An Evaluation of the Impact of Resternotomy Preparation Training for Bedside Nurses and

Advanced Care Providers for Post-Cardiac Surgery Arrests

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for the degree of Doctor of Nursing Practice in the Department of Nursing

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Abstract

The survival rate for post cardiac-surgery arrests has been shown to be higher than in-hospital cardiac arrests (50% vs. 24.8%). Success is attributed to the high incidence of three reversible causes: ventricular fibrillation, cardiac tamponade, and postoperative hemorrhage. A growing body of cardiac surgery literature suggests the need for a modified resuscitation protocol utilizing early resternotomy with internal cardiac massage and preparation training for all providers. This study evaluated the resuscitation practice trends and the impact of resternotomy preparation training and compared patient outcomes to those treated with standardized resuscitation compared to those treated with resternotomy. The researchers found that semiannual resternotomy preparation training effectively decreased time-to-resternotomy by three minutes, improving 24-hour survival to 76.9% among resternotomy patients compared to 44.4% pre-training, and improved survival-to-discharge to 23.1% post-training compared to 0% pre-training. The researchers also identified a high incidence of arrhythmias as the primary cause for post-operative cardiac arrest (45.5% for resternotomy patients and 56.8% for non-resternotomy patients) and recommend modification to current resuscitation practices. Finally, the study identified a need for improved management of post-resuscitative complications such as anoxic brain injury and respiratory failure.

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Dedication

I dedicate this work to my family. To my father, the belated Pastor Charles M. Bullins, you made me the man I am today. Through the years you instilled the virtues of faith, honor, and integrity. Every day I find myself reflecting on your teachings and thankful to have had someone who reminded me to always put God first. To my mother, Joyce C. Bullins, you taught me leadership. You have always been the leader in our family and I'm so thankful you instilled the direction in my life. When I feel like I've lost my way, I've always looked to you to find my path. To my sister and "mother," Charlene M. McKinney, although you chose not to have a child of your own, you've always been a mother to me. When I needed to learn life lessons you taught them to me, when I needed a friend you were there, and you pushed me beyond who I thought I could be. Each of you have played a critical role in my life and I couldn't be where I am without you.

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Sandy Sayre—thank you for supporting this project and my growth throughout it. From the first time you heard this project presented, you were enthusiastic and ready to provide whatever support we needed.

To the patients who have and will undergo cardiac surgery—as healthcare providers our job is to improve the lives of those we care for. I hope this research not only improves your outcomes, but also improves your quality of life. This work is for you.

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Chapter 1: Introduction

Nearly 400,000 patients undergo cardiac surgery in the United States annually; of those individuals, 0.7% to 8% are predicted to develop a postoperative cardiac arrest (Dunning et al., 2017). Survival-to-discharge for all inpatient cardiac arrests remains relatively low at 24.8% primarily due to etiologies of arrest being related to non-reversible cardiac cellular death or functional changes (American Heart Association, 2018; E.Lee, personal communication, March 15, 2018). Conversely, survival-to-discharge for post-cardiac surgery arrests are estimated as high as 50% (Dunning et al., 2009; Maccaroni & Watson, 2013). Researchers attribute the relatively high survival-to-discharge in postoperative cardiac surgery patients due to reversible etiologies. The three primary reversible etiologies for post-cardiac surgery arrests include ventricular fibrillation (VF) (45%), cardiac tamponade (9-28%), and postoperative hemorrhage (86%) (Anthi et al., 1998; Charalambous, Zipitis, & Keenan, 2006; Dunning et al., 2017; Maccaroni & Watson, 2013; Runte et al., 2012). In the postoperative cardiac surgery patient who develops a cardiac arrest, traditional resuscitation maneuvers may be ineffective in restoring spontaneous circulation (ROSC) and potentially harmful to patients (Anthi et al., 1998; Dunning et al., 2017).

As early as 1998, researchers such as Anthi et al. (1998) highlighted the importance of managing post-cardiac surgery arrests differently than typical arrests. The researchers found that when closed-chest cardiopulmonary resuscitation (CPR), also known as external cardiac massage (ECM), failed to achieve ROSC after five minutes, conversion to open-chest CPR, also known as internal cardiac massage (ICM), could improve patient survival by nearly 50% (Anthi et al., 1998). In 2009 the European Association of Cardiothoracic Surgery (EACTS) published the first set of recommendations regarding the management of patients who arrested following cardiac surgery (Dunning et al., 2009). Following the publication, both European and American cardiac surgery programs begin to evaluate their postoperative cardiac arrest resuscitation practices (Dunning et al., 2009; Lees, Powell, & Mackay, 2012; Maccaroni & Watson, 2013). However, the EACTS recommendations were not formally incorporated into a resuscitation protocol until the European Resuscitation Council's (ERC) 2015 guideline update which included "a detailed subsection for resuscitating patients who arrest after cardiac surgery" (Dunning et al., 2017). These recommendations highlighted the critical role of rapid resternotomy (RS) and ICM when ECM had been performed for five minutes and failed to obtain ROSC, the use of sequential defibrillations for arrhythmias prior to ECM, and reductions in vasopressor administration (Dunning et al., 2009, 2017).

Despite strong evidence demonstrated by the EACTS and ERC regarding a need for a modified resuscitation protocol for post-cardiac surgery arrests, the American Heart Association (AHA) made no specific recommendations for the management of post-cardiac surgery arrests in the 2015 guidelines update (Dunning et al., 2017). In early 2017 the Society of Thoracic Surgeons (STS) acknowledged the potential need for change in post-cardiac surgery arrest resuscitation practices and released an expert consensus supporting the recommendations of the EACTS and ERC for the first time in the United States (Dunning et al., 2009, 2017). Based on the STS expert consensus, it is expected that there will be an increased trend to modify resuscitation protocols in the United States to include specific management for patients who arrest post-cardiac surgery.

Purposes of the Study

As part of a continuous quality improvement program (QI) and prior to release of the 2017 STS recommendations, a high-volume single center cardiac surgery program in Virginia developed a resternotomy preparation training (RSPT) for nursing and advanced care provider (ACP) staff. RSPT was implemented in October 2011 to be used with patients who developed a post-cardiac surgery arrest and failed to obtain ROSC with ECM. Prior to implementation of the full scope of the 2017 STS guidelines for post-cardiac surgery arrests, a retrospective review of the resternotomy preparation training and its related patient outcomes was conducted.

The two major aims of the study were (1) to investigate the resuscitation practice trends and the related patient outcomes before (2009 to 2011) and after (2011 to 2016) implementation of the RSPT and (2) to compare patient outcomes between patients with and without RS as the method of resuscitation among those who underwent cardiac surgery and experienced a post-cardiac surgery arrest.

Chapter 2: Literature Review

Developed by the AHA in 1979, advanced cardiac life support (ACLS) has been the standard for resuscitative practices for all American in-hospital cardiac arrests (American Heart Association, 2018). ACLS has been shown successful in improving survival-to-discharge for inpatient cardiac arrests up to 24.8% of the time (Go et al., 2013). However, researchers warn that ACLS can be harmful if applied to the post-cardiac surgery patient resulting in complications such as structural cardiac injuries or disruption of the surgical suture lines (Ley, 2015; Maccaroni & Watson, 2013). To date, the AHA makes no specific recommendation modifications for the resuscitation of post-cardiac surgery arrests (Dunning et al., 2017).

The 2017 STS expert consensus statement is the first American publication to highlight the need for differentiated resuscitation practices in post-cardiac surgery arrests (Dunning et al., 2017). The guidance document recommends the revision of five major practices for post-cardiac surgery arrest management which are above and beyond the current AHA ACLS guidelines. The details of the STS recommendations for post-cardiac surgery arrest management and comparisons to current resuscitative practices will be presented in the following sections. An overview and comparative summary is provided in Table 1.

Table 1

Recommendations for Management of Cardiac Arrest: ACLS versus the 2017 STS Recommendations

ACLS Recommendations	CSU-ALS Recommendations
Ventricular Fibrillation/Pulseless Ventricular Tachycardia	
Immediate external cardiac massage	Defibrillate first if available within 1 minute
External cardiac massage → single shock → external cardiac massage x 2 minutes before repeating shock	Three stacked shocks before external cardiac massage
Asystole or profound bradycardia	
External cardiac massage → vasopressor	DDD pacing at maximum outputs if available within 1 minute → external cardiac massage
All pulseless cardiac arrests	
Epinephrine 1000 ug every 3-5 minutes	No epinephrine or vasopressin during arrest Reduce epinephrine dose to 100ug prearrest or as directed by senior clinician Rapid resternotomy (<5 minutes) if no response to initial therapies

Source: Ley, S. J. (2015). Standards for resuscitation after cardiac surgery. *Critical Care Nurse*, *35*(2), 30–7; quiz 38. Journal Article. http://doi.org/10.4037/ccn2015652

Recognition of Patient Decompensation and Initiation of ECM

Following cardiac surgery, patients are monitored in the intensive care unit (ICU). Due to the highly invasive nature of continuous bedside monitoring in the ICU and the advanced skill set of the ICU staff, recognition of cardiac arrest should be prompt (Dunning et al., 2017). Post-cardiac surgery patients who develop an arrest will demonstrate flattened invasive waveforms and lack of pulsatility at the time of arrest (Dunning et al., 2017). Therefore, the current AHA recommendation of assessing the patient for 10 seconds prior to intervening should not be required for post-cardiac surgery patients (Dunning et al., 2017). In post-cardiac surgery patients, it is recommended that the caregiver summon help and initiate resuscitation based on the STS recommendations at the first sign of decompensation. The STS recommendations support a delay of ECM up to one minute while preparing for interventions such as defibrillation or temporary pacing (Dunning et al., 2017). In contrast, the AHA practices recommend immediate ECM while simultaneously preparing for defibrillation for patients with pulseless ventricular tachycardia/fibrillation (VT/VF) or pulseless electrical activity (PEA) (Link et al., 2015).

Defibrillation for VF or Pulseless VT

The AHA 2015 guidelines recommend immediate initiation of ECM while simultaneously preparing for defibrillation for patients who develop VF or pulseless VT (Link et al., 2015). The AHA recommends “a single-shock strategy” (as opposed to sequential shocks) for defibrillation of VF or pulseless VT followed by continuous ECM for a complete two minute cycle prior to reattempting defibrillation (Link et al., 2015). In contrast to the AHA recommendations, the STS expert consensus recommends that if “patients develop VF or pulseless VT, three sequential shocks should be given without intervening with ECM” (Dunning et al., 2017). The International Liaison Committee on Resuscitation (ILCOR) found that recognition of lethal arrhythmias was prompt for in-hospital patients and “there is no benefit from a period of ECM before immediate defibrillation” (Dunning et al., 2017). Richardson, Dissanayake, & Dunning (2007) support such findings and note the likelihood of successful termination of VF post-cardiac surgery dramatically decreased with time. For the first attempt of defibrillation, the authors noted success at nearly 78% and down to 14% by the third attempt (Richardson et al., 2007). Given the findings of the review, Richardson et al. (2007) concluded that three sequential defibrillations should be attempted without cycles of ECM. Based on the evidence, the STS recommends providers administer three sequential shocks prior to ECM for postoperative cardiac surgery patients (Dunning et al., 2017).

Temporary Pacing Before ECM for Asystole or PEA

Another departure from the AHA recommendations is the institution of temporary pacing of asystole or PEA prior to ECM. Per the AHA recommendations, a patient is to receive two minutes of ECM with vasopressor therapy for asystole or PEA until the restoration of perfusion and cardiac rhythm (Link et al., 2015). The AHA "makes no recommendations for the use of temporary pacing wires in asystolic cardiac arrest" (Dunning et al., 2017). However, Ley (2015) highlights the potential for damage to the conduction system following valve or arrhythmia surgeries which could result in asystole or bradyarrhythmias and is easily amendable to epicardial or transcutaneous pacing and does not require ECM. Thus, the STS expert consensus recommends temporary pacing either by epicardial or transcutaneous methods for patients with asystole or PEA prior to ECM (Dunning et al., 2017).

Bedside RS with ICM Versus ECM

The 2017 STS expert consensus places a strong emphasis on performing emergent RS and ICM for post-cardiac surgery patients if ROSC is not obtained within five minutes (Dunning et al., 2009, 2017). Multiple studies have compared ECM to ICM and found that early RS and ICM provides better coronary perfusion pressure, increases instances of ROSC, and provides superior organ blood flow (Anthi et al., 1998; Dunning et al., 2009, 2017; Pottle, Bullock, Thomas, & Scott, 2002). Additionally, RS may relieve external compression forces associated with cardiac tamponade or allow the provider to identify a source for post-operative hemorrhage (Dunning et al., 2017). While Dunning et al. (2017) notes there is risk of cardiac structural and graft anastomotic injury with RS and ICM, the authors also note the risk can be minimized with proper training.

In post-cardiac surgery patients, ECM can also pose the risk of "chamber rupture, prosthetic valve dehiscence, and disruption of vascular sutures" (Ley, 2015; Maccaroni & Watson, 2013). While data regarding post-resuscitation iatrogenic cardiac injury is limited, two case reports cited in the STS consensus statement did support the potential. In a case report provided by Kempen & Allgood (1999), a post-pneumonectomy patient requiring ECM following arrest was noted to develop an acute right ventricular chamber rupture due to rib perforation caused by ECM. Böhrer, Gust, & Böttiger (2017) also reported a case of a post-cardiac surgery patient who acutely ruptured the right atrial chamber suture line and developed massage hemorrhage after receiving ECM. Based on these case studies, the potential for iatrogenic cardiac injury and subsequent hemorrhage related to ECM is likely higher in the post-cardiac surgery setting when compared to the general population due the recent surgical interventions required during cardiac surgery.

In addition to the risk of iatrogenic injury from ECM, survival rates were higher when ICM was performed compared to ECM alone (Adam et al., 2009; Anthi et al., 1998; Maccaroni & Watson, 2013; Pottle et al., 2002). Anthi et al. (1998) found that up to 28% of cardiac arrests post-cardiac surgery can be attributed to mechanical impediments to cardiac function (tamponade or graft malfunction). By performing early RS, within fifteen minutes of ECM, Anthi et al. (1998) found survival-to-discharge rates up to 63%. Similarly, Pottle et al. (2002) noted initial ROSC rates up to 46% for patients who developed a post-cardiac surgery arrest and ICM was performed following five minutes of ECM. More recent research by Maccaroni and Watson (2013) found that patients who underwent RS with ICM within ten minutes had a survival rate of 48%, compared to only 12% if RS took longer.

Administration of Epinephrine or Vasopressin

The 2015 AHA guidelines recommend "standard-dose epinephrine as 1mg every three to five minutes for patients in cardiac arrest" (Link et al., 2015). However, much of the evidence supporting standard-dose vasopressor administration, including vasopressin and epinephrine, during cardiac arrest is based entirely on animal studies and has not been successfully duplicated in human trials. The lack of human trials makes it harder to conclude whether to refute or accept the use of standard dose vasopressor therapy (Dunning et al., 2017; Tsagkataki, Levine, Strang, & Dunning, 2008). Cardiac surgery researchers not only suggest reconsideration of the routine use of epinephrine given that no benefit on survival-to-discharge with good neurologic function has been shown, but also warn providers of the potential negative sequela associated with vasopressor administration (Dunning et al., 2017; Link et al., 2015; Tsagkataki et al., 2008). Standard-dose vasopressor administration may potentiate profound hypertension with subsequent hemorrhaging from the vascular suture lines created during cardiac surgery once sinus rhythm and cardiac output are restored either by defibrillation or RS (Tsagkataki et al., 2008). Dunning et al. (2017) reported one such case of cardiac arrest due to a tension pneumothorax where administration of a vasopressor resulted in extreme hypertension and subsequent aortotomy hemorrhage following thoracoscopy tube placement which required chest re-exploration.

Given the lack of data, there is no evidence to support or refute the use of vasopressors in a non-post-cardiac surgery arrest (Dunning et al., 2017). However, in the post-cardiac surgery population, the literature cites instances of profound hypertension and hemorrhage associated with standard-dose vasopressor administration following restoration of sinus rhythm (Dunning et al., 2017; Tsagkataki et al., 2008). Based on the existing evidence and relative risk, the STS expert consensus recommends reconsideration of the routine administration of standard-dose epinephrine or vasopressin for post-cardiac surgery arrests (Dunning et al., 2017). If a vasopressor is deemed necessary, epinephrine should be the vasopressor of choice and only administered in reduced doses (up to 100ug) at the direction of a senior clinician (Dunning et al., 2017). The highest potential for restoring rhythm, cardiac output, and improving survival-to-discharge following post-cardiac surgery arrest remains either by defibrillation or RS.

Chapter 3: Study Methods

A retrospective observational two-group comparison study was designed using retrospective chart reviews to investigate the resuscitation practice trends and evaluate the related patient outcomes before (2009-2011) and after (2011-2016) implementing RSPT that was designed to improve nursing and ACP staff's performance when bedside RS was required as a method of resuscitation. As part of a continuous QI program, the training was implemented in October 2011 and considered for all patients who underwent cardiac surgery at a local hospital, developed a post-cardiac surgery arrest, and did not receive ROSC with ECM. Within each group, patients' outcomes were compared between those who developed a post-cardiac surgery arrest and were resuscitated with and without RS as a method of resuscitation.

Study Settings

CRMH is a 703-bed academic, level I trauma, tertiary care center located in southwest Virginia. CRMH features a cardiothoracic surgery program with more than 35 years' experience and has performed well over 21,000 heart and lung procedures. The specific research settings are the cardiac surgery intensive care unit (CSICU), an 11-bed intensive care unit located on the 6^{th} floor of CRMH, the cardiac surgery operating room (CSOR), a 4-bed operating suite (3 standardized cardiac surgery operating rooms and 1 hybrid operating room) adjacent to the

CSICU, and the cardiac surgery progressive care unit (CSPCU), a 20-bed progressive care unit located on the 9th floor.

Study Subjects

All patients who underwent cardiac surgery by means of median sternotomy at Carilion Roanoke Memorial from January 2009 to December 2016, developed a postoperative cardiac arrest, and received resuscitation either by standardized ACLS with ECM or RS with ICM were selected for the study. Thoracic surgery patients (i.e. lobectomies or esophagectomies) or patients with cardiac surgery by means of non-median sternotomy were excluded from the study. Both Carilion Clinic and Radford University Institutional Review Boards deemed the project to be a quality assurance/quality improvement activity prior to accessing patient data and the waver of patient consent was approved.

The Society of Thoracic Surgeons (STS) national database, a voluntary national reporting database established for QI and safety monitoring among participating cardiac surgery programs, was queried in addition to review of individual patient medical records from 2009 to 2016 to identify patients who underwent cardiac surgery and developed a postoperative arrest at CRMH. Cardiac arrest was defined as the "cessation of cardiac activity so that the victim becomes unresponsive, with no normal breathing and no signs of circulation" (Al-Khatib et al., 2017). For the purposes of this study, a post-surgical cardiac arrest was defined as a cardiac arrest within twelve days following cardiac surgery.

The STS query identified 135 patients who underwent cardiac surgery from January 2009 to December 2016 and met the definition of cardiac arrest. Of the 135 patients identified, the patient chart reviews identified 18 patients who were excluded due to not meeting criteria for inclusion (2 cases were excluded due to not having a median sternotomy, 2 were excluded due to not having a cardiac arrest, and 14 were excluded due to having a RS that was not associated with the cardiac arrest). The final analysis included a total of 117 patients. To investigate the aims of the study, a two-group comparison was performed.

AIM 1. Comparison of Resuscitation Practice Trends From 2009-2011 and 2011-2016

In October 2011, CRMH implemented a RSPT that prepared bedside nurses and ACPs to assist the attending cardiac surgeon in performing RS with ICM as a method of resuscitation when standardized ACLS with ECM was unsuccessful at achieving ROSC. The RSPT was based on the 2009 EACTS recommendations which recommended key roles for individuals involved, a minimal surgical supplies technique, and routine clinical-based simulation scenarios (Dunning et al., 2009). This RSPT trained the beside nurses and ACPs that staffed the CSICU and CSPCU the integral role of assisting the cardiac surgeon in performing bedside RS.

To investigate and compare the resuscitation practice trends and change in patient outcomes in post-cardiac surgery arrests at CRMH, a two-group comparison study was designed. The 117 patients who underwent cardiac surgery by means of median sternotomy from 2009 to 2016 and developed a post-cardiac surgery arrest were stratified into two group: those who were resuscitated from 2009-2011 (Group A) and those who were resuscitated from 2011-2016 (Group B) (see Figure 1).

AIM 2: Comparison of Patient Outcomes Between Patients Resuscitated with RS Versus Patients Resuscitated with non-RS

Another aim of the study was to compare outcomes between patients who either underwent standardized ACLS with ECM (non-RS) or RS with ICM (RS) as a method of resuscitation. Among the 117 patients who developed a postoperative cardiac surgical cardiac arrest from 2009 to 2016, intragroup outcome comparisons between the RS group (Group C) and the non-RS group (Group D) were retrospectively performed for 2009 to 2011, 2011 to 2016, and whole group comparisons for 2009 to 2016 respectively.

Non-RS Group (Group C)

All patients who underwent cardiac surgery at CRMH from 2009 to 2016, experienced cardiac arrest after cardiac surgery, and were resuscitated without a RS were included in this group. This group of patients received ECM and resuscitation practices based on the AHA ACLS guidelines for adult cardiac arrest; no RS was performed on patients in this group.

RS with ICM (Group D)

All patients who underwent cardiac surgery at CRMH from 2009 and 2016, experienced a cardiac arrest following cardiac surgery, and received a RS with ICM per the resternotomy preparation training module (see below) were included in this group. This group received ECM and AHA ACLS resuscitative measures until RS and ICM was performed by an attending cardiac surgeon.

Emergent RS with ICM—The RSPT: The RSPT was implemented at CRMH in October 2011. Prior to RSPT, bedside RS would be performed by the cardiac surgeon with the assistance of the operating room staff. RSPT was based on the 2009 EACTS recommendations and provides bedside clinicians with the training necessary to prepare a patient and assist a surgeon with bedside surgical re-exploration in the event of a post-cardiac surgical arrest. The mandatory biannual clinical simulated training for the CSICU and CSPCU staff includes review of sterile prepping of the patient and staff, setup and operation of standardized surgical instrument trays required for emergent RS, and serving as the surgical first assistant until trained operating room staff are available. The

RSPT currently in place at CRMH focuses on preparing clinicians to assist a surgeon with bedside resternotomy.

Figure 1

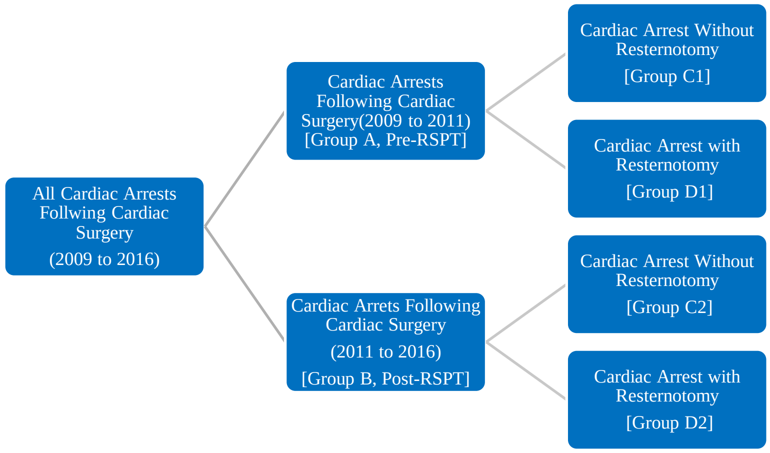

Figure 1. Study Design Diagram. This figure displays all patients who developed a cardiac arrest following cardiac surgery from 2009 to 2016 and the two group comparisons for those developed a cardiac arrest and either had an arrest with RS or an arrest without an RS.

Study Procedures and Data Collection

Prior to access of medical records, approval of both the Carilion Clinic and Radford University IRBs was obtained, and the protection of human subjects was followed throughout the data collection process. The STS database was queried in addition to review of individual patient medical records from 2009 to 2016 to identify patients who underwent cardiac surgery and developed a post-cardiac surgery arrest at CRMH. All-cause post-cardiac surgery arrests at CRMH from 2009 and 2016 were retrospectively reviewed. Data obtained from the retrospective review included the type of surgical procedure originally performed, the patients' STS mortality (scoring is calculated based on patients who underwent cardiac surgery and died during hospitalization or within 30 days of discharge), and STS morbidity and mortality (scoring is calculated based on the percentage of patients who developed 1 of 5 complications of cardiac surgery: reoperation, stroke, kidney failure, infection of the chest, or prolonged period of mechanical ventilation). The STS predicted mortality scoring is used to assess a patient's perioperative risk for mortality: low risk (<4%), intermediate risk (4% to <8%), high risk (8% to >12%) (Vassileva et al., 2015). In addition, the timeframe from surgery-to-arrest, the etiology for cardiac arrest, the incidence of resternotomy performed, the location of the resternotomy (CSICU, CSPCU, CSOR), the intensive care length-of-stay (LOS), the overall hospital length-of-stay, patient survival-rate, the presence of cardiac assist device, and post-resuscitation complications were also evaluated (See Table 2). An anonymized data collection tool including demographic, procedural, and patient outcome variables was created within a Microsoft Excel spreadsheet to allow ease of data extrapolation.

Table 2

Major Study Variables

Patient Variables
• Age • BMI • Past Medical History • STS Morbidity Score* • STS Morbidity/Mortality Score* • Etiology for Cardiac Arrest
Cardiac Arrest Variables
• Type of Procedure Performed • Etiology of Cardiac Arrest • Location of Cardiac Arrest • Timeframe from Surgery to Cardiac Arrest
Resternotomy Variables
• Frequency Resternotomy Performed • Timeframe from Surgery to Arrest • Location of Resternotomy (CSICU, CSPCU, CSOR)
Patient Outcome Variables
• Presence of Cardiac Assist Device • ICU Length of Stay • Overall Hospital Length of Stay • Patient Survival Rate from Resuscitation • Patient Survival to Hospital Discharge • Post-Resuscitation Complications • Cause of Death

*STS mortality scoring is calculated based on patients who underwent cardiac surgery and died during hospitalization or within 30 days of hospital discharge, the higher the percentage, the higher the patient's 30 day risk for mortality; STS morbidity scoring is calculated based on the percentage of patients who expereince at least 1 of 5 complications of cardiac surgery: reoperation, stroke, kidney failure, infection of the chest, or prolonged period of mechanical ventilation; the higher the percentage, the higher the patient's overall risk for morbidity/mortality.

The information obtained from the retrospective review provided baseline data regarding current cardiac arrest trends following cardiac surgery at CRMH. Following the review, patient outcomes between groups with and without RS with ICM were compared within patients in 2009 to 2011, within patients in 2011 to 2016, and among all patients from 2009 to 2016 to determine if there was, indeed, a significant improvement in outcomes following implementation of the RS preparation training module.

All patient information was de-identified to ensure protection of patient privacy. Any hard copies of patient information (i.e. copies of charts prior to implementation of the electronic medical record, scratch notes, or printouts of STS data) were stored in a locked file cabinet at CRMH until information was imported into the data collection tool. All digital forms of data were accessed using a research account that was created by the Student Support Services office at CRMH. This office verifies the student's active status and the presence of a collaborative agreement contract with Radford University. No patient information was shared with Radford University. The Microsoft Excel document was stored on a dedicated hospital sharedrive with limited access and data encryption.

Statistical Analysis Plan

The first purpose of this study was to investigate the resuscitation practice trends between 2009 to 2011 and 2011 to 2016. Frequency and percentages for nominal variables and standard variation for continuous variables were extracted from the demographic data, clinical data, and the resuscitation practice trend data from all groups (2009 to 2016) and two comparison cohorts (2009 to 2011 vs 2011 to 2016). The differences in demographic and clinical data, resuscitation practice data, and clinical outcome data in two groups were compared using Chi-Square testing or Fisher's-Exact testing for nominal or categorical variables, respectively, and compared using independent t-testing for continuous variables.

The second purpose of the study was to investigate whether there was a statistical difference in the patient outcomes between patients who received RS for resuscitation and patients who did not receive RS for resuscitation among patients who underwent cardiac surgery and developed a postoperative arrest. The primary patient outcome measure was survival-to-discharge. Other patient outcome measures evaluated included ICU LOS, hospital LOS, and post-arrest complications. Patient outcome variables in the two groups were described as frequencies and percentages for nominal variables and mean with standard deviations for continuous variables. The differences in the patient outcomes in the two groups were evaluated using Chi-square testing for nominal variables and independent t-testing for continuous variables. A p-value of <0.05 was considered significant. Statistical analysis was performed using Statistical Analysis System (SAS) Enterprise version 7.1 (SAS, Inc., Cary, NC, USA).

Chapter 4: Study Results

AIM 1: Comparison of Resuscitation Practice Trends Between 2009-2011 and 2011-2016

Demographic and Clinical Data (Refer to Table 3)

A total of 117 patients suffered a cardiac arrest following cardiac surgery and received either standardized resuscitation or standardized resuscitation followed by RS with ICM from January 2009 and December 2016. The mean age of those individuals was 63.8 years ± 12 and 70 (59.8%) were male. The primary cardiac surgical procedures that were performed included isolated coronary artery bypass grafting (n=44, 37.6%), valve replacement or repair (n=16, 13.7%), and coronary artery bypass grafting with a valve replacement or repair (n=16, 13.7%). The mean predicted STS patient mortality score was 5.8% ± 8.8 with a mean patient predicted 30-day STS predicated morbidity/mortality score of 27.7 ± 20.9. No statistically nor clinically significant differences were found in the patient demographic and clinical variables when the 2009-2011 cohort was compared to the 2011-2016 cohort (see Table 3).

50 patients suffered a postoperative cardiac arrest from 2009 to 2011 whereas 67 patients suffered a postoperative cardiac arrest from 2011 to 2016. In both cohorts, males were dominantly prevalent (62%, n=31 male from 2009-2011 and 58.2%, n=39 male from 2011-2016). Distributions of surgical procedures performed prior to cardiac arrest were similar between the two cohorts except for an increase in "other procedures," primarily aortic dissections, thoracic aortic aneurysm repair, or aortic root replacement 11 (16.4%) cases from 2011-2016 compared to 3 (6%) cases from 2009-2011 (p = 0.09). No statistical significance was found between the two groups in regard to STS predicated mortality (5.1% from 2009-2011 vs 6.5% from 2011-2016, p=0.51) and 30-day STS predicted morbidity/mortality scores (28.8% from 2009-2011 vs 26.7% from 2011-2016, p=0.67).

Table 3

Patient Demographic and Clinical Data

	All Patients	2009 to 2011	2011 to 2016	P value
	Frequency (%) or Mean ± SD (n = 117)	Frequency (%) or Mean ± SD (n = 50)	Frequency (%) or Mean ± SD (n = 67)	
Patient and Clinical Variables				
Male	70 (59.83%)	31 (62.00%)	39 (58.21%)	0.68
Mean Age in Years	63.80 ± 12.15	64.26 ± 10.52	63.45 ± 13.32	0.73
Mean Body Mass Index	29.81 ± 6.53	30.99 ± 6.47	28.92 ± 6.48	0.09
Past Medical History				
• Cerebral Vascular Accident	18 (15.38%)	7 (14.00%)	11 (16.42%)	0.72
• Chronic Kidney Disease	23 (19.66%)	11 (22.00%)	12 (17.91%)	0.58
• Congestive Heart Failure	14 (11.97%)	9 (18.00%)	5 (7.46%)	0.08
• Coronary Artery Disease	32 (27.35%)	13 (26.00%)	19 (28.36%)	0.78
• Diabetes Mellitus	54 (46.15%)	26 (52.00%)	28 (41.79%)	0.27
• Hyperlipidemia	66 (56.41%)	29 (58.00%)	37 (55.22%)	0.76
• Hypertension	93 (79.49%)	43 (86.00%)	50 (74.63%)	0.13
• Lung Disease	21 (17.95%)	9 (18.00%)	12 (17.91%)	0.99
• Tobacco Abuse	17 (14.53%)	9 (18.00%)	8 (11.94%)	0.36
Surgical Procedure(s) Prior to Cardiac Arrest and Risk Stratification				
• Isolated CABG	44 (37.6%)	23 (46%)	21 (31.3%)	0.11
• Isolated Valve(s) Replaced/Repaired	16 (13.7%)	7 (14%)	9 (13.4%)	0.93
• CABG + Valve(s)	12 (10.2%)	6 (12%)	6 (9%)	0.59
• CABG + Valve(s) with Additional Procedure (i.e. MAZE, PFO closure)	16 (13.7%)	7 (14%)	9 (13.4%)	0.93

• CABG + Additional Procedure without Valve(s)	4 (3.4%)	2 (4%)	2 (3%)	0.77
• Valve + Additional Procedure without CABG	11 (9.4%)	2 (4%)	9 (13.4%)	0.08
• Other Procedure (i.e. Aortic Dissections, ECMO)	14 (12%)	3 (6%)	11 (16.4%)	0.09
Risk Stratification				
Mean STS Predicted Mortality Score*	58.32% ± 8.82	5.13% ± .6.83	6.50% ± 10.41	0.51
Mean STS Predicted Morbidity/Mortality Score	27.71% ± 20.86	28.81% ± 20.49	26.68% ± 21.44	0.67

*The STS predicted mortality scoring is used to assess a patient's preoperative risk for mortality: low risk (<4%), intermediate risk (4% to <8%), high risk (8% to < 12%), very high risk (>12%) (Vassileva et al., 2015).

Characteristics of Post-Cardiac Surgery Arrests (Refer to Table 4)

The characteristics of cardiac arrests were evaluated in the 117 individuals who underwent cardiac surgery and developed a postoperative cardiac arrest from 2009-2016. The mean time from cardiac surgery to cardiac arrest was 5.57 days ± 7.74 days. The most frequent etiology of arrest was an arrhythmia (n=64, 54.7%), followed by respiratory failure (n=19, 16.24%), and bleeding (n=8, 6.84%). The primary location for a postoperative cardiac arrest was in the CSICU (n = 95, 81.2%).

When the 2009-2011 cohort was compared to the 2011-2015 cohort, arrhythmias remained the primary cause of arrests in both groups (50% and 58.2% respectively, p=0.17). Location distributions for post-cardiac surgery arrests were also similar in both groups with a clinically significant increase in the instances of cardiac arrests on the CSPCU: 4% (n=2) in the 2009-2011 cohort and 7.5% (n=5) in the 2011-2016 cohort. No differences were found in either etiology of arrest or location of arrest among the two cohorts (p > 0.05) (Refer to Table 4)

Table 4

Cardiac Arrest Data

	All Patients	2009 to 2011	2011 to 2016	P value
	Frequency (%) or Mean ± SD (n = 117)	Frequency (%) or Mean ± SD (n = 50)	Frequency (%) or Mean ± SD (n = 67)	
Cardiac Arrest Data				
Etiology of Arrest				
• Arrhythmia	64 (54.70%)	25 (50.00%)	39 (58.21%)	0.17
• Respiratory Failure	19 (16.24%)	8 (16.00%)	11 (16.42%)	0.95
• Bleeding	8 (6.84%)	4 (8.00%)	4 (5.97%)	0.67

• Other	26 (22.22%)	13 (26.00%)	13 (19.40%)	0.4
Location of Cardiac Arrest				
• CSICU	95 (81.20%)	40 (80.00%)	55 (82.09%)	0.78
• CSPCU	7 (5.98%)	2 (4.00%)	5 (7.46%)	0.44
• CSOR	5 (4.27%)	2 (4.00%)	3 (4.48%)	0.9
• Other	10 (8.55%)	6 (12.00%)	4 (5.97%)	0.25
Time from Surgery to Cardiac Arrest (Days)	5.57 ± 7.74	4.85 ± 6.16	6.11 ± 8.75	0.37

RS Practice Data (Refer to Table 5)

Bedside RS was performed on 22 (18.8%) of the 117 patients who suffered a post-cardiac surgery arrest from 2009-2016; 9 (18%) RS were performed from 2009-2011 and 13 (19.4%) were performed from 2011-2016 (p=0.85). Of the 22 bedside RS performed for cardiac arrest from 2009-2016, 12 (54.6%) were performed in the CSICU and 10 (45.4%) were performed in the CSOR. Location distributions remained the same for the CSOR location between to two cohorts (n=5 and n=5 respectively). However, there was an increase in the instances of RS being performed in the CSICU (44.4% in the 2009-2011 cohort vs 61.5% in the 2011-2016 cohort, p=0.43), although no statistical significance was found. There were no instances of RS being performed in any other locations.

The mean time from cardiac arrest to performing RS among the 22 individuals who suffered a post-cardiac surgery arrest from 2009-2016 was 33.5 minutes ± 22.8. No statistically significant differences were found in the mean time from the onset of cardiac arrest to performing a RS between the 2009-2011 cohort and the 2011-2016 cohort (35.4 minutes ± 26.9 vs 32.1 minutes ± 20.6, p=0.75). However, the mean time-to-resternotomy did decrease in the 2011-2016 cohort by an average of 3.29 minutes ± 6.31.

Table 5

Resternotomy Practice Data

	Patients Who Underwent RS after cardiac arrest from 2009 to 2016 (n = 22)	Patients Who Underwent RS after cardiac arrest from 2009 to 2011 (n = 9)	Patients Who Underwent RS after cardiac arrest from 2011 to 2016 (n = 13)	P value
Resternotomy Practice Data				

Resternotomy Performed	22 (18.8%)	9 (18%)	13 (19.4%)	0.85
Location of RS				
• CSICU	12 (54.55%)	4 (44.44%)	8 (61.54%)	0.43
• CSOR	10 (45.45%)	5 (55.56%)	5 (38.46%)	0.43
• CSPCU	0 (0%)	0 (0%)	0 (0%)	----
• OTHER	0 (0%)	0 (0%)	0 (0%)	----
Mean Time from Arrest to RS (Minutes)	33.50 ± 22.82	35.44 ± 26.90	32.15 ± 20.59	0.75
Use of a Cardiac Assist Device Following Resternotomy	12 (54.55%)	4 (44.44%)	8 (61.54%)	0.43

Patient Outcomes Following RS for Cardiac Arrest (Refer to Table 6)

The mean ICU and hospital lengths of stay for patients who underwent RS following cardiac arrest from 2009-2016 were 10 days ± 19.3 and 15.3 days ± 20.5, respectively. When the 2009-2011 cohort was compared to the 2011-2016 cohort, there was an increase in both ICU LOS (6 days ± 11.8 versus 12.8 day ± 23.1, p=0.43) and hospital LOS (12.4 days ± 15.2 versus 17.1 days ± 23.1, p=0.61) in the 2011-2016 cohort, although neither were clinically significant.

Among the 22 patients who underwent RS after cardiac arrest from 2009-2016, a total of 14 (63.6%) patients survived greater than 24hrs following resuscitation, but only 3 (13.6%) patients survived-to-discharge; all of the 3 patients who survived-to-discharge were in the 2011-2016 cohort with an average ICU LOS of 9 ± 6 days and hospital LOS of 17 ± 13 days. When the 2009-2011 cohort was compared to the 2011-2016 cohort, there was an improvement in both the 24-hour survival (44.5% (n=4) vs 76.9% (n=10), p=0.12) and survival-to-discharge (0% versus 23.1% (n=3), p=0.12), although neither were statistically significant. Dispositions for those three patients who underwent RS and survived-to-discharge included facility (n=2, 66.7%) and home (n=1, 33.3%).

The primary post-resuscitation complications for the 22 patients who underwent a RS for cardiac arrest from 2009 to 2016 included renal failure (n=11, 50%), anoxic brain injury (n=7, 31.8%), and respiratory failure (n=6, 27.3%). When the 2009-2011 cohort was compared to the 2011-2016 cohort, there were no statistically significant differences in post-resuscitation complications: renal failure (p=0.66), anoxic brain injury (p=0.42), and respiratory failure (p=0.66). There were more instances of anoxic brain injury (n=5, 38.5%) for the 2011-2016 cohort when compared to the 2009-2011 cohort (n=2, 22.2%), followed by an increase in respiratory failure (n=4, 30.8% in 2011-2016 vs. n=2, 22.2% in 2009-2011). There were no cases of complications that involved hemorrhage or mediastinitis related to RS. Among the three survivors, only one patient had complications, renal failure.

The primary causes of death for patients who underwent a RS following cardiac arrest but did not survive-to-discharge included anoxia (n=5, 26.3%), PEA/VF (n=5, 26.3%), withdrawal of care (n=3, 15.8%), and multisystem organ failure (n=2, 10.5%). Among the two cohorts, there were no statistically significant differences: anoxia (p=0.15), pulseless electrical activity/ventricular fibrillation (p=0.47), withdrawal of care (p=0.47), and multisystem organ failure (p=0.16). Although cause of death distributions were fairly similar among the two cohorts based on statistical results, there were higher incidences of deaths related to PEA in the 2009-2011 cohort than the 2011-2016 cohort (33.3% versus 10%, p=0.47) and anoxia in the 2011-2016 cohort compared to the 2009-2011 cohort (40% versus 11.1%, p=0.15).

Table 6

Patient Outcome Variables Following Resternotomy

	Patients Who Underwent RS after cardiac arrest from 2009 to 2016	**Patients Who Underwent RS after cardiac arrest from 2009 to 2011**	**Patients Who Underwent RS after cardiac arrest from 2011 to 2016**	**P value**
Patient Outcome Variables				
Length of Stay	**n = 22**	**n = 9**	**n = 13**	
Mean ICU LOS (Days)	10.04 ± 19.25	6.04 ± 11.81	12.82 ± 23.14	0.43
Mean Hospital LOS (Days)	15.17 ± 20.49	12.43 ± 15.22	17.06 ± 23.89	0.61
Survival Rate	**n = 22**	**n = 9**	**n = 13**	
24 hour Survival Following RS (Survived with RS)	14 (63.64%)	4 (44.44%)	10 (76.92%)	0.12
Survival to Hospital Discharge	3 (13.64%)	0 (0%)	3 (23.08%)	0.12
Post Resuscitation Complications	**n = 22**	**n = 9**	**n = 13**	
Renal Failure	11 (50.00%)	5 (55.56%)	6 (46.15%)	0.66
Anoxic Brain Injury	7 (31.82%)	2 (22.22%)	5 (38.46%)	0.42
Respiratory Failure	6 (27.27%)	2 (22.22%)	4 (30.77%)	0.65

Hemorrhage	0 (0%)	0 (0%)	0 (0%)	----
Mediastinitis	0 (0%)	0 (0%)	0 (0%)	----
Cause of Death	**n = 19**	**n = 9**	**n = 10**	
Anoxia	5 (26.32%)	1 (11.11%)	4 (40.00%)	0.15
PEA/VF	5 (26.32%)	4 (44.44%)	1 (10%)	0.47
Withdraw of Care	3 (15.79%)	2 (22.22%)	1 (10.00%)	0.47
Multisystem Organ Failure	2 (10.53%)	0 (0%)	2 (20.00%)	0.16
Other	2 (10.53%)	1 (11.11%)	1 (10.00%)	0.94
Coagulopathy	1 (5.26%)	0 (0%)	1 (10.00%)	0.33
Electrolyte Abnormalities	1(5.26%)	1 (11.11%)	0 (0%)	0.28
Ischemia/Lactic Acidosis	0(0%)	0 (0%)	0 (0%)	----
Pneumothorax	0 (0%)	0 (0%)	0 (0%)	----
Vasospasm	0 (0%)	0 (0%)	0 (0%)	----
Survival to Discharge Length of Stay	**n = 3**	**n = 0**	**n = 3**	
Mean ICU LOS (Days)	9.03±6.06	----	9.03±6.06	----
Mean Hospital LOS (Days)	17.40±13.74	----	17.40±13.74	----
Survival to Discharge Complications	**n = 3**	**n = 0**	**n = 3**	
No complication	2 (66.67%)	0 (0%)	2 (66.67%)	----
Renal Failure	1 (33.33%)	0 (0%)	1 (33.33%)	----
Discharge Disposition	**n = 3**	**n = 0**	**n = 3**	
Facility	2 (66.67%)	0 (0%)	2 (66.67%)	----
Home	1 (33.33%)	0 (0%)	1 (33.33%)	----

*RS= Resternotomy and LOS= Length of Stay; PEA= Pulseless Electrical Activity, VF= Ventricular Fibrillation

Aim 2: Comparisons of Patient Outcomes Between RS vs Non-RS Groups

Demographic and Clinical Data (Refer to Table 7)

When patients who developed a postoperative cardiac arrest were compared based on those who either were resuscitated with a RS or a non-RS, there were no significant differences between gender, body mass index, or ejection fraction. In all patients reviewed (2009-2016) there was a statistically significant difference in age (69.5 years ± 8.7 for RS versus 62.5 years ± 12.5 for non-RS, p=0.02). This finding was similar between the 2009-2011 cohort (68.3 years ± 9.9 for RS versus 63.4 years ± 10.6 for non-RS, p = 0.20), but only statistically significant in the 2011-2016 cohort (70.3 years ± 8.2 for RS versus 61.9 years ± 13.8 for non-RS, p = 0.047).

Distributions of past medical history variables were similar without statistical significance between all patients (2009-2016) and the individual cohorts (2009-2011 and 2011-2016) except for a statistically significant higher incidence of hyperlipidemia among RS groups compared to non-RS groups (81.8% vs 50.5%, p=0.01) for all patients in 2009-2016 and was also similar in the RS vs non-RS groups in the 2011-2016 cohort (46.3%, p=0.01).

Table 7.

Demographic and Clinical Data

	All Patients from 2009 to 2016 (N=117)			Patients from 2009 to 2011 (N=50)			Patients from 2011 to 2016 (N=67)		
	RS (N=22)	Non-RS (N=95)		RS (N=9)	Non-RS (N=41)		RS (N=13)	Non-RS (N=54)	
	Frequency (%) or Mean ± SD		P value	Frequency (%) or Mean ± SD		P value	Frequency (%) or Mean ± SD		P value
Patient and Clinical Data									
Male	13 (59.1%)	57 (60.0%)	0.94	5 (55.6%)	26 (63.4%)	0.66	8 (6.41%)	31 (57.4%)	0.79
Mean Age in Years	69.5 ± 8.7	62.6 ± 12.5	0.02	68.3 ± 9.9	63.4 ± 10.6	0.20	70.3± 8.2	61.9 ± 13.8	0.05
Mean Body Mass Index	29.7 ± 6.8	29.8 ± 6.5	0.93	32.1 ± 9.1	30.8 ± 5.9	0.57	28.1 ± 25.5	29.1 ± 27.2	0.59
Ejection Fraction	54.1 ± 12.6	51.4 ± 15.2	0.45	50.0 ± 17.1	48.3 ± 15.6	0.77	56.9 ± 7.8	53.8 ± 14.6	0.29
Past Medical History									
Cerebral Vascular Accident	1 (4.6%)	17 (17.9%)	0.12	0 (0%)	7 (17.1%)	0.18	1 (7.7%)	10 (18.5%)	0.34
Chronic Kidney Disease	4 (18.2%)	19 (20.0%)	0.85	1 (11.1%)	10 (24.3%)	0.38	3 (23.1%)	9 (16.6%)	0.59
Congestive Heart Failure	2 (9.1%)	12 (12.6%)	0.64	2 (22.2%)	7 (17.1%)	0.72	0 (0%)	5 (9.3%)	0.25
Coronary Artery Disease	8 (36.4%)	24 (25.3%)	0.29	4 (44.4%)	9 (21.9%)	0.16	4 (30.8%)	15 (27.8%)	0.83
Diabetes Mellitus	10 (45.4%)	44 (46.3%)	0.94	3 (33.3%)	23 (56.1%)	0.22	7 (53.9%)	21 (38.9%)	0.33
Hyperlipidemia	18 (81.8%)	48 (50.5%)	0.01	6 (66.7%)	23 (56.1%)	0.56	12 (92.3%)	25 (46.3%)	0.01
Hypertension	19 (86.4%)	74 (77.9%)	0.38	8 (88.9%)	35 (85.4%)	0.78	11 (84.6%)	39 (72.2%)	0.36
Lung Disease	3 (13.6%)	18 (18.9%)	0.56	2 (22.2%)	7 (17.1%)	0.72	1 (7.7%)	11 (20.4%)	0.28
Tobacco Abuse	3 (13.6%)	14 (14.7%)	0.890	1 (11.1%)	8 (19.5%)	0.55	2 (15.4%)	6 (11.1%)	0.67

Prearrest Procedural Data (Refer to Table 8)

The primary cardiac surgical procedures that were performed included isolated coronary artery bypass grafting (8.5% for RS versus 34% for non-RS between 2009-2016), valve replacement or repair (4.3% for RS versus 9.4% for non-RS between 2009-2016), and coronary artery bypass grafting with a valve replacement or repair (3.4% for RS versus 10.3% for non-RS between 2009-2016). Among all patients (2009-2011) and the two cohorts (2009-2011 and 2011-2016) there were no statistically significant differences in surgical procedure distributions performed prior to cardiac arrest between the RS vs non-RS groups.

Among all patients (2009-2016) and the two cohorts (2009-2011 and 2011-2016), incidences of arrest were higher in the non-RS groups than the RS groups. No significant differences were found in STS mortality nor STS 30-day morbidity/mortality scores between RS vs non-RS groups among all patients (2009-2016), or in the individual cohorts (2009-2011 and 2011-2016) (Refer to Table 8).

Table 8

Procedures Performed Prior to Cardiac Arrest

	All patients from 2009 to 2016 (N=117)			Patients from 2009 to 2011 (N=50)			Patients from 2011 to 2016 (N=67)		
	RS (N=22)	Non-RS (N=95)		RS (N=9)	Non-RS (N=41)		RS (N=13)	Non-RS (N=54)	
	Frequency (%) or Mean ± SD		P value	Frequency (%) or Mean ± SD		P value	Frequency (%) or Mean ± SD		P value
Procedure(s) Performed Prior to Cardiac Arrest									
Isolated CABG	10 (8.5%)	34 (29.1%)	0.39	4 (8%)	19 (38%)	0.92	6 (9%)	15 (22.4%)	0.20
Isolated Valve(s) Replaced/Repaired	5 (4.3%)	11 (9.4%)	0.17	3 (6%)	4 (8%)	0.06	2 (3%)	7 (10.4%)	0.82
CABG + Valve(s)	2 (1.7%)	10 (8.5%)	0.84	0	6 (12%)	0.22	2 (3%)	4 (6%)	0.37
CABG/Valve(s) + Additional Procedure	4 (3.4%)	12 (10.3%)	0.49	2 (4%)	5 (10%)	0.43	2 (3%)	7 (10.4%)	0.82
CABG + Additional Procedure without Valve(s)	1 (0.9%)	3 (2.6%)	0.75	0	2 (4%)	0.50	1 (1.5%)	1 (1.5%)	0.27
Valve + Additional Procedure without CABG	0	11 (9.4%)	0.09	0	2 (4%)	0.50	0	9 (13.4%)	0.11
Other Procedure	0	14 (11.9%)	0.05	0	3 (6%)	0.40	0	11 (16.4%)	0.08
Risk Stratification									
Mean STS Predicted Mortality Score	6.06% ± 7.08	5.76% ± 9.39	0.90	7.24% ± 9.31%	4.50% ± 5.99	0.33	5.12% ± 5.01	7.01% ± 11.85	0.50
Mean STS Predicted Morbidity/Mortality Score	27.98% ± 17.89	27.62% ± 21.92	0.95	33.07% ± 21.42	27.54% ± 20.45	0.51	23.91% ± 14.37	27.70% ± 23.69	0.64

Post-Cardiac Surgery Arrest Patient Characteristics (Refer to Table 9)

The primary etiology for post-cardiac surgery arrests between the RS and non-RS groups were arrhythmias (45.5% vs. 54.8%, p = ns) with no significant differences among all patients and the two cohorts. The second etiology for post-cardiac surgery arrests in RS group was bleeding and its incidence was significantly higher in RS group than non-RS group (27.3% vs. 2.11%, p = 0.000), and this result was similar within the 2009-2011 cohort and the 2011-2016 cohort group with statistical significance (See Table 9). Oppositely, respiratory failure was the primary cause of post-cardiac surgery arrest among all (2009-2016) non-RS patients (0% in RS group vs. 20% in non-RS group, p = 0.022).

The CSICU was the primary unit post-cardiac surgery arrests occurred among the all patients (2009-2016) in both RS and non-RS groups (86.4% vs. 80%, p = 0.49). However, among 117 patients who underwent cardiac surgery, 22 patients (18.8%) experienced cardiac arrest outside the CSICU: 7 (5.9 %) in the CSPCU, 5 (4.3 %) in the CSOR, and 10 (8.5 %) in other hospital units. No significant differences were found between the RS and non-RS groups in terms of the location of cardiac arrest, within the 2009-2011 cohort or within the 2011-2016 cohorts.

The mean time from cardiac surgery-to-arrest among the RS group was significantly shorter than the non-RS group in all patients (2009-2016) (32.9 hours ± 65.9 for RS patients versus 157.1 hours ± 196.8 for non-RS patients, p <0.0001). Among all patients (2009-2016), cardiac assist devices were used more frequently in the RS group rather than in non-RS group (p=0.00).

Table 9

Cardiac Arrest Characteristics

	All patients from 2009 to 2016 (N=117)			Patients from 2009 to 2011 (N=50)			Patients from 2011 to 2016 (N=67)		
	RS (N=22)	Non-RS (N=95)		RS (N=9)	Non-RS (N=41)		RS (N=13)	Non-RS (N=54)	
	Frequency (%) or Mean ± SD		P value	Frequency (%) or Mean ± SD		P value	Frequency (%) or Mean ± SD		P value
Cardiac Arrest Data									
Etiology of Arrest									
Arrhythmia	10 (45.5%)	54 (56.8%)	0.33	3 (33.3%)	22 (53.7%)	0.27	7 (53.9%)	32 (59.3%)	0.72
Bleeding	6 (27.3%)	2 (2.1%)	0.00	3(33.3%)	1 (2.4%)	0.00	3 (23.2%)	1 (1.9%)	0.00
Respiratory Failure	0 (0%)	19 (20.0%)	0.02	0 (0%)	8 (19.5%)	0.15	0 (0%)	11 (20.4%)	0.08
Other	6 (27.3%)	20 (21.1%)	0.53	3 (33.3%)	10 (24.4%)	0.58	3 (23.1%)	10 (18.5%)	0.71
Location of Cardiac Arrest (not the location resternotomy was performed)									
CSICU	19 (86.4%)	76 (80.0%)	0.49	6 (66.7%)	34 (82.9%)	0.27	13 (100%)	42 (77.8%)	0.06
CSPCU	1 (4.6%)	6 (6.3%)	0.75	1 (11.1%)	1 (2.4%)	0.23	0 (0%)	5 (9.3%)	0.25
CSOR	1 (4.6%)	4 (4.2%)	0.94	1 (11.1%)	1 (2.4%)	0.23	0 (0%)	3 (5.6%)	0.39
Other	1 (4.6%)	9 (9.5%)	0.46	1 (11.1%)	5 (12.2%)	0.93	0 (0%)	4 (7.4%)	0.31

Time from Surgery to Cardiac Arrest (Hours)	32.9 ± 65.9	157.1 ± 196.8	0.00	61.5 ± 95.4	128.6 ± 155.4	0.22	13.1 ± 22.3	178.7 ± 222.2	0.00
Use of CAD Following Resuscitation	12 (54.6%)	21 (22.1%)	0.00	4 (44.4%)	10 (24.4%)	0.23	8 (61.54%)	11 (20.4%)	0.00

*CAD = cardiac assist device (i.e. extracorporeal membrane oxygenation or intra-aortic balloon pump)

Patient Outcomes Following Bedside RS for Post-Cardiac Surgery Arrest (Refer to Table 10)

There were no significant differences between the RS and non-RS groups in ICU LOS (10 days ± 19 for RS vs 15 days ± 19 for non-RS, p=0.23) and in overall hospital LOS (15 days ± 20 for RS vs 23 days ± for 27 for non-RS, p=0.21) in all patients (2009-2016). 24-hour survival rates in all 117 patients who experienced a post-cardiac surgery arrest and received ether method of resuscitation was 61.5% (n=72) and there were no significant differences between the RS and non-RS groups for all patients (63.6% for RS vs 61.1% for non-RS), within the 2009-2011 cohort (44.4% for RS versus 58.5% for non-RS), and within the 2011-2016 cohort (76.9% for RS vs 63% for non-RS). However, survival-to-discharge in the non-RS groups were higher compared to the RS groups in the all patient cohort (2009-2016) (13.6% RS group vs 44.2% non-RS group, p=0.01), within the 2009-2011 cohort (0% RS group vs 39% non-RS group, p=0.02), and within the 2011-2016 cohort (23.1% RS vs 48.2% non-RS, p=0.1).

Among the RS group (n=22) who experienced a cardiac arrest, 14 patients (63.6%) survived 24-hours following resuscitation, but only three patients (13.6%) survived-to-discharge. None of patients in the RS group survived-to-discharge within the 2009-2011 cohort, but three patients within the 2011-2016 RS group survived-to-discharge. Among the all patient cohort (2009-2016) non-RS group (n=95) who experienced post-cardiac surgery arrests, 58 (61.1%) survived 24-hours following resuscitation and 42 (44.2%) survived-to-discharge. Survival-to-discharge improved between the 2009-2011 cohort (39%) to the 2011-2016 cohort (48.2%).

Overall, among the 14 patients who survived 24-hours following resuscitation in the RS group, 3 (21.4%) survived to hospital discharge; whereas 42 out of 58 (72.4%) of patients in the non-RS group survived-to-discharge.

The primary post-resuscitation complication in both RS and non-RS groups was renal failure (50% in RS group vs 48.9% in non-RS group, p=ns). However, the second highest complication was different among the two groups: anoxic brain injury (31.8% RS group vs 20.8% for non-RS group, p=ns) and respiratory failure (27.3% for RS group vs 55.8% for non-RS group). There were no instances of post-resuscitation hemorrhage or mediastinitis in the RS groups compared to the non-RS groups which had 2 (2.1%) instances of hemorrhage and 3 (3.2%) instances of mediastinitis post-resuscitation.

The primary causes of death for all patients (2009 to 2016) that did not survive-to-discharge included anoxia (26.3% for RS and 5.7% for non-RS, p=0.01), PEA/VF (26.3% for RS and 26.4% for non-RS, p=ns), withdrawal of care (15.8% for RS and 17% for non-RS), and multisystem organ failure (10.5% for RS and 15.1% for non-RS, p=ns). There was a statistically significant higher incidence of anoxia associated deaths in the RS group for all patients in the 2009-2016 cohort (p=0.01) and the 2011-2016 cohort (p=0.04). Among all patients who survived-to-discharge, there were no statistically significant differences in the disposition to facility or home between RS and non-RS patients (p > 0.05).

Table 10

Patient Outcomes between Resternotomy versus Non-Resternotomy

	All patients from 2009 to 2016 (N=117)			**Patients from 2009 to 2011 (N=50)**			**Patients from 2011 to 2016 (N=67)**		
	RS (N=22)	Non-RS (N=95)		RS (N=9)	Non-RS (N=41)		RS (N=13)	Non-RS (N=54)	
	Frequency (%) or Mean ± SD		P value	Frequency (%) or Mean ± SD		P value	Frequency (%) or Mean ± SD		P value
Patient Outcome Variables									
Mean ICU LOS (Days)	10.0 ± 19.3	15.5 ± 18.9	0.22	6.0 ± 11.8	13.7 ± 12.0.	0.09	12.8 ± 23.1	16.8 ± 22.8	0.57

Mean Hospital LOS (Days)	15.2 ± 20.5	22.9 ± 27.2	0.21	12.4 ± 15.2	18.72 ± 13.22	0.21	17.1 ± 23.9	26.1 ± 33.9	0.37
24-hour Survival Following Cardiac Arrest	14 (63.6%)	58 (61.1%)	0.82	4 (44.4%)	24 (58.5%)	0.44	10 (76.9%)	34 (63.0%)	0.34
Incidence of Survival to Hospital Discharge	3 (13.6%)	42 (44.2%)	0.01	0 (0%)	16 (39.0%)	0.02	3 (23.1%)	26 (48.2%)	0.10
Post Resuscitation Complications									
Renal Failure	11 (50.0%)	46 (48.9%)	0.93	5 (55.6%)	24 (58.5%)	0.87	6 (46.2%)	22 (41.5%)	0.76
Respiratory Failure	6 (27.3%)	53 (55.8%)	0.02	2 (22.2%)	24 (58.5%)	0.05	4 (30.8%)	29 (53.7%)	0.14
Anoxic Brain Injury	7 (31.8%)	19 (20.2%)	0.24	2 (22.2%)	11 (26.8%)	0.78	5 (38.5%)	8 (15.1%)	0.06
Hemorrhage	0 (0%)	2 (2.1%)	0.50	0 (0%)	1 (2.4%)	0.64	0 (0%)	1 (1.9%)	0.63
Mediastinitis	0 (0%)	3 (3.2%)	0.41	0 (0%)	1 (2.4%)	0.64	0 (0%)	2 (3.7%)	0.49
Cause of Death									
	RS (N=19)	Non-RS (N=53)		RS (N=9)	Non-RS (N=25)		RS (N=10)	Non-RS (N=28)	
Anoxia	5 (26.3%)	3 (5.7%)	0.01	1 (11.1%)	0 (0%)	0.09	4 (40.0%)	3 (10.7%)	0.04
Coagulopathy	1 (5.3%)	0 (0%)	0.09	0 (0%)	0 (0%)	----	1 (10.0%)	0 (0%)	0.09
Electrolyte Abnormalities	1 (5.3%)	2 (3.8%)	0.78	1 (11.1%)	2 (8.0%)	0.78	0 (0%)	0 (0%)	----
Ischemia/LA	0 (0%)	5 (9.4%)	0.16	0 (0%)	1 (4.0%)	0.54	0 (0%)	4 (14.3%)	0.21
MSOF	2 (10.5%)	8 (15.1%)	0.62	0 (0%)	3 (12.0%)	0.27	2 (20.0%)	5 (17.9%)	0.88
Other	2 (10.5%)	10 (18.9%)	0.40	1 (11.1%)	8 (32.0%)	0.22	1 (10.0%)	2 (7.1%)	0.77
Pneumothorax	0 (0%)	2 (3.8%)	0.39	0 (0%)	1 (4.0%)	0.54	0 (0%)	1 (3.6%)	0.55
PEA	3 (15.8%)	12 (22.6%)	0.53	2 (22.2%)	6 (24.0%)	0.91	1 (10.0%)	6 (21.4%)	0.42
Vasospasm	0 (0%)	0 (0%)	----	0 (0%)	0 (0%)	----	0 (0%)	0 (0%)	----
Ventricular Fibrillation	2 (10.5%)	2 (3.8%)	0.27	2 (22.2%)	0 (0%)	0.02	0 (0%)	2 (7.1%)	0.39
Withdraw of Care	3 (15.8%)	9 (17.0%)	0.91	2 (22.2%)	4 (16.00%)	0.68	1 (10.0%)	5 (17.9%)	0.56
Discharge Disposition									
	RS (N=3)	Non-RS (N=42)		RS (N=0)	Non-RS (N=16)		RS (N=3)	Non-RS (N=26)	
Facility	2 (66.7%)	21 (50.00%)	0.577	0 (0%)	7 (43.8%)	----	2 (66.7%)	14 (53.9%)	0.67
Home	1 (33.3%)	21 (50.00%)	0.577	0 (0%)	9 (56.3%)	----	1 (33.3%)	12 (46.2%)	0.67

*RS= Resternotomy, LOS = Length of Stay, LA = Lactic Acidosis, MSOF = Multisystem Organ Failure

Predictive Factors in Patient Outcomes (Refer to Table 11)

Further analysis was performed among the 117 patients who developed a post-cardiac surgery arrest to investigate the predictive factors for patient outcomes. The 24-hour survival rate was shown to be poorer in female patients and individuals who had a greater number of hours from surgery-to-arrest. Conversely, the 24-hour survival rate was positively correlated with survival-to-discharge. Survival-to-discharge was positively correlated for patients who did not have anoxic brain injury or respiratory failure as a complication, but negatively correlated for patients who underwent a RS. Patients who arrested due to bleeding etiologies were more likely to survive 24-hours after resuscitation; whereas not having respiratory failure as a complication was a strong predictor of survival-to-discharge.

Younger patients were more likely to have a higher ICU LOS whereas not having respiratory failure as a complication correlated to a lower ICU LOS. Time from surgery-to-arrest strongly correlated with a higher ICU LOS. Both 24-hour survival following resuscitation and ICU LOS correlated with longer hospital LOS. Oppositely, arrhythmias as the etiology of cardiac arrest showed the predictive value of a lower hospital LOS (p = 0.048).

Table 11

Predictive Factors in Patient Outcomes

N = 117		
24 Hour Survival	Estimate (Correlation Direction)	P value
# Hours Surgery to Arrest	-0.00731	0.0009
ICU LOS Days	0.1754	0.0002
Gender (Male)	0.69	0.0107
Etiology of Arrest (Bleeding)	1.189	0.012
Survival to Hospital Discharge		
Survived 24hrs (Yes)	8.3783	0.0001
Anoxic Brain Injury (None)	1.2549	0.0019
Resternotomy (Yes)	-1.7361	0.0054
Resp Failure (None) (Complication)	1.2735	0.0218
ICU Length of Stay		
Age	-0.0489	0.0355
Hours from Surgery to Arrest	0.00495	0.006
Respiratory Failure (None) (Complication)	-1.0755	<.0001
Hospital Length of Stay		
ICU LOS Days	0.352	<.0001
Survived 24hrs	2.9846	0.0005
Etiology of Arrest (Arrhythmias)	-2.3613	0.0483

Chapter 5: Discussions

High-quality CPR [ECM] has been the longstanding, primary factor, that influences survival-to-discharge (Meaney et al., 2013). However, modifications to ECM have been recommended for various “special populations” including the morbidly obese, pediatric, and obstetric populations (Vanden Hoek et al., 2010). Another “special population” of growing interest is the post-cardiac surgery population. Post-cardiac surgery arrests have been strongly associated with reversible etiologies such as VF, cardiac tamponade, and postoperative hemorrhage (Anthi et al., 1998; Dunning et al., 2009, 2017; Pottle et al., 2002). Following cardiac surgery, the literature has shown that ICM provides better coronary perfusion pressure, increases the instances of ROSC, and provides superior organ blood flow when compared to traditional ECM (Anthi et al., 1998; Dunning et al., 2009, 2017; Pottle et al., 2002). Based on such evidence, European resuscitation guidelines have incorporated specific recommendations for resuscitating patients who arrest after cardiac surgery and place a strong emphasis on early RS with ICM (Dunning et al., 2017). While the AHA has not recommended RS with ICM in the 2015 ACLS guidelines, it is expected that RS with ICM will be incorporated in future guideline updates following the 2017 STS expert consensus recommendations for management of post-cardiac surgery arrests.

The two major aims of this research study were (1) to investigate the resuscitation practice trends and the related patient outcomes before (2009 to 2011) and after (2011 to 2016) implementation of RSPT for bedside nurses and ACP staff and (2) to compare patient outcomes between patients with and without RS as the method of resuscitation among those who underwent cardiac surgery and experienced a postoperative cardiac arrest. The first part of this chapter will present a discussion of the study findings. The second part will include study implications, limitations, and recommendations for future studies.

Aim 1: Investigation of the Resuscitation Practice Trends and the Related Patient Outcomes Before and After Implementation of a RS Preparation Training Module

From 2009 to 2011, a total of 50 patients suffered a post-cardiac surgery arrest. The mean STS predicted mortality score for the cohort was 5.1% ± 6.8 which classified the patients as an intermediate risk for perioperative mortality (Vassileva et al., 2015). The mean time from surgery-to-arrest was 4.9 days ± 6.2 which was within the recommended optimal 10-day or less window cited in 2009 EACTS recommendations for performing a RS with ICM (Dunning et al., 2009). Similar to previous post-cardiac surgery arrest research, arrhythmias (n = 25, 50%) were number one cause of post-cardiac surgery arrests in this study (Anthi et al., 1998; Charalambous et al., 2006; Dunning et al., 2017; Maccaroni & Watson, 2013; Runte et al., 2012). Whereas bleeding and tamponade were determined to be the second leading cause of post-cardiac surgery arrest noted by Dunning in both the 2009 EACTS and 2017 STS recommendations, respiratory failure (n = 8, 16%) was the second leading cause of arrest observed in this study (Dunning et al., 2009, 2017). Bleeding and cardiac tamponade were the fourth leading cause of arrest in this study (n = 4, 8%). In the 2009-2011 cohort, 24-hour survival following resuscitation was 56% (n=28), but overall survival-to-discharge was 32% (n=16). These findings were less than the 50% survival rate cited in the literature (Dunning et al., 2009, 2017; Maccaroni & Watson, 2013).

As part of the continuous QI program, the cardiac surgery program at CRMH developed and implemented RSPT in 2011 to improve resuscitation outcomes for patients who developed a post-cardiac surgery arrest and did not obtain ROSC with traditional resuscitative maneuvers. Following implementation of RSPT, a total of 67 patients developed a cardiac arrest from 2011-2016. The mean STS predicted mortality score for 2011-2016 cohort was 6.5% ± 10.4 which was higher than the 2009-2011 cohort (5.1% ± 6.8). Both 24-hour survival following resuscitation (65.7%, n = 44) and hospital-to-discharge (43.3% n = 29) improved when compared to the 2009-2011 cohort (56%, n=28 for 24-hour survival and 32%, n=16 for survival-to-discharge). 11 (16.4%) resternotomies were performed with 3 (4.5%) surviving-to-discharge. The mean time-to-RS for the cohort was 32.1 minutes ± 20.6.

Researchers have highlighted the value of educational training in regard to the management of non-cardiac surgical arrests and how such training has allowed staff to participate with "speed and confidence" resulting in improved patient outcomes (Dunning et al., 2006). Dunning et al. (2006) proposed similar findings could be observed in post-cardiac surgery arrest management, but acknowledged that there were minimal educational trainings available to providers. Dunning et al. (2006) developed a three-day clinical scenario-based training known as the Cardiac Surgical Unit Advanced Life Support (CALS) course. The CALS educational training course included emergency scenarios commonly encountered following cardiac surgery including arrest management. Dunning et al. (2006) proposed that following the CALS course, providers would demonstrate improved clinical skills and responses to common post-cardiac surgery emergencies including arrests. The authors administered pre and post course testing for participates and evaluated multiple aspects of their performance including time-to-RS with ICM. Dunning et al. (2006) found that mean pre-course time-to-RS with ICM for participates was 451 seconds ± 39 and post-course it had improved to 228 seconds ± 17 ($p = 0.011$). Overall time-to-definitive treatment improved from 565 seconds ± 27 to 303 seconds ± 24 ($p < 0.0005$) (Dunning et al., 2006). Based on the findings noted by Dunning et al. (2006), the authors proposed participants' performance could be improved when a structured education training program is implemented. While the current study did not directly evaluate participate performance on multiple aspects, the authors did note that following the RS educational training module that was implemented in 2011, time-to-RS did decrease by an average of 3.29 minutes ± 6.31 although statistical significance was not found ($p = 0.75$) in this study. Similarly, there was a clinically significant increase in survival-to-discharge among patients who underwent RS in 2011-2016 (n = 3) when compared to 2009-2011 (n = 0). The second aim of this study further analyzed RS outcomes and compared the outcomes to patients who were resuscitated without RS.

Aim 2: Comparison of Patient Outcomes Between Patients with and without RS as a Method of Resuscitation Among those who Underwent Cardiac Surgery and Experienced a Postoperative Arrest

Etiologies of Arrest

From 2009-2016 at total of 117 patients developed a post-cardiac surgery arrest. Of those individuals, 22 (18.8%) patients underwent a RS as a method of resuscitation and 95 (81.2%) were resuscitated with standardized ACLS alone. The primary etiology of arrests for both RS and non-RS groups among all patients (2009-2016) were arrhythmias (45.5% for RS vs 56.8% for non-RS, p=ns) in this study which was similar to the estimated 45% incidence rate of arrhythmia related arrests cited in the literature (Anthi et al., 1998; Charalambous, Zipitis, & Keenan, 2006; Dunning et al., 2017; Maccaroni & Watson, 2013). In this study, logical regression models demonstrated a predictive value of a lower hospital LOS (p=0.048) if post-cardiac surgery arrests were related to arrhythmias. Richardson et al. (2007) found that arrhythmia related post-cardiac surgery arrests could be terminated and ROSC obtained 78% of the time when recognition was prompt but warned that success would decrease to 14% when treatment was delayed. In cases of arrhythmia related arrest, the STS expert consensus recommended delayed ECM and attempts at sequential defibrillation or temporary pacing in order to improve patient related outcomes (Dunning et al., 2017). If ROSC could be obtained with defibrillation or temporary pacing, there was no indication for ECM and thus the potential for harm associated with ECM would be avoided (Ley, 2015; Maccaroni & Watson, 2013).

Postoperative hemorrhage was noted as the second primary etiology of arrest among all patients (2009-2016) who underwent RS (27.3%, p=0.00), but the incidence in this study was lower than the estimated 86% of post-cardiac surgery arrests related to hemorrhage cited in the literature (Anthi et al., 1998; Charalambous, Zipitis, & Keenan, 2006; Dunning et al., 2017; Maccaroni & Watson, 2013). The researchers found that for both the 2009-2011 and the 2011-2016 cohorts, bleeding related arrests were significantly higher in the RS groups compared to the non-RS groups (33.3% for RS vs 2.4% for non-RS, p=0.00 and 23.2% for RS vs 1.9% for non-RS, p=0.00, respectively). Logistical regression models also demonstrated a positive correlation between bleeding related arrests and 24-hour survival. In the case of an identified post-cardiac surgery hemorrhage, Dunning et al. (2017) recommended early RS in order for providers to successfully identify the source for post-operative hemorrhage and control it. Although the incidence of postoperative hemorrhage (6.8%) among all patients (2009-2016) was lower than the cited 86% in the literature, the researchers in this study found RS was more likely to be performed if hemorrhage was identified as an etiology for arrest (Anthi et al., 1998; Charalambous, Zipitis, & Keenan, 2006; Dunning et al., 2017; Maccaroni & Watson, 2013).

Unlike the research suggests, this study noted a statistically significant number of arrests related to respiratory failure (0% for RS and 20% for non-RS, p=0.02) as the third leading cause of post-cardiac surgery arrests among all patients (2009-2016) instead of the etiologies of bleeding, arrhythmia, or cardiac tamponade previously cited (Anthi et al., 1998; Charalambous, Zipitis, & Keenan, 2006; Dunning et al., 2017; Maccaroni & Watson, 2013). The 2017 STS expert consensus recommends supplemental oxygen, ventilatory support, and cause identification which is no different from the current AHA ACLS practices (Dunning et al., 2017; Link et al., 2015). Neither the 2009 EACTS nor the 2017 STS expert consensus provided preventative or additional resuscitation measures regarding post-cardiac surgery respiratory arrests (Dunning et al., 2009, 2017).

Timeframe to Arrest and Lengths of Stay

In this study, the researchers found that the time-to-arrest was significantly shorter in the RS groups among all patients (2009-2016) (32.9 hours ± 65.9 for RS vs 157.1 hours ± 196.8 for non-RS, $p < 0.00$). RS patients also had shorter ICU LOS when compared to non-RS patients (10 days ± 19 for RS vs 19 for non-RS ±, p=0.23) and a shorter hospital LOS (15 days ± 20 for RS vs 23 days ± 27 for non-RS, p=0.21) in all patients (2009-2011). Despite the increased ICU and hospital LOS, non-RS patients were more likely to survive-to-discharge (13.6% for RS vs 44.2 in non-RS, p=0.01) among all patients (2009-2016), within the 2009-2011 cohort (0% for RS vs 39% for non-RS, p=0.02), and within the 2011-2016 cohort (23.1% for RS vs 48.2% for non-RS, p=0.10). To the researchers' knowledge, there are no studies that compare ICU LOS and hospital LOS for patients with and without RS as a method of resuscitation. While not statistically significant when compared to non-RS patients (p=0.1) and below the predicted 50% survival rate cited by Dunning et al. (2017), survival-to-discharge outcomes did improve in the post-RS education cohort (2011-2016) with 3 (23.1%) patients discharged from the hospital compared to 0% in the pre-education cohort (2009-2011).

Post-Resuscitation Complications and Causes of Death

The primary post-resuscitation complication among all patients (2009-2016) observed in this study was renal failure (50% for RS vs 48.9% for non-RS, p=ns). The second highest complication was different among the two groups: anoxic brain injury was the second highest in the RS group (31.8% for RS vs 20.8% for non-RS, p=ns) and respiratory failure in the non-RS group (27.3% for RS vs 55.8% for non-RS, p=0.02). There are many factors that could contribute to anoxic brain injury within the RS group including time-to-ROSC, mechanism of arrest, and prolonged hypoperfusion which merit further investigation in future studies. Interestingly, there was a significantly higher incidence of the use of a cardiac assist device (i.e. extracorporeal membrane oxygenation) following resuscitation of patients who underwent RS (54.6% for RS vs 22.1% for non-RS, p=0.00). Further analysis is recommended regarding the use of ECMO post-resuscitation to determine if it contributed to a lower incidence of respiratory failure in the RS groups when compared to the non-RS group, or if ECMO usage contributed to increased incidences of anoxic brain injury.

The primary causes of death for all patients (2009-2016) included anoxia (26.3% for RS and 5.7% for non-RS, p=0.001), PEA/VF (26.3% for RS vs 26.4% for non-RS, p=ns), and withdrawal of care (15.8% for RS and 17% for non-RS, p=ns). Similar to post-resuscitation complications, there were statistically significant higher incidences of anoxia associated deaths in the RS group for all patients (2009-2016) (p=0.01) and in the 2011-2016 cohort (p=0.04). Again, multiple variables that merit further research could have contributed to this finding, researchers have cited that RS and ICM provides better coronary perfusion pressure, increases instances of ROSC, and provides superior organ blood flow (Anthi et al., 1998; Dunning et al., 2009, 2017; Pottle et al., 2002). However, to the researchers' knowledge, studies that demonstrate survival-to-discharge with good neurologic outcomes following RS are currently lacking.

Strengths and Limitations of the Study

This study contains both strengths and limitations. To the researcher's knowledge, this is one of the first studies to evaluate the impact of resternotomy preparation training both pre-and post-implementation. Also, this is one of the first studies to compare patient outcomes both with and without resternotomy as a method of resuscitation. This study also contains limitations. The RSPT was based on the 2009 EACTS recommendations which included key roles for individuals involved, a minimal surgical supplies technique, and routine clinical simulations (Dunning et al., 2009). This study has limitations to measure the impact of a protocol driven resuscitation practice using RS with ICM over standard practice because it was an educational training only. Dunning et al. (2009) recommended a protocol that utilized RS with ICM after five minutes of failed ECM in which any provider (bedside nurses, ACPs, or physicians) would perform a RS and then administer ICM. In the current study, RS with ICM was always performed by an attending cardiac surgeon at their discretion. There were also multiple untold variables that could have influenced the results including surgeon preference of when to perform RS, ACP presence and availability, and patient acuity. There were too many variables involved in the study to conclude a causal relationship. This study was also a single-center retrospective study design with a relatively small cohort thus making generalizability impossible.

Conclusions

This study supported RSPT as an effective method to improving patient outcomes for post-cardiac surgery arrests. Both 24-hour survival (44.4%, n=4 of 9 pre-RSPT) and survival-to-discharge (0%, n=0 of 9) dramatically improved post-RSPT (24-hr survival 76.9%, n=10 of 13 and survival-to-discharge 23.1%, n=3 of 13), although no statistical significance was found in either measure due to the small sample size. RSPT allowed more RS to be performed in the

CSICU (61.5% post-RSPT compared to 44.4% RSPT) than the CSOR (38.5% post-RSPT compared to 55.6% pre-RSPT) and showed a decrease in time-to-RS by 3 minutes, again, not statistically significant but a clinically significant improvement. In this study, the researchers found that RS with ICM was not associated with better survival-to-discharge rates when compared to non-RS patients (13.6% vs. 44.2%, $p=0.00$). However, the results in this study were comparable to results noted by Maccaroni and Watson (2013) who observed survival-to-discharge rates of 12% if RS was performed after ten minutes. When RS was performed in less than ten minutes, the researchers noted survival-to-discharge improvements up to 48% (Maccaroni & Watson, 2013). The researchers observed that the post-cardiac surgery arrest 24-hour survival rate was correlated with the etiology of arrest. Whereas ICU LOS, hospital LOS, and survival-to-discharge were more correlated to the post-resuscitation complication, specifically not having anoxic brain injury or respiratory failure. The researchers have concluded that more efforts are needed to reduce incidences of anoxic brain injury and respiratory failure. Arrhythmias (PEA/VF, 45.5% in the RS group and 56.8% in the non-RS group) were the major etiology for post-cardiac surgery arrests in both RS and non-RS groups and were negatively associated with survival-to-discharge. The researchers concluded that close monitoring of arrhythmias post-cardiac surgery with timely and effective intervention would help improve survival-to-discharge. The 2017 STS expert consensus supports RSPT, RS within five minutes, and aggressive arrhythmia management for post-cardiac surgery arrests. Based on findings in this study, adoption of a modified resuscitation protocol for post-cardiac surgery arrests is recommended (Dunning et al., 2017). Additional research is also recommended to further compare patient outcomes between standardized resuscitation practices (ACLS) and a modified protocol using RS with ICM for post-cardiac surgery arrests.

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Tables

Table 1

Recommendations for Management of Cardiac Arrest: ACLS versus the 2017 STS Recommendations

ACLS Recommendations	CSU-ALS Recommendations
Ventricular Fibrillation/Pulseless Ventricular Tachycardia	
Immediate external cardiac massage	Defibrillate first if available within 1 minute
External cardiac massage → single shock → external cardiac massage x 2 minutes before repeating shock	Three stacked shocks before external cardiac massage
Asystole or profound bradycardia	
External cardiac massage → vasopressor	DDD pacing at maximum outputs if available within 1 minute → external cardiac massage
All pulseless cardiac arrests	
Epinephrine 1000 ug every 3-5 minutes	No epinephrine or vasopressin during arrest Reduce epinephrine dose to 100ug prearrest or as directed by senior clinician Rapid resternotomy (<5 minutes) if no response to initial therapies

Source: Ley, S. J. (2015). Standards for resuscitation after cardiac surgery. *Critical Care Nurse*, *35*(2), 30–7; quiz 38. Journal Article. http://doi.org/10.4037/ccn2015652

Table 2

Major Study Variables

Patient Variables
• Age • BMI • Past Medical History • STS Morbidity Score* • STS Morbidity/Mortality Score* • Etiology for Cardiac Arrest
Cardiac Arrest Variables
• Type of Procedure Performed • Etiology of Cardiac Arrest • Location of Cardiac Arrest • Timeframe from Surgery to Cardiac Arrest
Resternotomy Variables
• Frequency Resternotomy Performed • Timeframe from Surgery to Arrest • Location of Resternotomy (CSICU, CSPCU, CSOR)
Patient Outcome Variables
• Presence of Cardiac Assist Device • ICU Length of Stay • Overall Hospital Length of Stay • Patient Survival Rate from Resuscitation • Patient Survival to Hospital Discharge • Post-Resuscitation Complications • Cause of Death

*STS mortality scoring is calculated based on patients who underwent cardiac surgery and died during hospitalization or within 30 days of hospital discharge, the higher the percentage, the higher the patient's 30 day risk for mortality; STS morbidity scoring is calculated based on the percentage of patients who expereince at least 1 of 5 complications of cardiac surgery: reoperation, stroke, kidney failure, infection of the chest, or prolonged period of mechanical ventilation; the higher the percentage, the higher the patient's overall risk for morbidity/mortality.

Table 3

Patient Demographic and Clinical Data

	All Patients	2009 to 2011	2011 to 2016	P value
	Frequency (%) or Mean ± SD (n = 117)	**Frequency (%) or Mean ± SD (n = 50)**	**Frequency (%) or Mean ± SD (n = 67)**	
Patient and Clinical Variables				
Male	70 (59.83%)	31 (62.00%)	39 (58.21%)	0.68
Mean Age in Years	63.80 ± 12.15	64.26 ± 10.52	63.45 ± 13.32	0.73
Mean Body Mass Index	29.81 ± 6.53	30.99 ± 6.47	28.92 ± 6.48	0.09
Past Medical History				
• Cerebral Vascular Accident	18 (15.38%)	7 (14.00%)	11 (16.42%)	0.72
• Chronic Kidney Disease	23 (19.66%)	11 (22.00%)	12 (17.91%)	0.58
• Congestive Heart Failure	14 (11.97%)	9 (18.00%)	5 (7.46%)	0.08
• Coronary Artery Disease	32 (27.35%)	13 (26.00%)	19 (28.36%)	0.78
• Diabetes Mellitus	54 (46.15%)	26 (52.00%)	28 (41.79%)	0.27
• Hyperlipidemia	66 (56.41%)	29 (58.00%)	37 (55.22%)	0.76
• Hypertension	93 (79.49%)	43 (86.00%)	50 (74.63%)	0.13
• Lung Disease	21 (17.95%)	9 (18.00%)	12 (17.91%)	0.99
• Tobacco Abuse	17 (14.53%)	9 (18.00%)	8 (11.94%)	0.36
Surgical Procedure(s) Prior to Cardiac Arrest and Risk Stratification				
• Isolated CABG	44 (37.6%)	23 (46%)	21 (31.3%)	0.11
• Isolated Valve(s) Replaced/Repaired	16 (13.7%)	7 (14%)	9 (13.4%)	0.93
• CABG + Valve(s)	12 (10.2%)	6 (12%)	6 (9%)	0.59
• CABG + Valve(s) with Additional Procedure (i.e. MAZE, PFO closure)	16 (13.7%)	7 (14%)	9 (13.4%)	0.93
• CABG + Additional Procedure without Valve(s)	4 (3.4%)	2 (4%)	2 (3%)	0.77
• Valve + Additional Procedure without CABG	11 (9.4%)	2 (4%)	9 (13.4%)	0.08
• Other Procedure (i.e. Aortic Dissections, ECMO)	14 (12%)	3 (6%)	11 (16.4%)	0.09
Risk Stratification				
Mean STS Predicted Mortality Score*	58.32% ± 8.82	5.13% ± .6.83	6.50% ± 10.41	0.51
Mean STS Predicted Morbidity/Mortality Score	27.71% ± 20.86	28.81% ± 20.49	26.68% ± 21.44	0.67

*The STS predicted mortality scoring is used to assess a patient's preoperative risk for mortality: low risk (<4%), intermediate risk (4% to <8%), high risk (8% to < 12%), very high risk (>12%) (Vassileva et al., 2015).

Table 4

Cardiac Arrest Data

	All Patients Frequency (%) or Mean ± SD (n = 117)	2009 to 2011 Frequency (%) or Mean ± SD (n = 50)	2011 to 2016 Frequency (%) or Mean ± SD (n = 67)	P value
Cardiac Arrest Data				
Etiology of Arrest				
• Arrhythmia	64 (54.70%)	25 (50.00%)	39 (58.21%)	0.17
• Respiratory Failure	19 (16.24%)	8 (16.00%)	11 (16.42%)	0.95
• Bleeding	8 (6.84%)	4 (8.00%)	4 (5.97%)	0.67
• Other	26 (22.22%)	13 (26.00%)	13 (19.40%)	0.4
Location of Cardiac Arrest				
• CSICU	95 (81.20%)	40 (80.00%)	55 (82.09%)	0.78
• CSPCU	7 (5.98%)	2 (4.00%)	5 (7.46%)	0.44
• CSOR	5 (4.27%)	2 (4.00%)	3 (4.48%)	0.9
• Other	10 (8.55%)	6 (12.00%)	4 (5.97%)	0.25
Time from Surgery to Cardiac Arrest (Days)	5.57 ± 7.74	4.85 ± 6.16	6.11 ± 8.75	0.37

Table 5

Resternotomy Practice Data

	Patients Who Underwent RS after Cardiac Arrest from 2009 to 2016 (n = 22)	Patients Who Underwent RS after Cardiac Arrest from 2009 to 2011 (n = 9)	Patients Who Underwent RS after Cardiac Arrest from 2011 to 2016 (n = 13)	P value
Resternotomy Practice Data				
Resternotomy Performed	22 (18.8%)	9 (18%)	13 (19.4%)	0.85
Location of RS				
• CSICU	12 (54.55%)	4 (44.44%)	8 (61.54%)	0.43
• CSOR	10 (45.45%)	5 (55.56%)	5 (38.46%)	0.43
• CSPCU	0 (0%)	0 (0%)	0 (0%)	----
• OTHER	0 (0%)	0 (0%)	0 (0%)	----
Mean Time from Arrest to RS (Minutes)	33.50 ± 22.82	35.44 ± 26.90	32.15 ± 20.59	0.75
Use of a Cardiac Assist Device Following Resternotomy	12 (54.55%)	4 (44.44%)	8 (61.54%)	0.43

Table 6

Patient Outcome Variables Following Resternotomy

	Patients Who Underwent RS after Cardiac Arrest from 2009 to 2016	Patients Who Underwent RS after Cardiac Arrest from 2009 to 2011	Patients Who Underwent RS after Cardiac Arrest from 2011 to 2016	P value
Patient Outcome Variables				
Length of Stay	**n = 22**	**n = 9**	**n = 13**	
Mean ICU LOS (Days)	10.04 ± 19.25	6.04 ± 11.81	12.82 ± 23.14	0.43
Mean Hospital LOS (Days)	15.17 ± 20.49	12.43 ± 15.22	17.06 ± 23.89	0.61
Survival Rate	**n = 22**	**n = 9**	**n = 13**	
24 hour Survival Following RS (Survived with RS)	14 (63.64%)	4 (44.44%)	10 (76.92%)	0.12
Survival to Hospital Discharge	3 (13.64%)	0 (0%)	3 (23.08%)	0.12
Post Resuscitation Complications	**n = 22**	**n = 9**	**n = 13**	
Renal Failure	11 (50.00%)	5 (55.56%)	6 (46.15%)	0.66
Anoxic Brain Injury	7 (31.82%)	2 (22.22%)	5 (38.46%)	0.42
Respiratory Failure	6 (27.27%)	2 (22.22%)	4 (30.77%)	0.65
Hemorrhage	0 (0%)	0 (0%)	0 (0%)	----
Mediastinitis	0 (0%)	0 (0%)	0 (0%)	----
Cause of Death	**n = 19**	**n = 9**	**n = 10**	
Anoxia	5 (26.32%)	1 (11.11%)	4 (40.00%)	0.15
PEA/VF	5 (26.32%)	4 (44.44%)	1 (10%)	0.47
Withdraw of Care	3 (15.79%)	2 (22.22%)	1 (10.00%)	0.47
Multisystem Organ Failure	2 (10.53%)	0 (0%)	2 (20.00%)	0.16
Other	2 (10.53%)	1 (11.11%)	1 (10.00%)	0.94
Coagulopathy	1 (5.26%)	0 (0%)	1 (10.00%)	0.33
Electrolyte Abnormalities	1(5.26%)	1 (11.11%)	0 (0%)	0.28
Ischemia/Lactic Acidosis	0(0%)	0 (0%)	0 (0%)	----
Pneumothorax	0 (0%)	0 (0%)	0 (0%)	----
Vasospasm	0 (0%)	0 (0%)	0 (0%)	----
Survival to Discharge Length of Stay	**n = 3**	**n = 0**	**n = 3**	
Mean ICU LOS (Days)	9.03±6.06	----	9.03±6.06	----
Mean Hospital LOS (Days)	17.40±13.74	----	17.40±13.74	----
Survival to Discharge Complications	**n = 3**	**n = 0**	**n = 3**	
No complication	2 (66.67%)	0 (0%)	2 (66.67%)	----
Renal Failure	1 (33.33%)	0 (0%)	1 (33.33%)	----
Discharge Disposition	**n = 3**	**n = 0**	**n = 3**	
Facility	2 (66.67%)	0 (0%)	2 (66.67%)	----
Home	1 (33.33%)	0 (0%)	1 (33.33%)	----

*RS= Resternotomy and LOS= Length of Stay; PEA= Pulseless Electrical Activity, VF= Ventricular Fibrillation

Table 7.

Demographic and Clinical Data

	All Patients From 2009 to 2016 (N=117)			Patients from 2009 to 2011 (N=50)			Patients from 2011 to 2016 (N=67)		
	RS (N=22)	Non-RS (N=95)		RS (N=9)	Non-RS (N=41)		RS (N=13)	Non-RS (N=54)	
	Frequency (%) or Mean ± SD		P value	Frequency (%) or Mean ± SD		P value	Frequency (%) or Mean ± SD		P value
Patient and Clinical Variables									
Male	13 (59.1%)	57 (60.0%)	0.94	5 (55.6%)	26 (63.4%)	0.66	8 (6.41%)	31 (57.4%)	0.79
Mean Age in Years	69.5 ± 8.7	62.6 ± 12.5	0.02	68.3 ± 9.9	63.4 ± 10.6	0.20	70.3± 8.2	61.9 ± 13.8	0.05
Mean Body Mass Index	29.7 ± 6.8	29.8 ± 6.5	0.93	32.1 ± 9.1	30.8 ± 5.9	0.57	28.1 ± 25.5	29.1 ± 27.2	0.59
Ejection Fraction	54.1 ± 12.6	51.4 ± 15.2	0.45	50.0 ± 17.1	48.3 ± 15.6	0.77	56.9 ± 7.8	53.8 ± 14.6	0.29
Past Medical History									
Cerebral Vascular Accident	1 (4.6%)	17 (17.9%)	0.12	0 (0%)	7 (17.1%)	0.18	1 (7.7%)	10 (18.5%)	0.34
Chronic Kidney Disease	4 (18.2%)	19 (20.0%)	0.85	1 (11.1%)	10 (24.3%)	0.38	3 (23.1%)	9 (16.6%)	0.59
Congestive Heart Failure	2 (9.1%)	12 (12.6%)	0.64	2 (22.2%)	7 (17.1%)	0.72	0 (0%)	5 (9.3%)	0.25
Coronary Artery Disease	8 (36.4%)	24 (25.3%)	0.29	4 (44.4%)	9 (21.9%)	0.16	4 (30.8%)	15 (27.8%)	0.83
Diabetes Mellitus	10 (45.4%)	44 (46.3%)	0.94	3 (33.3%)	23 (56.1%)	0.22	7 (53.9%)	21 (38.9%)	0.33
Hyperlipidemia	18 (81.8%)	48 (50.5%)	0.01	6 (66.7%)	23 (56.1%)	0.56	12 (92.3%)	25 (46.3%)	0.01
Hypertension	19 (86.4%)	74 (77.9%)	0.38	8 (88.9%)	35 (85.4%)	0.78	11 (84.6%)	39 (72.2%)	0.36
Lung Disease	3 (13.6%)	18 (18.9%)	0.56	2 (22.2%)	7 (17.1%)	0.72	1 (7.7%)	11 (20.4%)	0.28
Tobacco Abuse	3 (13.6%)	14 (14.7%)	0.890	1 (11.1%)	8 (19.5%)	0.55	2 (15.4%)	6 (11.1%)	0.67

Table 8

Procedures Performed Prior to Cardiac Arrest

	All Patients From 2009 to 2016 (N=117)			Patients from 2009 to 2011 (N=50)			Patients from 2011 to 2016 (N=67)		
	RS (N=22)	Non-RS (N=95)		RS (N=9)	Non-RS (N=41)		RS (N=13)	Non-RS (N=54)	
	Frequency (%) or Mean ± SD		P value	Frequency (%) or Mean ± SD		P value	Frequency (%) or Mean ± SD		P value
Procedure(s) Performed Prior to Cardiac Arrest									
Isolated CABG	10 (8.5%)	34 (29.1%)	0.39	4 (8%)	19 (38%)	0.92	6 (9%)	15 (22.4%)	0.20
Isolated Valve(s) Replaced/Repaired	5 (4.3%)	11 (9.4%)	0.17	3 (6%)	4 (8%)	0.06	2 (3%)	7 (10.4%)	0.82
CABG + Valve(s)	2 (1.7%)	10 (8.5%)	0.84	0	6 (12%)	0.22	2 (3%)	4 (6%)	0.37
CABG/Valve(s) + Additional Procedure	4 (3.4%)	12 (10.3%)	0.49	2 (4%)	5 (10%)	0.43	2 (3%)	7 (10.4%)	0.82
CABG + Additional Procedure without Valve(s)	1 (0.9%)	3 (2.6%)	0.75	0	2 (4%)	0.50	1 (1.5%)	1 (1.5%)	0.27
Valve + Additional Procedure without CABG	0	11 (9.4%)	0.09	0	2 (4%)	0.50	0	9 (13.4%)	0.11
Other Procedure	0	14 (11.9%)	0.05	0	3 (6%)	0.40	0	11 (16.4%)	0.08
Risk Stratification									
Mean STS Predicted Mortality Score	6.06% ± 7.08	5.76% ± 9.39	0.90	7.24% ± 9.31%	4.50% ± 5.99	0.33	5.12% ± 5.01	7.01% ± 11.85	0.50
Mean STS Predicted Morbidity/Mortality Score	27.98% ± 17.89	27.62% ± 21.92	0.95	33.07% ± 21.42	27.54% ± 20.45	0.51	23.91% ± 14.37	27.70% ± 23.69	0.64

Table 9

Cardiac Arrest Characteristics

	All Patients from 2009 to 2016 (N=117)			Patients from 2009 to 2011 (N=50)			Patients from 2011 to 2016 (N=67)		
	RS (N=22)	Non-RS (N=95)		RS (N=9)	Non-RS (N=41)		RS (N=13)	Non-RS (N=54)	
	Frequency (%) or Mean ± SD		P value	Frequency (%) or Mean ± SD		P value	Frequency (%) or Mean ± SD		P value
Cardiac Arrest Data									
Etiology of Arrest									
Arrhythmia	10 (45.5%)	54 (56.8%)	0.33	3 (33.3%)	22 (53.7%)	0.27	7 (53.9%)	32 (59.3%)	0.72
Bleeding	6 (27.3%)	2 (2.1%)	0.00	3(33.3%)	1 (2.4%)	0.00	3 (23.2%)	1 (1.9%)	0.00
Respiratory Failure	0 (0%)	19 (20.0%)	0.02	0 (0%)	8 (19.5%)	0.15	0 (0%)	11 (20.4%)	0.08
Other	6 (27.3%)	20 (21.1%)	0.53	3 (33.3%)	10 (24.4%)	0.58	3 (23.1%)	10 (18.5%)	0.71
Location of Cardiac Arrest (not the location resternotomy was performed)									
CSICU	19 (86.4%)	76 (80.0%)	0.49	6 (66.7%)	34 (82.9%)	0.27	13 (100%)	42 (77.8%)	0.06
CSPCU	1 (4.6%)	6 (6.3%)	0.75	1 (11.1%)	1 (2.4%)	0.23	0 (0%)	5 (9.3%)	0.25
CSOR	1 (4.6%)	4 (4.2%)	0.94	1 (11.1%)	1 (2.4%)	0.23	0 (0%)	3 (5.6%)	0.39
Other	1 (4.6%)	9 (9.5%)	0.46	1 (11.1%)	5 (12.2%)	0.93	0 (0%)	4 (7.4%)	0.31
Time from Surgery to Cardiac Arrest (Hours)	32.9 ± 65.9	157.1 ± 196.8	0.00	61.5 ± 95.4	128.6 ± 155.4	0.22	13.1 ± 22.3	178.7 ± 222.2	0.00
Use of CAD Following Resuscitation	12 (54.6%)	21 (22.1%)	0.00	4 (44.4%)	10 (24.4%)	0.23	8 (61.54%)	11 (20.4%)	0.00

*CAD = cardiac assist device (i.e. extracorporeal membrane oxygenation or intra-aortic balloon pump)

Table 10

Patient Outcomes between Resternotomy versus Non-Resternotomy

	All Patients from 2009 to 2016 (N=117)			Patients from 2009 to 2011 (N=50)			Patients from 2011 to 2016 (N=67)		
	RS (N=22)	Non-RS (N=95)		RS (N=9)	Non-RS (N=41)		RS (N=13)	Non-RS (N=54)	
	Frequency (%) or Mean ± SD		P value	Frequency (%) or Mean ± SD		P value	Frequency (%) or Mean ± SD		P value
Patient Outcome Variables									
Mean ICU LOS (Days)	10.0 ± 19.3	15.5 ± 18.9	0.22	6.0 ± 11.8	13.7 ± 12.0.	0.09	12.8 ± 23.1	16.8 ± 22.8	0.57
Mean Hospital LOS (Days)	15.2 ± 20.5	22.9 ± 27.2	0.21	12.4 ± 15.2	18.72 ± 13.22	0.21	17.1 ± 23.9	26.1 ± 33.9	0.37
24-hour Survival Following Cardiac Arrest	14 (63.6%)	58 (61.1%)	0.82	4 (44.4%)	24 (58.5%)	0.44	10 (76.9%)	34 (63.0%)	0.34
Incidence of Survival to Hospital Discharge	3 (13.6%)	42 (44.2%)	0.01	0 (0%)	16 (39.0%)	0.02	3 (23.1%)	26 (48.2%)	0.10
Post Resuscitation Complications									
Renal Failure	11 (50.0%)	46 (48.9%)	0.93	5 (55.6%)	24 (58.5%)	0.87	6 (46.2%)	22 (41.5%)	0.76
Respiratory Failure	6 (27.3%)	53 (55.8%)	0.02	2 (22.2%)	24 (58.5%)	0.05	4 (30.8%)	29 (53.7%)	0.14
Anoxic Brain Injury	7 (31.8%)	19 (20.2%)	0.24	2 (22.2%)	11 (26.8%)	0.78	5 (38.5%)	8 (15.1%)	0.06
Hemorrhage	0 (0%)	2 (2.1%)	0.50	0 (0%)	1 (2.4%)	0.64	0 (0%)	1 (1.9%)	0.63
Mediastinitis	0 (0%)	3 (3.2%)	0.41	0 (0%)	1 (2.4%)	0.64	0 (0%)	2 (3.7%)	0.49
Cause of Death									
	RS (N=19)	Non-RS (N=53)		RS (N=9)	Non-RS (N=25)		RS (N=10)	Non-RS (N=28)	
Anoxia	5 (26.3%)	3 (5.7%)	0.01	1 (11.1%)	0 (0%)	0.09	4 (40.0%)	3 (10.7%)	0.04
Coagulopathy	1 (5.3%)	0 (0%)	0.09	0 (0%)	0 (0%)	----	1 (10.0%)	0 (0%)	0.09
Electrolyte Abnormalities	1 (5.3%)	2 (3.8%)	0.78	1 (11.1%)	2 (8.0%)	0.78	0 (0%)	0 (0%)	----
Ischemia/LA	0 (0%)	5 (9.4%)	0.16	0 (0%)	1 (4.0%)	0.54	0 (0%)	4 (14.3%)	0.21
MSOF	2 (10.5%)	8 (15.1%)	0.62	0 (0%)	3 (12.0%)	0.27	2 (20.0%)	5 (17.9%)	0.88
Other	2 (10.5%)	10 (18.9%)	0.40	1 (11.1%)	8 (32.0%)	0.22	1 (10.0%)	2 (7.1%)	0.77
Pneumothorax	0 (0%)	2 (3.8%)	0.39	0 (0%)	1 (4.0%)	0.54	0 (0%)	1 (3.6%)	0.55
PEA	3 (15.8%)	12 (22.6%)	0.53	2 (22.2%)	6 (24.0%)	0.91	1 (10.0%)	6 (21.4%)	0.42
Vasospasm	0 (0%)	0 (0%)	----	0 (0%)	0 (0%)	----	0 (0%)	0 (0%)	----
Ventricular Fibrillation	2 (10.5%)	2 (3.8%)	0.27	2 (22.2%)	0 (0%)	0.02	0 (0%)	2 (7.1%)	0.39
Withdraw of Care	3 (15.8%)	9 (17.0%)	0.91	2 (22.2%)	4 (16.00%)	0.68	1 (10.0%)	5 (17.9%)	0.56
Discharge Disposition									
	RS (N=3)	Non-RS (N=42)		RS (N=0)	Non-RS (N=16)		RS (N=3)	Non-RS (N=26)	
Facility	2 (66.7%)	21 (50.00%)	0.577	0 (0%)	7 (43.8%)	----	2 (66.7%)	14 (53.9%)	0.67
Home	1 (33.3%)	21 (50.00%)	0.577	0 (0%)	9 (56.3%)	----	1 (33.3%)	12 (46.2%)	0.67

*RS= Resternotomy, LOS = Length of Stay, LA = Lactic Acidosis, MSOF = Multisystem Organ Failure

Table 11

Predictive Factors in Patient Outcomes

N = 117		
24 Hour Survival	Estimate (Correlation Direction)	P value
# Hours Surgery to Arrest	-0.00731	0.0009
ICU LOS Days	0.1754	0.0002
Gender (Male)	0.69	0.0107
Etiology of Arrest (Bleeding)	1.189	0.012
Survival to Hospital Discharge		
Survived 24hrs (Yes)	8.3783	0.0001
Anoxic Brain Injury (None)	1.2549	0.0019
Resternotomy (Yes)	-1.7361	0.0054
Resp Failure (None) (Complication)	1.2735	0.0218
ICU Length of Stay		
Age	-0.0489	0.0355
Hours from Surgery to Arrest	0.00495	0.006
Respiratory Failure (None) (Complication)	-1.0755	<.0001
Hospital Length of Stay		
ICU LOS Days	0.352	<.0001
Survived 24hrs	2.9846	0.0005
Etiology of Arrest (Arrhythmias)	-2.3613	0.0483

Figures

Figure 1

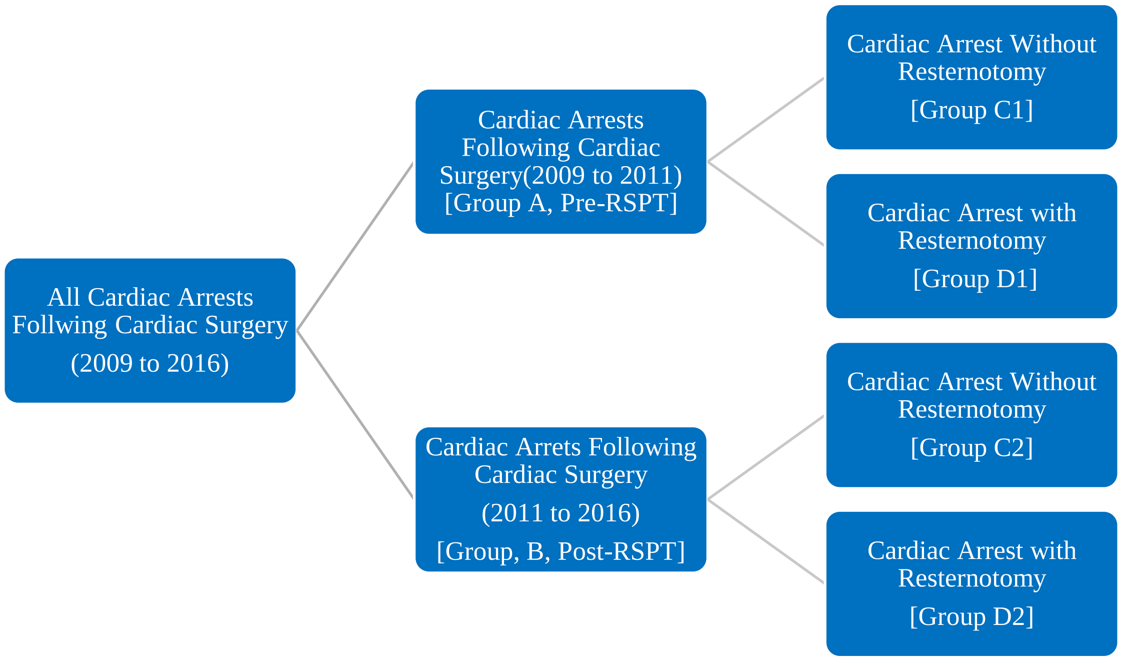

Figure 1. Study Design Diagram. This figure displays all patients who developed a cardiac arrest following cardiac surgery from 2009 to 2016 and the two group comparisons for those developed a cardiac arrest and either had an arrest with RS or an arrest without an RS.