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Inter-Institutional Collaboration Between Quaternary and Tertiary Hospitals: Cardiac Surgery Impact

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ABSTRACT

Background: An inter-institutional collaboration between a quaternary hospital (QH) with a high volume of cardiac surgery and a community-based, tertiary hospital (TH) with a newly established cardiac surgery program was established.

Methods: We retrospectively reviewed data of patients admitted to the TH between September 2015 and June 2017 for cardiac surgery. The decision to transfer a patient to the QH was based on a Society of Thoracic Surgeon-Predicted Risk of Mortality (STS-PROM) score of ≥ 3%, the potential need for hemodialysis, and other risk factors. The same team of surgeons performed operations at both hospitals. We analyzed the perioperative outcomes of the patients and the referral pattern.

Results: A total of 116 patients met eligibility criteria; 105 underwent surgery at the TH, while 11 were transferred to the QH. Among the 11 patients transferred to the QH, eight had a score of ≥ 3% (median = 8.2 [IQR 5.7-25.0]). The patients transferred to the QH prior to surgery had a significantly higher STS-PROM score (P = ≤ .001). Overall, the mortality of patients who underwent surgery at the TH was 0.9% (1/105); while surgeries at the QH had a mortality rate of 0% (0/11).

Conclusion: The collaborative effort between high-volume cardiac surgery programs and emerging community-based hospitals showed acceptable outcomes in perioperative cardiac surgical mortality. Elevated STS-PROM scores (>3%), previous sternotomy and anticipation of coagulopathy, and low left ventricular ejection fraction or dilated ventricles are factors that influenced the need to transfer from a TH to QH.

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INTRODUCTION

Despite advances in technology, knowledge, and surgical techniques, cardiovascular disease remains a leading cause of death in the U.S. The standardization of the quality of care and outcome measurements are key foci of recent healthcare disciplines. Comparable short-term results and reduced mortality of percutaneous interventions challenge cardiothoracic surgeons to achieve the best outcomes [Serruys 2009; Reardon 2017].

Every year, around 300,000 open-heart surgeries are performed around the country. Open heart programs have become attractive, prestigious, and profitable for healthcare facilities [Carey 2005]. The establishment of these programs in many community-based hospitals has resulted in an increased number of "low-volume hospitals" offering cardiac surgery. The concern is that there is an inverse relationship between the volume of surgeries and operative mortality [Halm; Dudley 2000]. According to the Society of Thoracic Surgeons (STS) adult cardiac surgery database in 2019, isolated coronary artery bypass graft (CABG) surgery has a hospital mortality of 1.8% [D'Agostino 2019]. To standardize perioperative risk, STS's predicted risk of mortality (STS-PROM) score has been validated to predict short-term morbidity and mortality after cardiac surgery [Society of Thoracic Surgeons].

While selective referral patterns are studied and published [Mercado 2005], this can be improved. We established an inter-institutional collaboration between a quaternary hospital (QH) with a high volume of open-heart surgery and advanced heart failure capabilities and a community-based, tertiary hospital (TH) with a new cardiac surgery program. Our goal was to implement an evidence-based referral protocol to minimize the mortality rate at the low-volume TH. We present our experience and the results of this approach. In addition, we compared the outcomes of high-risk patients who underwent surgery at either hospital.

MATERIALS AND METHODS

After obtaining institutional review board approval (HSC-MS-19-0702), we reviewed the data of patients from a community-based, TH with a newly established open-heart surgery program via waiver of informed consent. We analyzed the data from patients who were admitted to the TH for cardiac surgery between September 2015 and June 2017. The same four surgeons performed the operations and dictated the perioperative management at both the TH and QH.

We used an STS-PROM score of ≥ 3% as the primary criteria to differentiate high-risk from low-risk cases. However, the final decision to transfer patients to the QH was made by the surgeon. Additional factors in deciding to transfer patients to the QH included low ejection fraction, prior cardiac surgery, need for hemodialysis, temporary mechanical circulatory support, and frailty, among others.

The primary endpoint was in-patient hospital mortality and secondary endpoints included intensive care unit (ICU) stay, length of hospital stay, number of blood transfusions, the incidence of reoperation due to bleeding, need for mechanical circulatory support, stroke, and renal failure.

Statistical analysis: Continuous variables are presented as mean ± standard deviation if normally distributed, and non–normally distributed continuous variables are presented as median and interquartile range (IQR). Categorical variables are listed as proportions and frequencies. Clinical characteristics were compared between patients using Student's t-tests for normally distributed variables and Wilcoxon's rank sum tests for non–normally distributed variables. All P-values reported are from 2-sided tests where $P < .05$ was considered statistically significant. All statistical analyses were performed using STATA version 16 (Stata Corp LP). All investigators had full access to the data and assume responsibility for its integrity.

RESULTS

Between September 2015 and June 2017, 116 patients were admitted to the TH as candidates for cardiac surgery. Of these patients, 105 underwent surgery at the TH while 11 were transferred to the QH. (Figure 1) Eight of the 105 patients (7.6%), who underwent surgery at the TH, had STS-PROM scores ≥ 3% (Table 1); their median STS-PROM score was 4.9% (IQR 3.6-5.7). (Table 1) The surgeon in each of the eight cases considered the patients manageable and did not elect to transfer their care to the QH; the reasons included lack of bed availability at the QH, patient refusal for transfer, and others.

Eleven patients were transferred to the QH. Eight (72.7%) of the transferred patients had STS-PROM scores ≥ 3%; their median STS-PROM score was 8.2% (IQR 5.7-25.0). The other three transferred patients had STS-PROM scores that were < 3%, but they were transferred because of other risk factors, including low ejection fraction or dilated left ventricle (*N* = 3), prior cardiac surgery, and anticipation of postoperative coagulopathy (*N* = 2), and end-stage renal disease requiring hemodialysis (*N* = 1).

Table 1. Comparison of baseline characteristics of patients with STS-PROM scores that were higher than 3% who underwent open-heart surgery at either the tertiary or quaternary hospital

Variable	Tertiary hospital	Quaternary hospital	*P*-value
Number of patients	8	8	
Age (years)	67.0 (66-74)	69.5 (63-73.5)	.50
Male	4 (50.0)	8 (100)	.02
Hypertension	8 (100)	8 (100)	1.0
Diabetes mellitus	2 (25.0)	7 (87.5)	.01
Prior myocardial infarction	4 (50.0)	6 (75.0)	.30
Renal failure	3 (37.5)	4 (50.0)	.13
Left main coronary artery disease	2 (25.0)	5 (62.5)	.13
Hyperlipidemia	8 (100)	8 (100)	1.0
IABP	0 (0.0)	6 (75.0)	.003
Heart block	0 (0.0)	1 (12.5)	.30
STS-PROM score (%)	4.9 (3.6-5.7)	8.2 (5.7-25.0)	<.001
CABG cases	7 (87.5)	6 (75.0)	.52
Left ventricle ejection fraction of ≤45%	2 (25.0)	7 (87.5)	.04
Prior sternotomy	0 (0.0)	3 (37.5)	.20
End stage renal disease	0 (0.0)	4 (50.0)	.08

Data is presented as median (interquartile range) or frequency (percentage). CABG, coronary artery bypass graft; IABP, intra-aortic balloon pump; STS-PROM, Society of Thoracic Surgeons predicted risk of mortality

Of the 105 patients who underwent surgery at the TH, 93% had a diagnosis of hypertension, 79% had hyperlipidemia, 40% were diabetic, 32% had a history of prior myocardial infarction, and 22% had a history of left main coronary artery disease. Overall, they had a relatively normal renal function; the average serum creatinine was 1.2 ± 1.2 mg/dL/m2. The average STS-PROM score was 1.6 ± 1.3 %. After surgery, they were on mechanical ventilation on average for less than a day (0.9 ± 0.6 days) and required 3.7 ± 1.7 days of ICU stay.

Of the 105 patients with a low surgical risk who underwent surgery at the TH, five were later transferred to the QH for a higher level of care. All five patients had an STS-PROM score < 3%, with a mean STS-PROM score of 1.6 ± 1.1%. Two out of five patients needed postoperative extracorporeal membrane oxygenation (ECMO) support due to post-cardiotomy shock, and both were cannulated at the TH and immediately transferred to the QH. The first one had ventricular arrhythmias refractory to electrical shock and anti-arrhythmic medication; they were successfully weaned from ECMO after one day of support and transferred back to the TH two days later. The second patient suffered cardiac arrest due to massive aspiration and hypoxemia and later died at the QH due to intracranial bleed; this is the only mortality recorded in this study. Thus, the mortality rate for patients who underwent heart surgery at the TH was 1.0%. In regards to the other three patients, two patients were transferred to undergo continuous venous-venous hemodialysis (CVVHD) due to kidney failure, since this resource was not available at the TH. The last patient experienced worsening hypoxemic respiratory failure after aspiration and was transferred for advanced respiratory support and management since no pulmonary and critical care night shift coverage was available at the TH. With the exception of the patient on ECMO who died, all other transferred patients were transferred back to the TH after clinical improvement.

Sixteen patients initially were evaluated at the TH and had a calculated STS-PROM score of ≥ 3%, and they were deemed to have a higher surgical risk. However, eight patients underwent surgery in the same facility (TH). In five cases, there was a lack of beds for immediate transfer to the QH, and three patients refused to get the surgery done at the QH. The other eight patients were transferred to the QH and underwent surgery there. There was no significant difference in age when comparing patients with an STS-PROM score ≥ 3% who underwent surgery at the different hospitals. (Table 1) However, patients transferred to the QH exclusively were male and had a higher incidence of diabetes (*P* = .01). They also had a higher incidence of intra-aortic balloon pump support prior to the surgery (*P* = .003). High-risk patients treated at the QH were more likely to have a left ventricle ejection fraction of ≤45% and dilated left ventricles (*P* = .02). Of note, 37.5% (3/8) of high-risk, transferred patients had a prior sternotomy, and four patients had end-stage renal disease. The reasons for transfer included the following: high risk for coagulopathy, need for

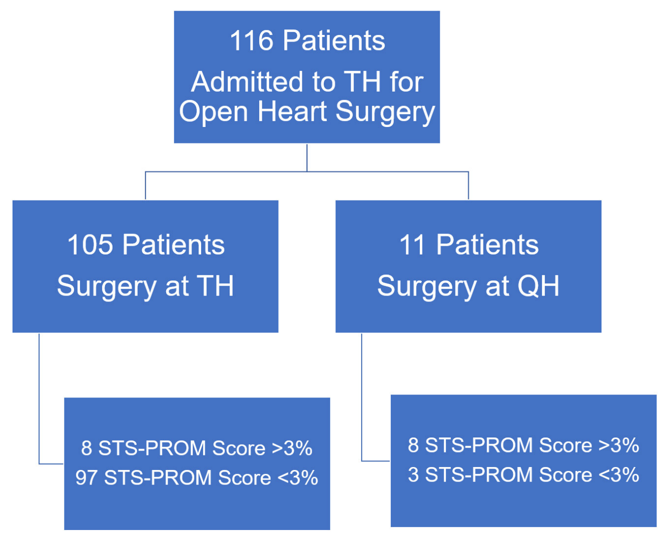

Figure 1. Distribution of patients enrolled into this retrospective study. QH, quaternary hospital; STS-PROM, Society of Thoracic Surgeons' predicted risk of mortality; TH, tertiary hospital

Table 2. Comparison of operative and outcome characteristics for high-risk patients.

Variable	Tertiary hospital	Quaternary hospital	*P*-value
Number of patients	8	8	
Length of stay (days)	11.0 (7-16)	19.0 (9-34.5)	.02
Intensive care unit stay (days)	4.0 (4-9)	6.0 (3-19)	.03
Mechanical ventilation (days)	1.0 (1-2)	2.5 (2-6)	<.001
Blood transfusion	1 (12.5)	6 (75.0)	.02
Reoperation for bleeding	0 (0.0)	3 (37.5)	.07
Stroke	0 (0.0)	1 (12.5)	.33
Atrial fibrillation	1 (12.5)	4 (50.0)	.05

Data is presented as median (interquartile range) or frequency (percentage) delay sternal closure due to redo sternotomy, CVVHD availability, larger blood bank, and the presence of a coagulation specialist (hemopathologist) in the QH.

The outcomes of the high-risk patients who underwent surgery at the QH versus the patients who underwent surgery at the TH were also compared. (Table 2) The high-risk patients who had surgery at the QH had a longer length of stay (P = .02), a longer ICU stay (P = .03), longer time on mechanical ventilation (P < .001), and more blood transfusions (P = .02).

DISCUSSION

The outcomes were favorable after implementation of our inter-institutional collaboration system and with the use of the STS-PROM score as the primary risk assessment tool for the transfer of high-risk cases to the QH. The low mortality after open-heart surgery at the TH can be explained by the mean STS-PROM score of 1.6% in this population. The majority of surgeries at the TH (97/105) had scores of 1.6% or below. These findings are similar to those reported by LaPar and colleagues who used multiple logistic regression models to analyze a large STS database [LaPar 2014]. They concluded that an STS-PROM score of less than 1.3% is a threshold to achieve operative mortality of 1.0% or less [LaPar 2014]. When comparing our high-risk patients who underwent open-heart surgery at the TH and those transferred to undergo surgery at the QH, the overall survival was higher than expected per STS-PROM score. Thus, low-volume hospitals can provide excellent results and serve the local community's cardiac needs. This is especially important when the travel burden is an important factor for the patient population [Subramanian 2017]. Further, treatment at a TH reduces the congestion and burden of facilities with higher levels of care. In addition, the model that we applied between the two hospitals facilitates the transfer of patients in case of the need for a higher level of care during the postoperative period.

The hospital and ICU lengths of stay, days on mechanical ventilation, and need for blood transfusion were longer or higher for patients transferred to the QH. This could have been expected by the significantly higher STS-PROM score as we delineated in Table 1. These patients also had lower ejection fractions, a higher need for preoperative IABP support, and larger ventricular dimensions. (Table 1) The incidence of reoperation for bleeding in our high-risk patients at the QH was higher since the transferred patients had previous sternotomies and/or cardiac surgery as well as mechanical circulatory support with IABP.

The high survival at the QH (87.5% [7/8]) despite a high calculated risk could be due to the regular multidisciplinary collaborative approach that occurs in the QH as well as the availability of continuous veno-venous hemodialysis [Huard 2020; Demirkiliç 2004]. Bond et al. analyzed a database of 3763 U.S. hospitals and found that higher staffing levels of medical residents, registered nurses, registered pharmacists, and medical technologists were associated with lower hospital mortality rates [Bond 1999].

Based upon STS-PROM scores, Umana-Pizano et al. reported a bimodal distribution of mortality centered on low-risk (<4%) and high-risk patients (>8%) in the postoperative and preoperative periods [Umana-Pizano 2019]. Specifically, the two most commonly involved subcategories affecting the postoperative ICU phase in the low-risk group were hemodynamic management and early recognition and treatment of decompensation [Umana-Pizano 2019]. This study, like ours, shows that by focusing on the patient's risk profile, facilities have opportunities to improve the quality of patient care and outcomes.

Our study has limitations as a retrospective data analysis of a single-center experience with a relatively low number of patients in the high-risk category. There was no operator bias since the same group of surgeons were involved in the operative procedure at both institutions.

Inter-institutional collaborative support for new, community-based cardiac surgery programs can support favorable outcomes and reduce congestion of the QH. While elevated STS-PROM scores can predict risk, previous sternotomy, low ejection fraction, and the need for preoperative mechanical circulatory support are other factors that can indicate the need to transfer patients to higher volume centers. The mortality rate at the QH was not affected by the transfer of high-risk patients; however, reduction in the duration of hospital stays and mechanical ventilation support requires further efforts to be improved.

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