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Research Article

Pump-Assisted Direct Coronary Artery Bypass (PAD-CAB) in Patients with Low Ejection Fraction: Potential Advantages

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Abstract

Background: Coronary Artery Bypass Grafting (CABG) is the most common adult cardiac surgical procedure worldwide. The techniques used to accomplish CABG range from the traditional use of Cardiopulmonary Bypass (CPB) with Aortic Cross-Clamping (AXC)-TRAD-CAB-to beating heart techniques without CPB (OP-CAB) or with CPB-assistance (PAD-CAB). This study aimed to examine the outcomes of the PAD-CAB procedure in a subset of high-risk patients with reduced Ejection Fraction (EF) and to compare them with the Society of Thoracic Surgery (STS) database.

Methods: One hundred twenty-five patients with an EF of 40% or less who underwent the PAD-CAB procedure by a single surgeon within a single healthcare network were retrospectively reviewed. Preoperative, intraoperative, and postoperative definitions of demographics and outcomes were in accordance with the Society of Thoracic Surgeons (STS). The STS risk calculator tool (version 4.2) and the STS database from Calendar Year 2021 were used for comparative purposes to the study group.

Results: There were 85 male and 40 female patients with a mean age of 63 years. Fifty-two percent were African Americans and 18% Hispanic. Sixty-six percent of patients were done urgently and the majority presented with CHF, NSTEMI, and/or Unstable Angina. The mean EF was 31.5% and the mean number of bypass grafts was 2.8. Hospital mortality occurred in three patients (2.4%); a total of thirteen patients either expired or suffered major morbidity (10.5%). The mortality alone and the combined mortality/morbidity were significantly lower than the STS risk calculator prediction. The study outcomes compared favorably to the CY2021 STS Database outcomes for all isolated CABG.

Conclusion: The PAD-CAB procedure in patients with low EF is safe and effective with operative mortality similar to STS mortality for all isolated CABG of every EF. This study exposed limitations in comparing the PAD-CAB procedure to the STS predictor tool and database because this technique is not a specific category for data collection.

Keywords: Coronary artery bypass grafting; Ejection fraction; Cardiopulmonary bypass

Introduction

For decades, cardiac surgeons have utilized various methods to address high risk patients including advancements in preoperative optimization, postoperative critical care, and intraoperative surgical approaches. In an effort to examine the utility of a Pump-Assisted Direct Coronary Artery Bypass technique (PAD-CAB) in a subset of patients with low Ejection Fraction (EF), the authors retrospectively reviewed all isolated CABG procedures performed by a single surgeon (L.S.) at a single health system. The results of this analysis were compared to the predicted risk and the outcomes for isolated CABG from the Society of Thoracic Surgeons (STS).

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Methods

From March 2017 through May 2022, all PAD-CAB cases performed by a single surgeon (L.S.) at two hospitals within the same health system were reviewed; a subset of these patients with a preoperative EF of 40% or less were identified and analyzed. The EF was defined by the Trans-Esophageal Echocardiogram (TEE) performed intraoperatively.

Patient demographics and clinical outcomes were tabulated in accordance with definitions from the STS. Preoperative risk assessment was determined using the STS risk calculator (Version 4.2) and patient outcomes were compared to the outcomes for isolated CABG in the most recent full calendar year (2021) STS database.

The PAD-CAB technique was standardized for all cases and performed in the following manner: median sternotomy, establishment of CPB via the Right Atrium (RA) and aorta, maintenance of mean Blood Pressure (BP) between 60 mmHg - 80 mmHg while on CPB, normothermia, maintenance of ventilation at 50% of the calculated tidal volume while on CPB, use of cardiac stabilizers (Maquet Cardiovascular, LLC, Wayne, NJ, USA), use of flow-thru intracoronary shunts and blow-mister, and monitoring with arterial line, central venous line, EKG, cerebral oximetry, TEE, and temperature-probe foley catheter. The use of a Swan-Ganz catheter was not routinely done and utilized in the minority of cases (i.e., <10%).

Results

Between March 2017 and May 2022, 502 isolated CABG patients were performed by a single surgeon (L.S.) at two facilities in a single health system utilizing the beating heart PAD-CAB technique. From this group, 125 patients (24.9%) were identified as having an EF of 40% or less; 33 patients (6.6%) had an EF under 30%.

There were 85 male and 40 female patients with a mean age of 63 years (range: 38 years to 90 years) (Figure 1). There were 65 (52%) African Americans, 33 (26%) Caucasians, 22 (18%) Hispanic, and 5 (4%) Asian Americans. The average EF was 31.5% (range: 10%-40%) with 92 patients between 30%-40% and 33 patients with <30% (Figure 2). The majority of patients presented with Non-ST-Segment Myocardial Infarction (NSTEMI), Congestive Heart Failure (CHF), or Unstable Angina (USA) (Figure 3).

Twenty- five patients underwent the procedure electively, eighty-three urgently, and seven emergently (Figure 3). The average number of bypass grafts was 2.8 (Figure 4). There were 115 patients (92%) with a history of Hypertension (HTN), 100 patients (80%) with Diabetes Mellitus (DM), 100 patients (80%) with Hyperlipidemia (HLD), and 61 patients (49%) with obesity. The mean HgA1C was 7.3 (Figures 5 and 6). There were 18 patients with Chronic Kidney Disease (CKD) Stage III, 1 Stage IV, and 12 (9.6%) with End-Stage Renal Disease (ESRD) on Hemodialysis (HD) (Table 1).

There were three hospital mortalities (2.4%): one died of a presumed arrhythmia (i.e., sudden death) at home having refused to wear the prescribed life vest; two patients with ESRD died of Pulseless Electrical Activity (PEA) arrest while on hemodialysis. Of the

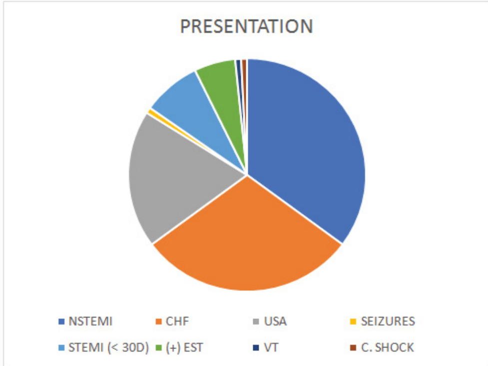

Figure 3: Patient presentation.

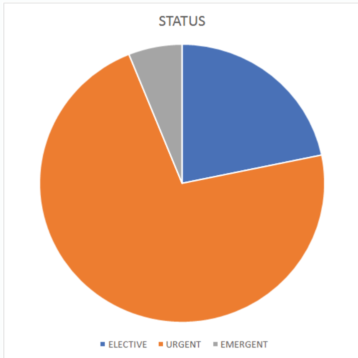

Figure 4: Distribution of patients by Status.

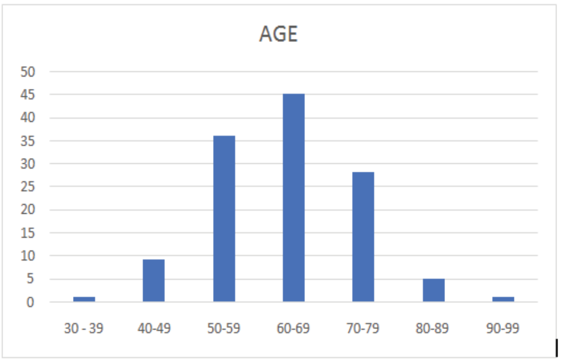

Figure 1: Distribution of patients by age.

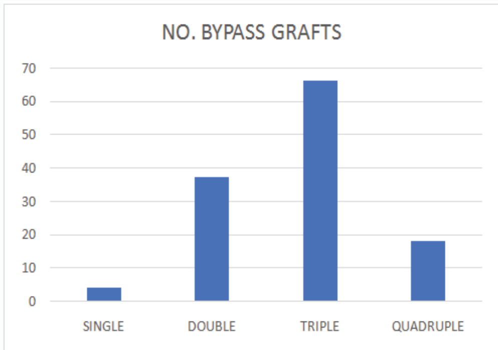

Figure 5: Distribution of bypass grafts.

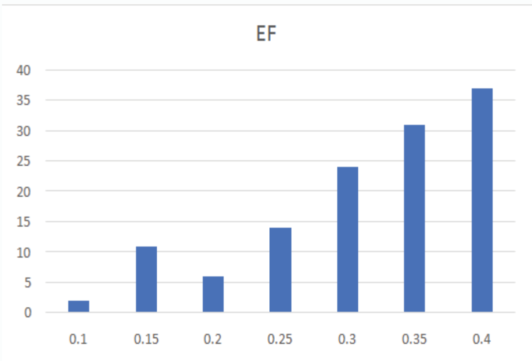

Figure 2: Distribution of patients by EF.

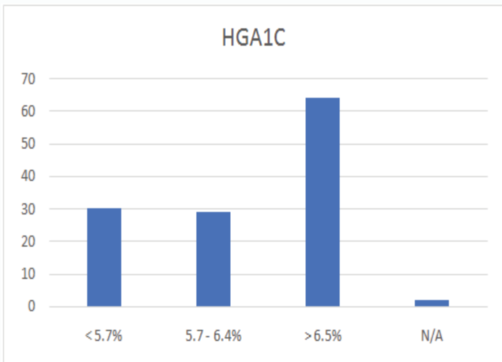

Figure 6: Distribution of HGA1C.
Normal: <5.7%; 5.7-6.4%: Prediabetic; >6.5%: DIABETIC; N/A: Not Available

morbidities, one patient developed acute renal failure postoperatively; three patients suffered stroke; and six patients required re-exploration for postoperative bleeding. A total of thirteen patients either expired or suffered morbidity. No patient required an Intra-Aortic Balloon Pump (IABP) or Left Ventricular Assist Device (LVAD). Comparison of the study patient outcomes with the STS predicted outcomes appear in Table 2.

Table 1: Study demographics compared to Sts Database.

DEMOGRAPHICS	STS DATABASE (% CY 2021)*	STUDY PTS (%)
LVEF <40%	14**	25**
MEAN AGE	66	63
FEMALE GENDER	23	32
OBESE	45	49
CAUCASIAN	79	26
AA	7	52
ASIAN	4	4
HISPANIC	8	18
HTN	90	92
DM	50	80
ESRD	3	10
OBESITY	43	49

*Isolated CABG; **Percentage of total isolated CABG patients

Table 2: Sts predicted outcomes *Vs* Actual study patient outcomes.

	PRED. STS (%)	STUDY PTS (%)	2021 STS DATABASE (%)
OP MORTALITY	3.3	2.4	2.4
RENAL F.*	3.6	0.9	2.2
CVA	2.3	2.4	1.3
REOP.	3.6	4.8	1.8
COMB. M/M	21.1	10.4	10.4

*12 pts w/ESRD pre-op not counted for development of post-op Renal F.

Discussion

Coronary Artery Bypass Grafting (CABG) is the most common adult cardiac surgical procedure performed worldwide. According to the Society of Thoracic Surgery database, 153,241 isolated CABG procedures were performed in Calendar Year (2021) [1]. During this time period, 24,666 (16.1%) isolated CABG patients went to the operating room with an Ejection Fraction (EF) of 40% or less. Low EF, along with other preoperative clinical conditions, is among an array of factors that elevate the risk for the CABG procedure.

The traditional CABG (TRAD-CAB) procedure is performed *via* a median sternotomy with aortic and right atrial cannulation followed by aortic cross-clamping and cardioplegic arrest. The results of the traditional CABG have withstood the test of time and remains the most commonly utilized technique to date. However, inherent in the procedure are elements that have the potential for complication: aortic cross-clamping may disrupt atheroma in the aorta resulting in stroke or fracture the aorta resulting in dissection; cardioplegic arrest may be suboptimal resulting in post-cardiotomy dysfunction or shock; non-pulsatile flow may impair end-organ function despite adequate perfusion; and the cytokine response with the release of inflammatory mediators may contribute to perioperative sequalae such as post-cardiotomy syndrome.

Decades ago, efforts to mitigate these undesirable side effects from the TRAD-CAB were attempted by some surgeons conducting the CABG procedure without the heart-lung machine-'Off-Pump' (OP-CAB). Although enthusiasm for this technique was initially adopted, most cardiac surgeons found the technique challenging, particularly for multi-vessel bypass grafting that included posterior and inferior territories where stabilization in these positions was hazardous and sometimes impossible. In an effort to reduce some of the risk of the procedure while maintaining hemodynamic stability during the case, a hybrid approach was adopted in which a pump-assisted beating heart technique was utilized the 'PAD-CAB'.

In a previous publication by the author (L.S.), the results of the OP-CAB and PAD-CAB in all profiles of isolated CABG procedures were examined with the conclusion that these beating-heart techniques were safe and effective with equivalent or superior outcomes to the traditional CABG [2]. Other investigators experienced similar findings and commented that the beating-heart CABG had particular efficacy in high-risk patients such as emergent cases [3], acute MI [4], hemodialysis patients [5], and so forth. Further experience and analysis of the on-pump beating-heart CABG in patients with severe LV dysfunction was reported by several authors [6-8]. In the study by Gulcan et al. [6] 46 patients with an LVEF <30% were examined: in addition to the CABG procedure, 24 patients required LV aneurysmectomy, 2 required mitral valve repair, and 5 required placement of an IABP. Hospital mortality occurred in 2 patients (4.3%) [6]. Darwazah and others compared their results of 137 patients with an LVEF <35% in which 39 patients underwent on-pump beating heart CABG (ONCAB/BH) and 98 underwent completely off-pump CABG (OP-CAB). The ONCAB/BH groups received more bypass grafts (2.2 *vs.* 1.7), were more likely to achieve complete revascularization (72% *vs.* 46%) and had less mortality and morbidity than their OP-CAB counterparts [7]. Erkut and colleagues subdivided 131 patients with low EF (mean LVEF ~ 27%) into 66 traditional CABG patients (Group I) and 65 On-Pump Beating-Heart (Group II). Although the authors state in the results section hospital mortalities of 12.7% and 1.8% for Group I and Group II respectively, the data calculates to different values: 14 deaths in the 66 Group I cohort (21.2%) and 2 deaths in Group II cohort (3.1%). Although these discrepancies are significant, the authors concluded that the On-Pump beating heart patients had superior outcomes compared to their traditional CABG counterparts [8]. In a relatively recent systematic review and meta-analysis of On-Pump Beating Heart CABG (OPBHC) in high-risk patients by Dominici and others, the study showed that this technique was effective in high-risk patients by preventing hemodynamic deterioration during the procedure and guaranteeing adequate end-organ perfusion. They concluded that OPBHC might be useful in patients with recent MI or with LV dysfunction [9].

Our study aimed to specifically examine the low EF patients with the PAD-CAB technique performed by a single surgeon at two sites within the same healthcare network in which the surgical team (i.e., anesthesia, nursing, and perfusion) were identical. Although this does not reflect a real-world experience, it does significantly limit such variables in preoperative planning, surgical technique, and perioperative management. In addition, the 125 patients were all planned for the PAD-CAB technique with no conversion to either OP-CAB or TRAD-CAB. Although this intent prevents conclusions that prospectively compare one technique to another, it does eliminate any operator bias associated with a choice in surgical approach.

Comparison of the study patients with STS preoperative risk calculator and postoperative database proved to be fascinating. The STS preoperative risk calculator does not account for the specific technique of CABG surgery, it only categorizes Isolated CABG. As such, there is no way to discriminate or compare preoperatively the calculated risk for a patient undergoing the CABG procedure based on technique. Regarding the STS database, the report identifies the traditional on-pump CABG (TRAD-CAB) and the off-pump CABG (OP-CAB) and assigns data points and outcomes measures for both categories without distinguishing between the two on-pump subcategories (i.e., on-pump beating heart (PAD-CAB) from on-pump with aortic cross-clamping and cardioplegic arrest (TRAD-CAB)). These STS limitations prevent comparison pre- and post-operatively with regard to surgical technique.

Additional findings when comparing the study patients with the STS showed some interesting site-specific characteristics. For example, the study site patients were represented by more African American and Hispanic ethnicities compared to the national numbers. Furthermore, there were significantly more study patients with such co-morbidities as DM and ESRD. More study patients underwent the procedure Urgently versus Electively. While these characteristics may simply reflect the societal profile of a poor urban population on the one hand, when contextualized and compared to the national profile there are implications beyond the scope of this study.

The PAD-CAB technique appears to have certain potential advantages compared to the TRAD-CAB approach. In the author's experience, both techniques perform extremely well in the low to moderate risk patient where myocardial and end-organ reserves are more 'forgiving' in the event of cardiac or extra-cardiac compromise. The PAD-CAB appears to have benefit in the high-risk cases where avoidance of cardioplegic arrest may reduce the risk of postoperative myocardial dysfunction. Indeed, several investigators demonstrated less cardiac enzyme release with the PAD-CAB technique compared to the TRAD-CAB approach [6,10,11].

Conclusion

Our study accomplished several things: 1) it demonstrated efficacy and potential advantages of the PAD-CAB procedure in patients with low EF, similar to the findings of others and; 2) it exposed the limitations in analyzing the PAD-CAB technique with the STS risk calculator and database.

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