Chapter 10
Cardiac Arrest in the Minimally Invasive Cardiac Surgery Patient: Is Conservatism an Aggressive Approach?

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Introduction

Over the last several decades a range of techniques have evolved to allow for less invasive cardiac surgery, including the ability to avoid a sternotomy and the morbidity associated with it. Sternal-sparing approaches to commonly performed cardiac operations have been well described and are now practiced routinely in many centers. However, such advances inevitably present new and distinct challenges. One clinical dilemma that remains as it relates to sternal-sparing cardiac surgery is how to safely and quickly resuscitate a non-sternotomy patient in refractory cardiac arrest. By contrast, cardiac surgery patients who have undergone a sternotomy have the option of undergoing immediate re-sternotomy at the bedside to alleviate tamponade, control hemorrhage or perform manual cardiac massage. As such, the consensus guidelines from both the European Association of Cardiothoracic Surgery and the Society of Thoracic Surgeons (STS) recommend immediate sternal re-entry as a central tenet to resuscitation of the post-operative cardiac surgery patient in cardiac arrest [1, 2]. The optimal approach to the non-sternotomy patient is, however, less straight-forward and without a clear consensus.

The purpose of this chapter was therefore to summarize the existing literature and to provide a recommendation for the resuscitation of the patient who is in refractory arrest after sternal-sparing cardiac surgery.

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V. A. Lonchyna (ed.), *Difficult Decisions in Cardiothoracic Critical Care Surgery*, Difficult Decisions in Surgery: An Evidence-Based Approach,
https://doi.org/10.1007/978-3-030-04146-5_10

Search Strategy

A literature search of English language publications was performed to identify reported cases of post-operative arrest in cardiac surgery patients following minimally invasive cardiac surgery using the PICO table outlined below (Table 10.1). The following databases were searched: Pubmed, Embase and Cochrane Evidence Based Medicine. The search terms used were the following: [“cardiac arrest” OR “resuscitation”] AND [“minimally invasive cardiac surgery” OR “robotic cardiac surgery” OR “minimally invasive aortic valve replacement” OR “minimally invasive mitral valve” OR “minimally invasive coronary artery bypass” OR “robotic coronary artery bypass” OR “robotic mitral” OR “nonsternotomy” OR “sternal sparing”].

A second search was performed to examine large series of sternal-sparing cardiac surgery for reports of post-operative cardiac arrest within the manuscript. Representative large series publications from the following forms of sternal-sparing cardiac surgical procedures were reviewed:

- Minimally invasive mitral valve repair (both robotic and thoracotomy approaches)
- Minimally invasive aortic valve replacement
- Robotic totally endoscopic coronary artery bypass
- Minimally invasive coronary artery bypass (robotic and thoracotomy)

Results

Cardiac Arrest After Sternal Sparing, Minimally Invasive Cardiac Surgery

The incidence of post-operative cardiac arrest in patients specifically undergoing minimally invasive, sternal-sparing cardiac surgery is unclear. Larger series of robotic, thoracoscopic, totally endoscopic or mini-thoracotomy approaches to cardiac surgery do not specifically report whether a post-operative arrest has occurred (Table 10.2) [3–10]. Other post-operative outcomes were provided, including mortality, however cardiac arrest was not a reported outcome measure in any of the large

Table 10.1 PICO table for cardiac arrest in the minimally invasive cardiac surgery patient

P	I	C	O
Patients	Intervention	Comparator	Outcome
Patients suffering cardiac arrest after “minimally invasive” cardiac surgery (i.e. robotic, mini-thoracotomy, thoracoscopic)	Emergent sternotomy	Alternative treatment such as peripheral venoarterial extracorporeal membrane oxygenation	Failure to resuscitate, death or morbidity

The quality of data in the papers evaluated was classified according to the GRADE system

Table 10.2 Reported incidence of post-operative cardiac arrest and interventions after sternal-sparing cardiac surgery.

Author (year)	Patient group	# Patients	In hospital mortality (%)	Incidence of post-operative arrest	Comment	Type of study	Quality of evidence
Murphy DA (2015) [3]	Robotic MVr	1257	0.9	N/A		Retrospective	Very low
Gillinov AM (2018) [4]	Robotic MVr	1000	0.1	N/A		Retrospective	Very low
Vollroth M (2002) [5]	Right thoracotomy MVR/r	714	4.2	N/A		Retrospective	Very low
Lamelas J (2018) [6]	Minimally invasive AVR	1018	1.3	N/A		Retrospective	Very low
Glauber M (2015) [7]	Minimally invasive AVR	593	1.5	N/A	5.1% reopened for bleeding or tamponade	Retrospective	Very low
Bonatti J (2013) [8]	Robotic TECAB	500	1	N/A		Retrospective	Very low
Halkos ME (2014) [9]	Robotic MIDCAB	307	1.3			Retrospective	Very low
McGinn JT (2009) [10]	MICS CABG	450	1.3	N/A	2.7% return to operating room for graft revision or bleeding	Retrospective	Very low

MVr mitral valve repair, *MVR/r* mitral valve replacement/repair, *AVR* aortic valve replacement, *TECAB* totally endoscopic coronary artery bypass, *MIDCAB* minimally invasive direct coronary artery bypass, *MICS CABG* minimally invasive cardiac surgery coronary artery bypass grafting

series we reviewed. Additionally, our review of the literature indicates that series reporting on the incidence and outcomes of post-operative cardiac arrest in the cardiac surgical patient do not address patients undergoing sternal sparing approaches [11–13].

In general, approximately 5% of all patients undergoing cardiac surgery will have a post-operative cardiac arrest according to a recent review of 80,000 patients (range 2.6–5.5%) [11]. The inciting event may be cardiac tamponade, air embolus, uncontrolled hemorrhage or technical issues related to the primary operation which may progress to hypotension, hypoxemia, ischemia and ultimately pulseless electrical activity, asystole or ventricular tachyarrhythmias. Failure to rescue these patients has been shown to vary among hospitals, and in one series an average failure rate of 60% that ranged from 50% to 83% was found across 17 hospitals [11]. This series did include patients who had undergone sternal-sparing cardiac surgery, however we were not able to extract this specific subset of patients from the database reviewed to determine the incidence of arrest and resuscitation strategy.

ECMO/ECPR After Cardiac Surgery

The majority of the published experience with Extracorporeal Cardio-Pulmonary Resuscitation (ECPR) or extracorporeal membrane oxygenation (ECMO) after cardiac surgery is related to pediatric cardiac surgery [14]. There are a limited number of series reporting the use of ECPR for post-operative adult cardiac surgery patients in refractory cardiac arrest. Mazzaffi et al. reported 23 patients who underwent either peripheral or central venoarterial (VA) ECMO after cardiac surgery [13]. Thirty day mortality and in-hospital mortality were 65.2% and 69.6%, respectively. Six of the 23 patients (26.1%) were discharged with a favorable neurologic outcome. This institution reported their experience with both resternotomy and central VA ECMO as well as femoral cannulation for peripheral VA ECMO. Because of a large institutional experience with ECPR and ECMO in general, peripheral VA ECMO has now become this center's strategy of choice for post-operative cardiac surgery patients in refractory cardiac arrest [13]. Similar results were found by Zhou et al. who reported a 33% survival to discharge in 24 patients, although 50% had a major neurologic injury [12].

Current Guidelines for Resuscitation

With regards to non-sternotomy patients the STS Guidelines emphasize the use of an agreed upon protocol for fresh sternotomy in the ICU or in the OR as outlined by the operating surgeon [2]. As an alternative to sternotomy, the Guidelines state that "experienced surgeons" may use ECMO as an alternative to fresh sternotomy.

Given the paucity of data for ECPR in adult cardiac surgery patients, the STS Guidelines provide little discussion of the use of ECMO in arresting patients [2]. Similar to the recommendations in non-sternotomy patients, the guidelines recommend the use of ECPR as an alternative to re-sternotomy in "expert institutions" that are capable of rapid deployment of ECMO [2].

Recommendations

Published reports of non-sternotomy cardiac surgery patients suffering cardiac arrest are sparse. Therefore the following recommendations are comprised from the authors' combined experience and in some cases a modification of existing guidelines for sternotomy patients [2].

For non-sternotomy patients in cardiac arrest we recommend the following:

1. Hospitals that perform sternal-sparing approaches to cardiac surgery should produce and rehearse an ICU-specific protocol for cardiac arrest in this patient population. This protocol should be based on the level of training and experience of

the providers in the ICU at night (surgical residents, ICU intensivists, nurses only, etc.) and also account for the institutional experience with ECMO or ECPR. Quality of Evidence: low, Level of Recommendation: Strong

2. For the non-sternotomy cardiac surgery patient in refractory cardiac arrest, peripheral VA ECMO is the optimal intervention to restore perfusion to the brain, coronary arteries and visceral organs. Quality of Evidence: Low, Level of Recommendation: Strong
   (a) Note: In the setting of cardiac tamponade peripheral VA ECMO can result in undrained upper extremity and cerebral venous blood flow, placing the patient at risk for cerebral edema. Therefore, peripheral VA ECMO may act as a temporizing measure for immediate resuscitation yet the patient should undergo sternotomy and relief of tamponade in an operating room as soon as possible.
3. If available, set-up for VA ECMO and preparation of the groin should begin as soon as a code is called in a non-sternotomy patient, in parallel to conservative efforts at resuscitation. This is equivalent to the immediate preparation for resternotomy described at the onset of a code in the STS resuscitation guidelines [2]. Quality of Evidence: Low, Level of Recommendation: Strong
4. If an ECPR or ECMO program is not already in place, its development should be considered in hospital centers regularly performing sternal sparing cardiac surgery procedures. Quality of Evidence: Very low, Level of Recommendation: Strong
5. Closed chest CPR is more effective in a patient with an intact sternum than a post-sternotomy patient and perhaps should be continued longer than the 5 min recommended for patients with previous sternotomy [2]. Quality of Evidence: Very low, Level of Recommendation: Strong
6. *Alternative:* If ECPR/ECMO is not an option, a protocol to perform a fresh sternotomy in the ICU or in the OR should be developed with the operating surgeon and the ICU per the STS guidelines [2]. Sternal saw and saw blades should be available on the unit and tested regularly. ICU personnel who may be performing the sternotomy should be familiar with its assembly and use. A fresh sternotomy in the ICU should be performed by a surgeon or provider who has been adequately trained. Quality of Evidence: Very low, Level of Recommendation: Weak

A Personal View of the Data

The optimal approach to the non-sternotomy patient in refractory cardiac arrest differs from that of the conventional cardiac surgery patient. Fortunately, these events are infrequent yet when they do occur it is often at night when an attending surgeon may not be immediately available. In such a scenario, our view is that the safest mode of resuscitation is via initiation of peripheral VA ECMO. The use of ECMO

in these patients should be viewed as a temporizing measure prior to further evaluation either in the catheterization lab or operating room as necessary.

We believe the use of peripheral ECMO over a fresh sternotomy in these patients has the following advantages:

1. Avoids the need to interrupt chest compressions for a sternotomy
2. Avoids the need for the immediate presence of a qualified cardiac surgeon
3. Avoids reliance on an inexperienced surrogate to perform an emergent sternotomy
4. Femoral access can be obtained by ICU providers as the code is initiated who may then either continue with cannulation if sufficiently trained or have the patient prepared for immediate cannulation upon arrival of the on call surgeon
5. Prevents the risk of a technical complication occurring during a fresh sternotomy in an arresting patient (i.e. – avoids a "bad to worse" situation):

    - Saw or finger sweep injury to a grossly distended RV
    - Ongoing and difficult to control blood loss from bone marrow and engorged bridging veins
    - Injury to bypass grafts
    - Injury to RV during manual cardiac massage
    - In the event central VA ECMO is required, central cannulation after emergent sternotomy in the ICU can be challenging due to:

        – Poor visualization of structures (hemorrhage, poor lighting)
        – Lack of necessary supplies, instruments, help
        – Frequent interruption of cardiac massage

When executed properly, the use of peripheral VA ECMO in this population can rescue the patient in refractory arrest and result in a favorable neurologic outcome if instituted early and with adequate concurrent CPR.

Finally, given the paucity of data on this topic, these recommendations were arrived at after reviewing our own experience as well as discussing with other practitioners of this approach their experience. We recommend that future prospective studies on sternal sparing cardiac surgery include management of cardiac arrest as one of the endpoints, and that future retrospective studies include this information in their results.

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