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Case Reports

Hypothermic Fibrillatory Arrest During Coronary Artery Bypass Grafting in a Man With Calcified Aorta and Ventricular Fibrillation

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A 67-year-old man undergoing coronary artery bypass grafting had aortic calcification that prohibited aortic cross-clamping. When ventricular fibrillation developed during surgery, we instituted hypothermic fibrillatory arrest to avoid aortic cross-clamping. In addition to our patient's case, we discuss the advantages and disadvantages of using hypothermic fibrillatory arrest during cardiac surgery. ***(Tex Heart Inst J 2021;48(4):e207349)***

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Embolic stroke can be a devastating complication of coronary artery bypass grafting (CABG). The prevalence of perioperative stroke is 1.5% to 3.5%.[1-4] Atherosclerosis of the ascending aorta (AA) is an independent predictor of embolic stroke in CABG.[5-8] In a prospective study of 921 consecutive patients undergoing cardiac surgery, the prevalence of perioperative stroke was 8.7% in those who had atherosclerotic disease in the AA on intraoperative epiaortic ultrasonograms.[5] We report the case of a patient whose calcified AA and ventricular fibrillation during CABG necessitated hypothermic fibrillatory arrest (HFA), a technique which we also review.

Case Report

A 67-year-old man presented with progressively worsening exertional dyspnea and intermittent chest pain several years after a myocardial infarction and drug-eluting stent placement. His medical history also included peripheral artery disease with claudication, diabetes, and hypertension. During a treadmill exercise stress test, he had left-sided chest pain and ST-segment elevations. A coronary angiogram showed multivessel coronary artery disease, and he was referred for surgical evaluation.

Cardiac catheterization revealed coronary artery disease involving the proximal left anterior descending coronary artery (LAD), left circumflex coronary artery, and distal right coronary artery. Transthoracic echocardiograms revealed mildly decreased systolic function (left ventricular [LV] ejection fraction, 40%–45%) and normal LV size and wall thickness. A computed tomogram of the chest, performed within the year for lung cancer screening, had shown extensive atherosclerosis, including calcification of the coronary vessels, anterior AA, and aortic arch (Fig. 1). The patient was scheduled for CABG.

After performing the sternotomy, we palpated the AA to evaluate where to place the arterial cannula for cardiopulmonary bypass (CPB). The AA was calcified along most of the anterior wall except in 2 areas proximally and distally. Results of epiaortic ultrasonography supported this finding. The degree of AA calcification would not prevent distal cannulation or the proximal anastomoses of the bypass grafts just above the aortic root; however, aortic cross-clamping would risk embolic stroke. Therefore, we decided to perform on-pump, beating-heart surgery without cross-clamping.

After arterial and venous cannulation of the distal AA and right atrial appendage, CPB was started. The distal right coronary artery was bypassed with a reverse saphenous vein graft. The distal anastomosis was completed, and the proximal anastomosis

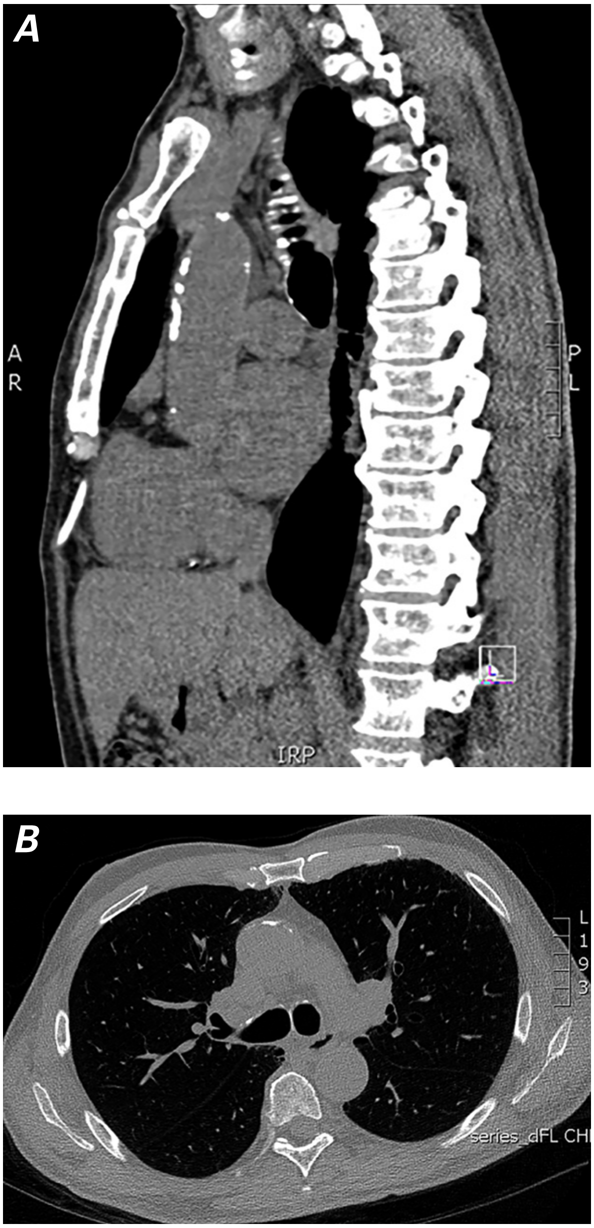

Fig. 1 *Noncontrast computed tomograms of the chest and upper abdomen in* ***A****) sagittal and* ***B****) cross-sectional views show calcification of the anterior wall of the ascending aorta.*

was created on the soft portion of the AA with use of the Heartstring III Proximal Seal System (MAQUET Cardiovascular). Just before we performed the second distal bypass anastomosis, ventricular fibrillation (VF) began. Fearing that the ischemic heart would fibrillate again soon if we attempted defibrillation, we decided to initiate HFA. We placed an LV vent through the right superior pulmonary vein and cooled the patient to 28 °C. The limited cardiac motion of the fibrillating heart avoided the need for off-pump stabilizers. We constructed the reverse saphenous vein graft to the obtuse marginal branch, and then the left internal mammary artery (IMA)-to-LAD anastomosis. The patient was rewarmed, and internal paddles were used to restore sinus rhythm. Total CPB time was 157 minutes. We weaned the patient from CPB and removed the venous and arterial cannulas. He did well in the intensive care unit and was discharged from the hospital 4 days postoperatively.

Discussion

Several techniques have been used during CABG to avoid atherosclerotic plaque embolization resulting from AA manipulation. These include off-pump “no-touch” (or anaortic) techniques, femoral or axillary artery cannulation for CPB, and deep hypothermic circulatory arrest. The no-touch technique completely avoids manipulation and cross-clamping of the AA. Proximal anastomoses to the aorta can be avoided through complete arterial revascularization with use of bilateral IMA grafts and the addition of other Y or T graft conduits.[9] As an alternative, proximal anastomoses to the aorta can be constructed without clamping by using a proximal anastomosis assist device, such as the Heartstring III Proximal Seal System or a partial clamp. In a meta-analysis of several large, nonrandomized clinical series,[10] the risk of perioperative stroke was reduced 78%, with total avoidance of aortic manipulation, when the procedure was performed off-pump with no anastomoses to the AA. Off-pump CABG with use of the Heartstring III was associated with a 55% reduction in perioperative strokes, compared with a 36% reduction when a partial aortic cross-clamp was used.[10] In our patient, the landing zone on the proximal aorta was soft enough to enable use of the Heartstring III. Otherwise, a Y graft from the left IMA would have been our alternative.

Off-pump CABG is technically demanding, so surgeon and institutional experience is vital to successful outcomes.[11] Overall, however, graft patency and complete revascularization are not as optimal as that with on-pump CABG.[11]

Hypothermic Fibrillatory Arrest

The history of HFA in cardiac surgery is long. Developed in the 1950s, HFA preserves myocardium by providing continuous perfusion of the heart in a relatively still operating field, avoiding the need for cardioplegia and aortic cross-clamping.[12]

Investigators have shown that HFA can be safe and effective in CABG; the clinical results are comparable with those in methods involving cardioplegia. Antunes and colleagues[13] performed isolated CABG with use of fibrillatory arrest instead of cardioplegia in more than 8,000 consecutive patients. The results included low rates of morbidity and mortality, an in-hospital mortality rate of 0.7%, and the need for inotropic support in 6.6% of patients and postoperative mechanical support in 0.8%. Akins[12,14,15] has published several clinical reports on the safety and efficacy of HFA in CABG patients. In a series of 1,000 consecutive patients who underwent nonemergency CABG with use of HFA, Akins and Carroll[15] reported a hospital mortality rate of 0.4%, a perioperative myocardial infarction rate of 1.8%, and a 5-year survival rate of 91.6%. In a group of more than 100 high-risk patients who underwent emergency CABG under hypothermic circulatory arrest, the in-hospital mortality rate was 0.8%, and survival at 45 months was approximately 90%.[16]

In CABG, HFA has several potential disadvantages. First, because the heart is constantly perfused during HFA, retraction to expose distal coronary artery targets is often more difficult than during intermittent cardioplegia arrest. Constructing distal anastomoses is also more difficult. Persistent blood flow through an artery during fibrillation hinders views after arteriotomy,[14] in which case a CO_2 blower/saline aerosolizer or an intracoronary shunt can be used to maintain a bloodless field for distal anastomoses. However, these devices can cause coronary air embolism or injure the target coronary artery, causing intimal dissection.

Perhaps the most important disadvantage of HFA is compromised subendocardial perfusion, especially in hypertrophied hearts or an inadequately vented LV.[17] Flow to the subendocardium occurs during diastole. Compression from increased intracavitary pressure in combination with compressive forces exerted on the subendocardial muscle by the strength of fibrillation restricts flow and oxygen delivery to the subendocardium during VF.[17] Left ventricular distention can increase oxygen requirements in a fibrillating heart on bypass to an even greater extent than that in a beating heart without bypass.[16,17]

Several basic principles apply when using HFA during cardiac surgery. Myocardial cooling is essential. Regional combined with moderate systemic hypothermia (28–32 °C) decreases myocardial oxygen consumption and preserves intermediary metabolites.[18] The rate of fibrillation, along with the strength of myocardial contraction, decreases with cooling. Oxygen demand is reduced by approximately 40% at a temperature of 28 °C.[17] With regional and systemic cooling, the heart can be allowed to fibrillate spontaneously.

Spontaneous fibrillation (rather than electrical fibrillation) has been shown to prevent maldistribution of regional coronary blood flow. Buckberg and colleagues[17] reported that less oxygen was delivered to the subendocardial muscle when fibrillation was sustained by electrical stimulus than with spontaneous fibrillation; moreover, electrical stimulus increased lactate production, reduced cell membrane integrity, and substantially depressed myocardial performance after defibrillation. If needed, direct electrical current can be briefly applied to induce VF after cooling; however, it should not be used to sustain fibrillation.[14]

The LV should always be vented to prevent myocardial distention and to help preserve subendocardial perfusion. A vent is usually placed in the right superior pulmonary vein and passed through the mitral valve into the LV to maintain an LV pressure near 0 mmHg. Intraoperative transesophageal echocardiography can be used to confirm accurate vent placement and effective LV decompression. Alternatively, a vent can be placed in the main pulmonary artery or the LV apex. These rarely used methods are helpful when access to the right superior pulmonary vein is difficult, as in repeat operations.

Subendocardial perfusion is also preserved by ensuring adequate coronary blood flow during fibrillation. Elevated perfusion pressures ranging from 80 to 100 mmHg are needed to deliver adequate oxygen and metabolites. Elevated LV pressure from both insufficient venting and fibrillating myocardium can impede blood flow.[19] Suitable systemic pressures can be achieved by regulating flow through the CPB circuit and using a supplemental α-agonist, such as phenylephrine, as needed. Closely monitoring the systemic blood pressure and LV pressure is essential to ensure that the ventricular myocardium is optimally perfused.

Because the fibrillating heart does not contribute to ejection, venous return may cause ventricular dilation. A beating heart rarely needs venting, but venting is essential for a fibrillating heart. In addition to venting, surgeons should be aware that hypothermia and the need for elevated perfusion pressures are limitations of HFA. Finally, CPB time is prolonged to allow for cooling and rewarming the patient.

After HFA and vent placement, CABG is performed. An advantage of HFA, unlike some operations performed when cardioplegia is used, is that the bypass grafts can be created in an optimal sequence to restore flow to the most ischemic territory first. Specifically, the IMA graft can be completed before other grafts, without affecting cardiac activity. Of course, care must then be taken to avoid excessive traction on the IMA graft while creating the other distal anastomoses.

Spontaneous conversion to sinus rhythm often happens during rewarming. We know of no data to suggest that postoperative cardiac dysrhythmias occur more often with HFA than with cardioplegic arrest. To restore sinus rhythm, defibrillation with internal paddles is effective. The patient must be warmed, have an adequate mean arterial pressure, and have no substantially abnormal electrolyte levels. Antiarrhythmic drugs, including lidocaine or amiodarone, may be infused. When VF persists, other underlying causes must be ruled out, including inadequate coronary flow, coronary air embolism, and LV distention.

In our patient, part of the AA was soft enough to enable proximal anastomoses with use of the Heartstring device. Otherwise, the surgeon would have had the option of constructing proximal grafts off the brachiocephalic artery as well as the subclavian artery, although the latter would have necessitated an additional infraclavicular incision.

Conclusion

Despite its long history of use and documented safety, HFA is rarely used for myocardial protection in cardiac surgery today, and indeed many cardiothoracic trainees may never be exposed to it. Hypothermic fibrillatory arrest avoids aortic cross-clamping while enabling continuous perfusion of the heart in a relatively still operating field. This technique is especially useful when manipulating the aorta during surgery increases the risk of embolic stroke, as was the case in our patient.

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