiac magnetic resonance imaging confirmed absence of coronary artery disease, endocardial thrombus, and PV stenosis or anomaly. Warfarin was replaced with Lovenox (Sanofi-Aventis Bridgewater, NJ) 5 days preoperatively.

After double-lumen endotracheal intubation, the patient was prepared in the left lateral decubitus position. Intraoperative TEE confirmed absence of LAA thrombus. Under single, left lung ventilation, an 11-mm trocar was inserted into the right third intercostal space (ICS) at the apex of the axillary hairline, and a 30-degree, downward-looking thoroscope was introduced, aided by carbon dioxide insufflation. Second and third 11-mm trocars were inserted into the fifth and seventh ICSs in the mid axillary line and anterior axillary line, respectively (Fig 1).

The pericardium was opened longitudinally, approximately 1.5 cm anterior to the phrenic nerve, with endoscopic scissors. Using an autosuture device (EndoStitch #173016, US Surgical, Norwalk, CT), pericardial traction sutures were placed along the posterior edge of the pericardiotomy and brought through the chest wall using a suture passer (Karl Storz #26173, Culver City, CA), exposing the right hilum and intrapericardial PVs.

Blunt dissection opened the transverse and oblique sinuses. A lighted, articulating dissector (MID 1, Atricure, Cincinnati, OH) was used to carefully create a posterior dissection plane behind the left atrium between the oblique and transverse sinuses. This dissector passed a guiding catheter, facilitating insertion of the bipolar radiofrequency clamp device (EMR, Atricure) through the seventh ICS. (The trocar itself was removed to allow insertion of the dissector and then the clamp device.) The clamp encompassed the orifices of both the right superior and inferior PVs with a cuff of atrium, avoiding injury to the PVs. It was fired twice and then repositioned high over the Waterston groove and fired twice more. The energy and duration of ablation were controlled by an impedance feedback mechanism. Entry and exit block were confirmed across these ablation lines by sensing and pacing with an electrophysiology catheter (QuadCable #401156, St. Jude Medical, Minnetonka, MN), which was inserted through the third ICS trocar and positioned with a thoracoscopic grasper. High-frequency stimulation was used to identify ganglionated plexi; none were found on the right side.

A soft pleural drain was inserted through the seventh ICS trocar site. An intercostal Marcaine block (AstraZeneca, Wilmington, DE) was performed from the third through eighth ribs. The right lung was reexpanded and the patient was placed in the right lateral decubitus position.

Under single, right lung ventilation with left-sided carbon dioxide insufflation, a 30-degree downward-looking thoroscope was inserted in the apex of the axillary hairline in the third ICS. Two additional 11-mm trocars were inserted in the fifth and seventh ICSs, progressing from the mid axillary line to the posterior axillary line. Thoracoscopic scissors were used to open the left-sided pericardium 1.5 cm posterior to the phrenic nerve. Pericardial traction sutures were placed in both the posterior and anterior edges of the pericardiotomy using the autosuture device and brought out through the chest wall under tension to expose the intrapericardial PVs.

A ganglionated plexus was identified in the ligament of Marshall by high-frequency stimulation; it was ablated and the ligament divided using a hook cautery device. Blunt dissection was then used to develop the transverse sinus on the left side. The lighted, articulating dissector device was passed behind the left inferior and superior PVs from the seventh ICS trocar site to exit between the left superior PV and the left pulmonary artery. The endoscopic dissector passed the guiding catheter, which subsequently positioned the left-sided radiofrequency bipolar clamp. The clamp included a cuff of left atrial

Dr Puskas discloses that he has a financial relationship with Medtronic and Boston Scientific; Dr Guyton with Medtronic, Boston Scientific, and US Surgical.
tissue, avoiding the PVs. It was fired three times and repositioned after the second firing to include a more generous atrial cuff. Entry and exit block were confirmed after ablation by sensing and pacing from both PVs.

The bipolar clamp device was removed and an Endopath E-Z 45 “no-knife” (Ethicon, Cincinnati, OH) stapling device was introduced through the seventh ICS site and used to occlude the base of the LAA with three rows of overlapping staples. The left-sided pericardiotomy was loosely closed by tying the pericardial traction sutures together with a knot pusher.

A soft pleural drain was placed through the seventh ICS trocar site. A Marcaine intercostal block was applied. The patient was extubated in the operating room.

The patient had several intraoperative episodes of AF but remained in normal sinus rhythm after ablation of the ligament of Marshall. She was hemodynamically stable throughout, and blood loss was negligible. The drains were removed on the first postoperative day. A Solu-Medrol dose pack (Pfizer, New York, NY) was initiated, and warfarin and antiarrhythmic drugs were resumed.

The patient was discharged home on postoperative day 3 in normal sinus rhythm. Continuous postoperative telemetry monitoring revealed no postoperative AF before hospital discharge. At the 1-week follow-up, the patient remained in sinus rhythm. At the 2-week follow-up, she reported a single brief episode of AF but was otherwise in continuous sinus rhythm, confirmed by 12-lead electrocardiogram. At the 1-month follow-up, her incisions had healed with a very pleasing cosmetic result.

Comment

This is a case report of a completely thoracoscopic bilateral PVI procedure that used bipolar radiofrequency energy in association with LAA occlusion. As such, it represents a step forward in minimizing the morbidity of surgical treatment of AF. Further evolution has allowed the use of smaller (5-mm) trocars in the third ICS site, with further reduction in surgical trauma. We recently performed a second totally thoracoscopic procedure with the patient positioned supine on the operating table and used a single preparation site and drape and placed the trocar sites slightly more anteriorly. Laboratory efforts are underway to develop thoracoscopic instrumentation to create connecting lesions in the left or right atria, or both.

The success of this technique in treating AF will depend upon the efficacy of the atrial lesions created and may differ among various patient subsets. It is possible that PVI alone may be effective therapy for many patients with paroxysmal AF and for some with persistent AF. The efficacy of this simplified lesion set in curing permanent longstanding AF remains to be demonstrated, however. The role of this minimally invasive surgical procedure in managing patients with AF should be determined by randomized clinical trials.

References