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OPERATIVE TECHNIQUE

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# Aortic root replacement in severe left ventricular dysfunction: The added value of beating-heart surgery

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## Abstract

There are limits to the use of cardioplegic arrest during complex cardiac surgical procedures, especially in patients with severe left ventricular dysfunction. In the current report, we graphically present the detailed surgical strategy and technique for beating-heart aortic root replacement with concomitant coronary bypass grafting, for patients otherwise deemed inoperable. With support of cardiopulmonary bypass (CPB), beating-heart bypass surgery is realized, after which the bypass grafts can selectively be connected to the CPB, preserving coronary flow. Then, on the beating and perfused heart, a complex procedure such as aortic root replacement can be performed, without jeopardizing postoperative cardiac function. However, several important caveats and remarks regarding the use of beating-heart surgery should be considered, including: coronary perfusion verification and maintenance, temperature management, and prevention of air embolisms. By use of this strategy, risks associated with cardioplegic arrest are minimized, while it circumvents the potential need for long-term postoperative extracorporeal membrane oxygenation.

KEYWORDS

aortic root replacement, beating-heart surgery, Bentall, heart failure

## 1 | INTRODUCTION

Conventional cardiovascular surgery, particularly when involving the aorta and cardiac valves, is generally performed during cardioplegic arrest. Important advances in cardioprotective techniques, such as developments in the use of cardioplegic solutions and anesthetic regimens,[1] have contributed to widespread use of these procedures. However, there are limits to our capability of preserving cardiac function in challenging and complex procedures, specifically in case of severe left ventricular (LV) dysfunction.[2] Indeed, prolonged cardioplegic arrest is associated with periprocedural myocardial infarction, low cardiac output syndrome, and—at least a temporarily—depressed LV function in the direct postoperative phase.[3] To circumvent these important drawbacks in these patients, off-pump beating-heart surgery is a valid option, frequently applied in coronary bypass surgery (CABG).[4] However, performing beating-heart surgery in complex cardiac procedures is challenging, especially when involving the aortic root. Although several groups have published their results using the beating-heart surgery technique, a comprehensive and visual presentation of the strategy itself is lacking in the literature. Therefore, in the current report, we present the surgical technique to perform concomitant aortic root replacement with coronary bypass surgery, on a beating heart.

## 2 | PATIENT

A 69-year-old patient was referred to our hospital with acute chest pain and dyspnea. His medical history included obesity (body mass index: 40 kg/m$^2$), atrial fibrillation, and diabetes. Transthoracic echocardiography (TTE) revealed a left ventricular ejection fraction (LVEF) of 15%, LV end-diastolic diameter of 70 mm, a bicuspid aortic valve (raphe type 1A) with prolapse and severe aortic valve regurgitation with severe pulmonary hypertension (>55 mmHg). Computed tomography showed an aortic root aneurysm of 50 mm. In addition, coronary angiography demonstrated significant three-vessel disease. As there were no transcatheter options and the patient was severely symptomatic, he was planned for pump-assisted CABG, pulmonary vein isolation (PVI), and concomitant aortic root replacement (EuroSCORE II 29%). Written informed consent of the patient was obtained before filming of the surgery and preparation of the current manuscript.

## 3 | SURGICAL TECHNIQUE

After median sternotomy, cardiopulmonary bypass (CPB) was initiated through central aortic and venous bicaval cannulation and the patient was cooled to 32°C. Bilateral PVI was performed after which vents were inserted in the right superior pulmonary vein and the aortic root. A retrograde coronary sinus (CS) cannula was used to assess lactate levels at baseline and during selective coronary perfusion. Pump-assisted CABG was performed to the right descending posterior (RDP) and circumflex artery (RCx) using single venous grafts, and to the left anterior descending (LAD) using the left internal mammary artery (LIMA). The venous grafts were anastomosed distally and selectively cannulated and connected with the CPB (Figure 1 and Video 1 graphically display the procedural setup). As coronary perfusion was now secured, the aorta was cross clamped, while backflow from the coronary ostia confirmed adequate

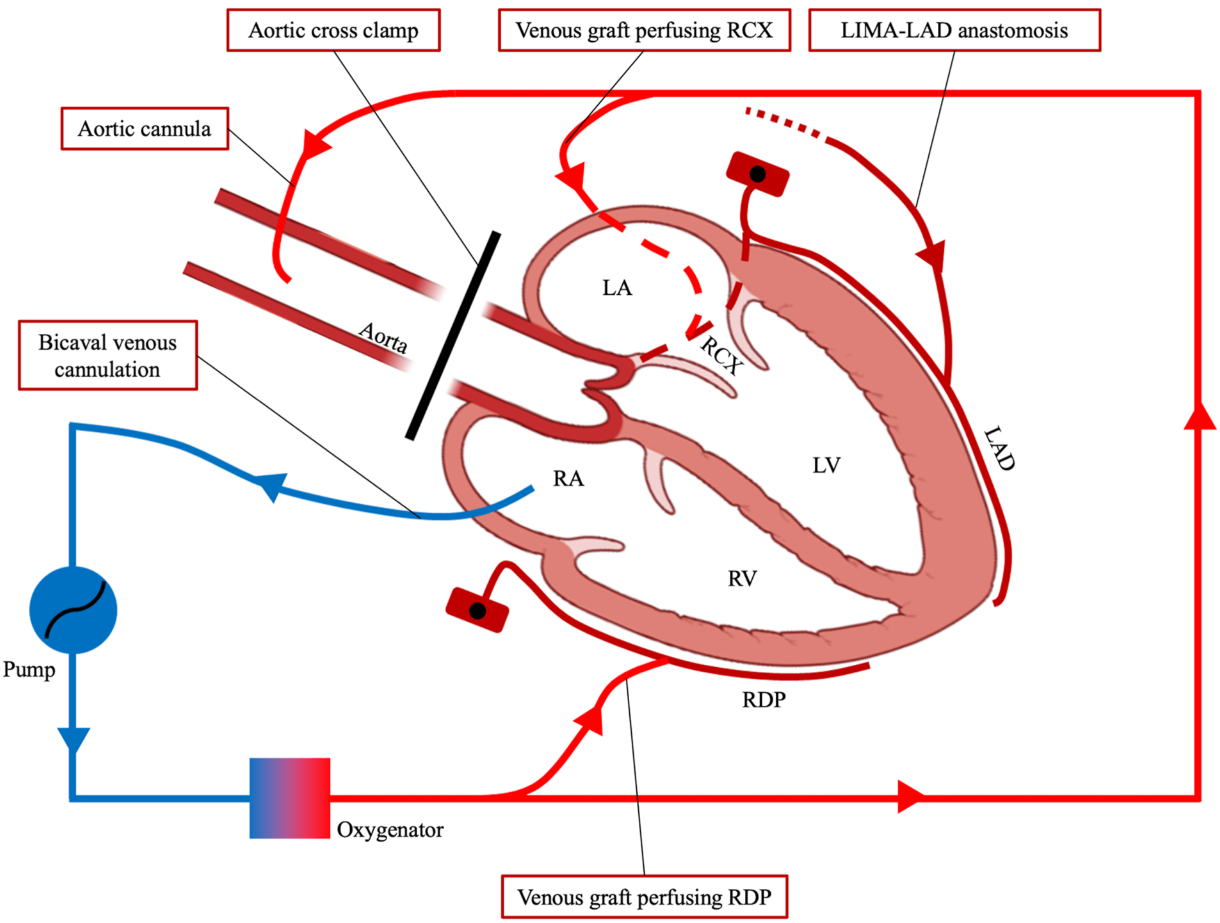


**FIGURE 1** Schematic overview of the CPB set-up. CPB, cardiopulmonary bypass; LA, left atrium; LAD, left anterior descending artery; LIMA, left internal mammary artery; LV, left ventricle; RA, right atrium; RCX, circumflex artery; RDP, right descending posterior artery; RV, right ventricle.

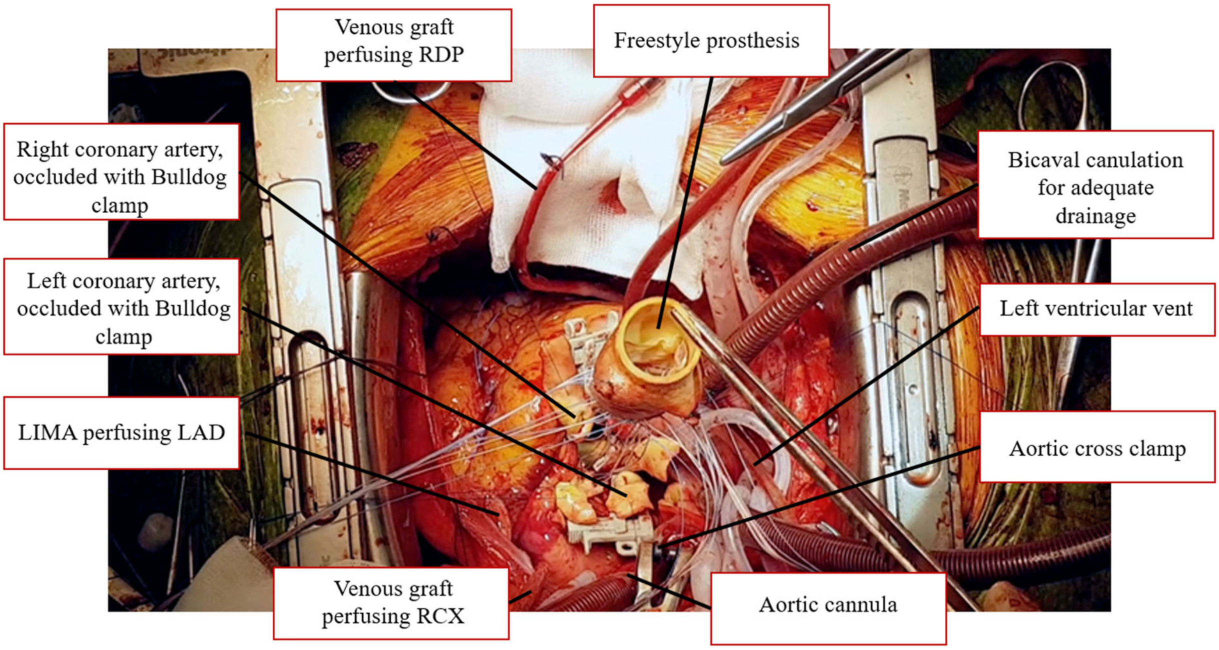


**FIGURE 2** Intra-operative view of the surgical setup of the procedure including the cannulation for CPB, selective cannulation of the venous bypass grafts, and aortic root freestyle prosthesis. LAD, left anterior descending; LIMA, left internal mammary artery; RCX, circumflex artery; RDP, right descending posterior artery.

LIMA-flow and perfusion of the venous grafts (80 cc/min). The aneurysm was resected along with the diseased aortic valve and root. After preparation, both coronary buttons were selectively occluded to prevent a steal phenomenon. Lactate concentrations were measured every 5 min at the CS to evaluate cardiac ischemia in relation to baseline CS lactate levels. A 27-mm stentless bioprosthesis (Freestyle, Medtronic Inc.) was implanted after which the coronary ostia were reanastomosed selectively (Figure 2). After the distal aortic anastomosis, the proximal bypass graft anastomoses were performed. Following a comprehensive process of de-airing, the aortic clamp was released, after which the patient was weaned off CPB.

## 4 | RESULTS

CPB time was 376 min and aortic cross-clamp time was 183 min, without cardioplegic arrest. The postoperative course was uncomplicated and the patient was discharged on the 9th post-operative day. Follow-up echocardiography after 2 years showed adequate function of the bioprosthesis with a preserved LVF, while the patients was in good clinical condition.

## 5 | DISCUSSION

In the current report, we present a reproducible method to perform complex cardiac surgical procedures on a beating heart. Although beating-heart bypass surgery—either with or without support of CPB[5]—is a well-known alternative to CABG using cardioplegic arrest, it is a less frequently applied technique for intracardiac surgical procedures. Still, this strategy has important considerations in more complex surgery, which we summarize as follows.

First, adequate maintenance and verification of coronary perfusion is imperative in beating-heart surgery.[6] Previous reports have presented several strategies, either using retrograde perfusion (through the CS) or selective coronary ostial cannulation using a Jehler cannula,[7–9] carrying the risk of inadequate flow distribution or risk of ostial injury or post-cannulation stenosis. In the current case, CABG was required for significant coronary artery disease, which allowed selective graft cannulation, avoiding the aforementioned drawbacks. Second, precise monitoring of selective perfusion pressure and flow rate is paramount, which should be adapted to signs of ischemia based on lactate levels. Indeed, resting coronary blood flow in awake human subjects (at a heart rate of 70–80/min) is estimated to range between 0.5 and 1.5 ml/min/g of myocardium,[10] and is even reduced in the decompressed heart during beating-heart surgery. Therefore, in our practice, we aim to maintain a coronary blood flow of 70–80 ml/min/100 g of myocardium. When lactate significantly increases compared with baseline levels, the flow is increased to a maximum of 125% (and not more, due to the possibility of graft and coronary damage secondary to increased pressures). In the unlikely event that this is still not sufficient based on rising lactate levels, the next step is to proceed to cardioplegic arrest.

Of note, adequate temperature management is imperative as well. It is generally not advised to reduce the temperature below 32°C, to prevent ventricular fibrillation, while moderate hypothermia promotes relative bradycardia.[9] In fact, this relative bradycardia also facilitates less challenging placement of sutures, while the reduced metabolic rate results in reduced cardiac contractility. As additional merit, this enables CPB flow to be reduced while attenuating red blood cell damage and improving the overview of the surgical field. Finally, during any intracardiac procedure, but especially on the beating heart, the risk of air embolism is substantial, but this should be minimized by adequate venting and a meticulous de-airing process.

When the abovementioned conditions are met, this strategy potentially results in an improved outcome as ischemia–reperfusion injury is avoided, and physiological conditions are preserved with normal LV function and tonus.[9]

To conclude, by use of the proposed technique, patients otherwise deemed inoperable can be operated on without jeopardizing postoperative LV function, diminishing short- and long-term risks associated with cardioplegic arrest and circumventing the need for extracorporeal membrane oxygenation.

## AUTHOR CONTRIBUTIONS

Berta Ganizada: Concept/design, data collection, data analysis/interpretation, drafting article, and approval article. Samuel Heuts: Concept/design, data collection, data analysis/interpretation, drafting article, and approval article. Colin Willems: Data collection, data analysis/interpretation, critical revision, and approval article. Inez Cortenraad data collection, data analysis/interpretation, critical revision, and approval article. Willemijn Tunnissen data collection, data analysis/interpretation, critical revision, and approval article. Jos G. Maessen: Concept/design, critical revision, and approval article. Elham Bidar: Concept/design, data analysis/interpretation, critical revision, and approval article. Ehsan Natour: Concept/design, data collection, data analysis/interpretation, critical revision, and approval article.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

## ETHICS STATEMENT

Written informed consent was obtained from the individual for the publication of images or data in this article.

## PATIENT CONSENT

Written informed consent was obtained prior to filming of surgery and the preparation of the manuscript.

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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