Peer Review File

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Reviewer 1

Excellent work pushing further the use (and its limits) of the robotic cardiac surgery.

The description of the procedure is very detailed, and no further comment is needed.

In regards to the last paragraph (lines176-184) and the clinical outcomes, I would suggest to either go more in details or leave out some of the numbers (lines 180-184). It could actually be a stand-alone paper with or without comparison to the robotic procedure with cardiac arrest.

While reading those lines it gives an impression of an easy procedure / alternative procedure but in reality, it should only be done in experienced and high-volume centers with extended experience with both the robotic and the ventricular fibrillation procedures.

Response to Reviewer 1

Thank you for the valuable feedback and insight. As suggested, we are planning to formally report our data comparing both arrested and fibrillating heart as a stand-alone paper. This last paragraph is intended to demonstrate that first our team has significant experience over several years and second that despite this alternative approach the outcomes do not differ.

As suggested, we have added the following text to clarify the need for experienced robotic cardiac team at the end of the discussion section:

> *"In order to achieve successful outcomes listed above, we have created a high-volume practice that is served by highly experienced and dedicated robotic cardiac surgery team. In our previous work we have highlighted the paramount importance of such minimally invasive team as the most effective way to overcome the steep learning curve associated with use of robotic technology for cardiac surgery"*

Reviewer 2

The authors described a very convenient and good surgical method that does not require periaortic dissection for ACC & root cannulation. In particular, it has a high educational value because it explains the process of removing air bubbles in the heart in great detail.

One thing to be curious about is that, in reoperation patients with severe pericardial adhesions, the LV apex is located above the chest wall, so air pocket is formed and de-airing procedure is difficult for some patients. In this case, do you have any experience of de-airing through the aorta with root cannula insertion to make it safer?

Also, when the heart starts beating, there could be an unexpected pulse pressure and the air bubble moves toward the aorta. What methods do you use to deal with this situation?

Response to Reviewer 2

Thank you for the insightful comments and important questions. Patients who require reoperative surgery are certainly challenging because multiple reasons especially in the presence of extensive pericardial adhesions. As mentioned in the manuscript we advance the LV vent through the valve into the left ventricle (LV) until we reach the apex. At this point we slowly start filling the LV while keeping the LV vent off. After the left atrium has been closed and that is usually is about the time the LV and LA have been filled with blood we turn on the LV vent that has been positioned in the apex. In such way we effectively deair any air bubbles located in the apex or the left ventricle before the patient has become pulsatile. In addition, to using deairng maneuvers with lung inflation, we gently massage the anterior wall of the left ventricle while apply high suction on the LV vent in order to mobilize any residual air bubbles. To date, using the technique described has been sufficient so that we have not utilized an additional root vent needle in the aorta to further optimize our deairing process.

In order to prevent air bubbles to unexpectedly to move towards the aorta, even with full LV we maintain the fibrillation so that the heart is not ejecting yet. Once the deairing process has been completed we conduct direct cardioversion using external defibrillator pads.

Reviewer 3

The authors present their established ventricular fibrillatory arrest technique for selected patients undergoing robotic mitral valve surgery. Congratulations on the success with your technique.

I just had a few questions and comments:

1. Certainly, CPB time is prolonged to allow for cooling and rewarming the patient. How do the CPB times with HFA compare to those in patients without HFA – in the procedures with endo-aortic balloon occlusion? While HFA provides a suitable alternative for selected MICS patients, perhaps a mention of CPB time differentials should be included in consideration of the associated adverse effects of prolonged CPB duration.

2. The authors mention equivalent postoperative outcomes in MV patients with moderate HFA compared to patients with endo-aortic occlusion. Please add more detail as to the postoperative outcomes. How did requirement for postoperative transfusions or vasopressors/inotropes differ? How did rates of postoperative arrhythmias differ?

In short, as moderate hypothermic ventricular fibrillatory arrest has been used in both index and reoperative cardiac surgery (as reflected in your own patient composition), it would help to add details regarding postoperative outcomes to promote adoption of this approach for selected patients. Perhaps comparison of patients with HFA vs endo-aortic balloon occlusion as to CPB

duration, postoperative transfusion requirement, vasopressor/inotropic support, and rates of postoperative arrhythmias should be included.

Once again, congratulations on the successful integration of your technique.

Response to Reviewer 3

Thank you for the valuable feedback. Exactly as suggested, the CPB time could be potentially prolonged because of the cooling and rewarming process. As mentioned above, our team is preparing a dedicated paper that compares the perioperative characteristics (CPB time etc) as well as postoperative outcomes in patients who underwent arrested heart (with Endoballoon) and fibrillatory arrest mitral valve surgery.

The main goal of this manuscript is to demonstrate the technical feasibility as well as to describe key technical points and challenges when performing such operation. In a future paper we are focusing on the exact outcomes following fibrillatory arrest for mitral valve.

Reviewer 4

I congratulate the authors for their results.

Minor Concerns:
1)
page 6, line 131: what do you mean by "core temperature down enough". Please specify exactly in value which temperature do you recommend before inducing fibrillation.
2)
page 6, line 136: a mean arterial pressure of 80 mmHg on CPB might be relöazed with post-CPB SIRS. what is your experience? Did you notice any adverse effects: such as postoperative vasoplegia? Bleeding? DIC?

3)
how long was the fibrillation time? is there maximal period that you consider and recommend not to be exceeded?

4)
was LV-EF maintained postoperatively?

5)
However, only 15% of your patients were operated on fibrillation? Why do you not use the technique more often? Avoiding aortic occlusion might be advantageous also in patients without prior operations.

Response to Reviewer 4

Thank you for the valuable feedback.

1)
The exact temperature to induce fibrillatory arrest is 31 C. We have corrected that in the manuscript as follows:

> "Rapid ventricular pacing at a rate of 800 beats/min and amplitude of 20 mm amperes is applied for several seconds to induce ventricular fibrillation. It is key to have cooled the body core temperature down to 31 °C in order to easily induce ventricular fibrillation at this time."

2)
Based on our experience, it is imperative to maintain high mean arterial pressure at time of fibrillatory arrest. The reasons are two: first – to provide excellent myocardial perfusion and second in order to prevent any air from going across the aortic valve into the aorta. To date we have not had any negative experience with the use of mean arterial pressure of 80.

We will present in a separate manuscript our experience combining the outcomes following fibrillatory arrest and arrest using Endo balloon. This future manuscript is intended to illustrate in detail if any difference in the perioperative or postoperative outcomes occur. While this current manuscript is merely intended to be as a technical paper, we did incorporate at the end of the discussion section a brief summary of what our future paper will show. There were no major differences between the two arresting techniques.

3)
Based on our current experience, we do not have a hard threshold on the time allowed to keep the patient in fibrillating hypothermic state.

4)
There was no change in the LVEF at the end of the procedure. In order to maintain good LV function, we focus on combination of good systemic hypothermia and heigh mean arterial pressure as mentioned in the body of the manuscript.

5)
Quite precisely as listed, our technique has been utilized in rather small fraction of our patients (15%). There are multiple reasons for that:
- only patients with completely competent aortic valve are eligible
- the type of the mitral pathology also plays a role. We have selected only non-complex mitral valve repair/replacement as eligible for this technique. In our patient selection section of the manuscript, we have listed our key relative contraindications:

> "Although there is no strict indication for this technique, patients with a history of cardiac surgery, especially with patent internal mammary graft, severely calcified aorta, atherosclerosis in the aorta and peripheral vascular disease are preferable candidates."

Reviewer 5:

The abstract mentions the rationale for fibrillatory arrest and outlines description of the technique as the aim of the contribution. The introduction elaborates on the main reasons for using fibrillatory arrest and states that it has been successfully used in non-robotic minimally invasive cardiac surgery. A long-detailed description of the procedure follows. It would help the reader if more headers for procedure elements could be introduced.

E.g.:
Indication and patient selection
Preoperative workup
Exclusion criteria
Anesthesia management and patient positioning
Cannulation
Port placement and access to the left atrium
Induction of ventricular fibrillation (one of the key parts of the manuscript)
Mitral valve procedure
De-airing and defibrillation
Weaning from CPB and last procedure steps

I suggest to add as many technical details as possible such as suture material, robotic instruments used for individual procedure steps, product names for the suction catheters used to clear the left atrial operative field.

A paragraph on specific intraoperative challenges and how to solve them would be extremely helpful for colleagues who would like to start this procedure.

I did not hear a voice over for the video – would increase the quality of the contribution.

Congratulations on development of a very important technique in robotic cardiac surgery!

Response to Reviewer 5:

Thank you for the valuable comments. As suggested, we have adjusted the body of the manuscript and added headers for the various procedure elements:
- Indications, contraindications and patient selection
- Preoperative work-up
- Anesthesia, patient positioning and port placement
- Cannulation and initial dissection
- Moderate hypothermic ventricular fibrillatory arrest
- Mitral valve procedure
- De-airing and defibrillation
- Weaning off CPB and final steps

In addition, as suggested we added additional specific technical details in the body of the manuscript describing the surgery more precisely.

An additional paragraph has been added including selected intraoperative challenges and how to address those.

We believe that the audience will be able to better focus on the images and the reading the added text instructions.