Investigating the Efficiency of Robotic and Conventional Open Surgical Methods in Coronary Artery Bypass Grafting Surgery

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Abstract

Mortality rates and length of stay in the ICU and hospital were compared in patients undergoing traditional open-heart coronary artery bypass grafting (CABG) to patients undergoing robotically-assisted minimally invasive direct coronary artery bypass (MIDCAB) to determine the optimal method of surgery. Peer-reviewed papers discussing the two approaches were gathered from various online research databases and reference sections of articles pertaining to the specific topic of this paper. Before conducting research, it was hypothesized that robotically-assisted cardiac surgery would be more beneficial for patients and would yield significantly lower mortality rates and length of stay in ICU and the hospital. Post data collection and statistical analysis, the alternative hypothesis was accepted for two factors: total time spent in the hospital throughout the procedure and 30-day mortality rates for patients in the MIDCAB group; there was an insignificant difference in length of stay in the ICU between the two groups.

Keywords: robotically-assisted cardiac surgery, minimally invasive heart surgery (MIDCAB), open-heart surgery, coronary artery bypass grafting (CABG), median sternotomy

Introduction

Coronary artery disease, also known as ischemic heart disease, is the leading cause of annual deaths in the United States, instituting a need for improvements in treatments and interventions. According to the American Heart Association, approximately 16 million patients are afflicted with severe coronary artery disease in the United States (Alturi et al., 2008). As expected, approximately 80% of all deaths caused by coronary heart disease occur in patients over age 65 due to increasing obesity and diabetic patients in this age group (Roger et al., 2011). Although coronary artery disease has been relatively addressed and reduced in developing countries in recent years, reports have claimed 7.2 million deaths have resulted from the disease all over the world, making research and treatment improvement vital (Howell, 2011).

Coronary artery disease refers to the narrowing or blockage of arteries in or leading to the heart, caused by the buildup of plaques on the inner walls of the arteries. Also referred to as atherosclerosis, plaque buildup is primarily caused by regular intake of high-cholesterol foods and saturated fatty acids (Ulbright and Southgate, 1991). Recent studies have also related obesity, diabetes, high blood pressure, stress, smoking and consumption of alcohol as potential factors of obstructed arteries with fat and cholesterol buildup. In fact, active and passive smoking caused higher deaths by aggravating heart disease than lung cancer, and scientists suggest avoiding environmental tobacco smoke (ETS) as a primary method to prevent coronary disease (Glantz & Parmley, 1990).

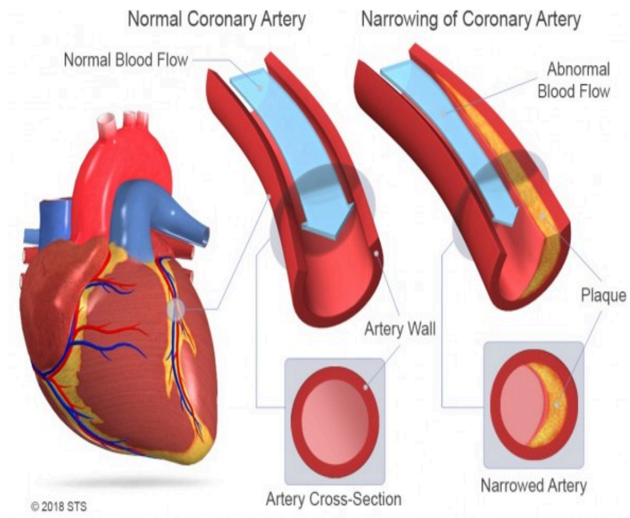


Fig 1. The coronary artery narrowed by plaque buildup, blocks blood flow. (The Society of Thoracic Surgeons).

Displayed in Fig 1, such narrowing of the coronary arteries can prevent sufficient blood flow, in turn reducing the supply of oxygen and transportation of nutrients to functioning organs of the body. As the plaque buildup continues within the artery, the risk of myocardial infarctions, or heart attacks, increases and patients may experience cardiac ischemia, which causes severe chest pain or angina and cardiac pressure (Glantz & Parmley, 1990). Additional symptoms prior to a stroke or a heart attack include difficulty in breathing, nausea, and arrhythmia, or irregularity in heartbeat. If the patient is untreated, complete blockage of the artery can cause heart attacks, leading to significant weakening of the heart, postoperative complications, reduced quality of life, and possible mortality.

Current Treatments

There are several methods to treat coronary artery disease including general medication with a combination of regular physical activity, percutaneous coronary intervention (PCI), and several types of coronary artery bypass grafting surgery (CABG). The treatment approach is determined based on several factors including the medical history of the patient, risk factors, results from a blood test and physical exam, and for some patients undergoing repeat revascularization, a higher level of treatment. Most instances of developing coronary disease can be reasonably prevented with implementing better lifestyle choices such as proper nutrition, exercise, control of weight and body fat, and minimal to no alcohol intake and smoking.

However, in case coronary artery disease is identified, a study by Yusuf et al. (2004) that analyzed the risk factors among patients that experience myocardial infarctions stated that potentially 80% - 90% risk of heart attack can be reduced by consuming a pill with a statin, antihypertensive drugs, and aspirin. Previously, since surgeons discovered higher patient survival post heart attack, treatment included close monitoring of the patient who remained at a bed for six weeks and was prohibited to move for the first two weeks. Along with this, patients were assisted with stress management, sufficient exercise, and other information regarding the proper treatment for heart attacks (Redfern, 2016). Although physical treatment and steady monitoring of patients was the primary treatment prior to early 2000s, such efforts merely increased the time before the disease eventually developed.

Percutaneous coronary intervention (PCI), also known as balloon angioplasty, involves a surgeon inserting a long, thin wire with a balloon and a stent attached at the tip. Once the tip reaches the blocked section of the artery, the balloon is inflated and the stent compresses the plaque and holds the artery open, restoring blood flow through the artery. This procedure is minimally invasive, as the wire is inserted through a tiny incision in the arm, leg, or sometimes in the abdomen. Although PCI is a popular procedure amongst bypass patients, yielding similar rate of survival, stroke, and myocardial infarctions, patients undergoing PCI often need repeated intervention and experience higher angina levels compared to bypass surgery patients (Serruys et al., 2001). Both procedures, PCI and CABG, have reduced symptoms and mortality compared to only medical therapy for patients with severe coronary disease. Although PCI can be performed in combination with bypass surgery, studies usually examine patients undergoing particular treatments individually.

Coronary Artery Bypass Grafting

In all forms of CABG, a healthy blood vessel is harvested from the arm, leg, chest or abdomen, and connected to the arteries in your heart to bypass the blocked artery and create a new path for blood flow to your heart. A traditional open-heart CABG surgery is performed under cardiopulmonary bypass (CPB), a machine that maintains the circulation of blood and oxygen while the heart is stopped for surgical purposes. One large incision down the front of the chest is made, usually dividing the breastbone and sternum. This incision, known as a median sternotomy, enables the surgeon to safely operate on all parts of your heart. The size of the actual incision varies between patients and surgeon preference. Due to the potential risk factors of discontinuing pumping of the heart, off-pump coronary artery bypass surgery (OPCAB) without exposure to the cardiopulmonary bypass machine was proposed for elderly patients (Ejiofor et al., 2015). Even though OPCAB was an improved version of conventional CABG, large incisions were still utilized to access the blocked artery and resulted in similar levels of trauma post-treatment.

Conveniently, new discoveries and knowledge in the field of robotics have increased manufacturing of computer-enhanced instrumentation systems and endoscopic instruments, eventually reaching the field of cardiac surgery. Initial robotic systems for cardiac surgeries were implemented in the early 2000s and comprised of the AESOP 3000, the da Vinci Robotic systems, and the Zeus robotic system, still being utilized to this day (Kypson et al., 2003). Although the widespread implementation of such robotic systems and adaptation of robotically-assisted procedures was minimal due to various limitations such as the costs of manufacture, limited experimentation and research, and learning curve for surgeons, clinical trials continued building credibility and feasibility of implementing totally robotic surgeries (Hemli et al., 2013). As a minimally invasive procedure, surgery was performed using instruments and equipment inserted through small incisions to operate on the patient (Cavusoglu et al., 2003).

In a typical robotically-assisted surgery, a surgeon sits at the surgeon console which consists of a viewing station, controls to the robotic hands, voice controls (Fig 2). A surgeon team, available near the patient throughout the operation, changes instruments and camera angles based on the surgeon's instructions and addresses any issues or problems during the procedure (Bonatti et al., 2006). Although technically demanding on the surgeon, robotic coronary bypass reduces surgical trauma and postoperative morbidity that occurs in conventional open-heart patients (Abu-Omar & Taggart, 2018).

Fig 2. The image above shares the common setup for robotic surgery, with the surgeon site on the left and the patient site on the right. The figure also shares the performance-enhancing tools provided by the surgical robot to help the surgeon perform complex endoscopic procedures with relative ease (Nuzzi and Brusasco, 2018).

Theoretical Benefits

Theoretically, there are many advantages of any robotically-assisted surgery over the conventional counterpart such as reduced dexterity decreasing accidents, infections, blood loss, and other complications that may occur after CCAB (Kypson et al., 2003). The robotic systems remove all unnecessary motion or tremor that cannot be replicated by any human, reducing risks of complications and decreasing recovery times. Robotic surgery, a type of minimally invasive surgery, is a procedure utilizing miniaturized surgical instruments that fit through a series of a quarter to half-inch incisions, unlike the open counterpart that needs a six to eight-inch incision in order to access the narrowed artery in the heart.

Robotically-assisted MIDCAB surgery, thus, has great potential in treating coronary artery disease and eliminating the side effects that other procedures transmit after treatment. While reducing mortality among patients as stated in studies discussed in this paper, Walther et al

(1999) also examined the pain levels and overall quality of life between patients undergoing median sternotomy and patients undergoing MIDCAB surgery, reporting that pain intensities were relatively similar but the quality of life improved with time but was better in the minimally-invasive approach. Likewise, other studies included in this literature review compare the two approaches of CABG based on other factors during and after surgery. Subsequently, this paper builds on previous research and attempts to reveal the optimal coronary bypass procedure to reduce mortality and time spent in the ICU and hospital.

Purpose

The purpose of this study is to examine the most efficient and applicable surgical treatment for coronary artery disease. Specifically, this paper analyzed three specific factors: stay in ICU, length of stay in the hospital, and 30-day mortality in a typical CABG treatment for the traditional open-heart procedure and robotically-assisted procedure to determine which approach is more efficient and applicable. Although open-heart surgery has been widely implemented with continuous improvements in the procedure, the rise of robotics in the medical industry has provided alternative methods of surgery and contributed towards potential improvements in treatments. Even though previous studies and systematic reviews have compared the two methods of CABG surgery with averages and standard deviations of the same factors mentioned above, this research is unique due to the conducted statistical analysis, used to determine whether there was a significant difference in the datasets for the two distinct operations.

Research Question

Which heart surgery is more effective in reducing the mortality rates and decreasing the length of stay in the ICU and at the hospital, robotically-assisted minimally invasive CABG surgery or standard open-heart CABG surgery?

Alternate Hypothesis

Robotically-assisted CABG surgery is the optimal approach compared to standard open-heart CABG, due to significantly lower lengths of stay in the ICU and the hospital and lower 30-day mortality rates in patients.

Null Hypothesis

There is either an insignificant difference between the standard open-heart surgery and the robotically-assisted CABG surgery for the lengths of stay in the ICU and the hospital and 30-day mortality rates, or the conventional CABG is more effective than the robotically-assisted CABG procedure.

Methods

Data Sources

A systematic literature review was conducted to analyze the studies. Due to safety guidelines and policies for high school students in Thousand Oaks High School's Center for Advanced Studies, a systematic literature review was considered to be the most practical method of data analysis in this paper. A meta-analysis was not applicable due to lack in the number of articles reporting data on both mortality and time spent in the ICU and hospital. A survey or questionnaire was not practical because numerical data was needed to conduct statistical analysis and evaluate differences. Finally, because this research study was to be entirely theoretical, personal experimentation or usage of a laboratory was prohibited.

Initially, general information and background were obtained using online textbooks and government websites such as NIH. Articles used for data analysis were collected using various online research databases including EBSCOhost, Google Scholar, ScienceDirect, and NCBI, and PubMed. For additional research, reference sections of collected articles were assessed to find related articles with similar data and equal variables included in this study.

In general, research and data collection occurred at Thousand Oaks High School, at the author's home, or at the local library. These locations were also utilized to gather basic information and an understanding of key terms and medical vocabulary used in clinical trials and articles prior to data collection and analysis.

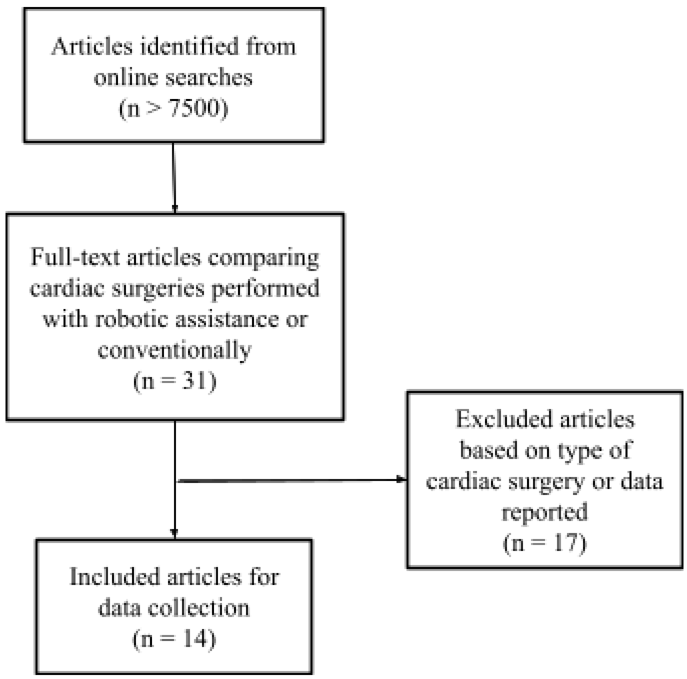
Inclusion and Exclusion Criteria

Only full-text, peer-reviewed articles with clinical trials on coronary artery bypass, open-heart and/or minimally invasive, were gathered to collect data and conduct statistical analysis.

Papers were excluded from the study if the paper reported on less than 10 patients undergoing any form of CABG treatment. Because of the lack of clinical trials and published experimentation reporting comparing data between conventional CABG and coronary bypass with robotic assistance, papers were included if published post-2000, with one exception for Walther et al.published in 1999. Walther and his research team reported data for both approaches of surgeries on the length of duration in the ICU and the total stay in the hospital, two of the data sets included in this paper. A broad range of publication was utilized because older data remained consistent with data published in recent studies.

Furthermore, papers were excluded from the literature review if the article provided qualitative data describing the differences between the two groups based on recovery times or other unrelated variables that were not discussed in this paper.

Fig 3. Diagram displaying process of article collection to find data used in the statistical analysis.



Data Collected

Data was collected on the length of stay in the ICU (intensive care unit) post-operation, the total length of stay in the hospital throughout the procedure, and the 30-day mortality rate for both open-heart CABG and robotic MIDCAB. Collected data was measured in hours, days, and percent, respectively. Each included study (n=14) reported data for either one or both types of CABG surgery, for at least two of the data sets mentioned before.

Analysis of Data

Statistical significance for the time spent in the ICU and the hospital, and the 30-day mortality rates between open-heart CABG and robotic MIDCAB using Student's t-test to determine whether one form of treatment was optimal. To evaluate whether there was a significant difference between each of the factors for both approaches, averages and standard deviations (SD) were calculated. Specifically, one-tailed, two sample t-tests were performed with Microsoft Excel's Data Analysis Toolpak to compute the significance of the difference in length of stay and mortality between the two groups. In total, three t-tests were performed comparing each of the factors for the two groups. In the t-tests, unequal variances were assumed because of varying sample sizes and the difference between the number of papers reporting data for each method.

Furthermore, any p-value $\leq .05$ was considered statistically significant between the two groups for each specific data. Confidence intervals for the t-tests were based on 95% confidence. In simpler terms, if a p-value less than .05 was obtained and the minimally invasive clearly lowered mortality and duration in ICU and hospital, the null hypothesis will be rejected. However, if the p-value was greater, the null hypothesis will be accepted and will represent an insignificant difference between the two procedures.

Results

Table 1: The chart shows all the studies used to conduct a statistical analysis, the type(s) of CABG surgery that was performed, the number of patients in each study, the average age of the patients in their groups for surgery, and the data was obtained from each paper to be compared in the statistical analysis.

Data reported:

1. Stay in the ICU (hours)
2. Length of stay at the hospital (days)
3. 30-day mortality rates (%)

Study Analyzed	**Type of surgery in the study**	**Number of patients in the study**	**Average age of patients in the study**	**Data reported**
Halkos et al. (2014)	MIDCAB	307	62.7	1, 2, 3
Yang et al. (2015)	MIDCAB	140	59.3	1, 3
Sabashnikov et al. (2014)	MIDCAB	425	63.4	1, 2, 3
Prasad et al. (2001)	MIDCAB	24	NR	1, 2
Bayramoglu et al. (2013)	MIDCAB	100	57.9	1, 2
Kofler et al. (2017)	MIDCAB	60	65	1, 2, 3
Repossini et al. (2019)	MIDCAB	1,060	71	1, 2, 3
Giambruno et al. (2017)	MIDCAB	605	61.2	1, 2, 3
Poston et al. (2008)	MIDCAB CCAB	100 100	61.8 66.2	1, 2, 3
Bachinsky et al. (2012)	MIDCAB CCAB	25 27	63.2 66.7	1, 2, 3
Walther et al. (1999)	MIDCAB CCAB	65 95	60.5 63.5	1, 2
Cavallaro et al. (2015)	MIDCAB CCAB	2,582 481,546	64.4 64.9	2, 3
Leyvi et al. (2014)	MIDCAB CCAB	150 1,619	64.7 63.3	2, 3

Alturi et al. (2009)	MIDCAB CCAB	16 462	62.6 64.9	2, 3

Of the papers included in the statistical analysis, eight articles evaluated results of only MIDCAB with robotic assistance or comparison between MIDCAB and another treatment for coronary artery disease such as PCI, which was not included in this study. Six more articles that were included provided data for both traditional CABG and robotically-assisted MIDCAB. These articles were especially important because they already compared the two types of CABG treatments for efficiency in their study, hence implementing similar variables and conditions of surgery, methods for selection of their patients, comparable observation and data collection techniques to conclude most accurate and legitimate results. As mentioned previously and in Table 1, articles were included if they reported quantitative data on at least two of the factors analyzed in this study. Although this technique of gathering data from peer-reviewed articles was most viable, an insufficient number of articles reported on the stay in ICU for the conventional group.

A total of 5,659 were analyzed in the MIDCAB group and a total of 483,849 were analyzed in the conventional CABG group. Although there was a major difference in the number of patients analyzed between the two groups, the high number of patients in the conventional group was heavily influenced by Cavallaro et al. (2015), who studied 481,546 patients who underwent open-heart CABG. Additionally, the number of patients in each study were not taken into consideration because a t-test does not account for the weight of each study, and ultimately, the averages from each included study were utilized for statistical analysis.

Of the patients in the MIDCAB group, the average age was 62.91± 3.22 years, while the average age in the other group was 64.94 ± 1.39 years. After conducting a two-tailed t-test to determine whether there was a significant difference in ages of the two groups, a p-value of 0.07 was obtained, meaning that there is an insignificant difference between the ages and the data will be comparable between these two groups.

Table 2. Studies reporting the ICU stay in hours after either MIDCAB surgery or conventional surgery, and the overall p-value after conducting the statistical analysis.
Abbreviations: ICU- Intensive Care Unit, MIDCAB- Minimally Invasive Direct Coronary Artery Bypass, CCAB- Conventional Coronary Artery Bypass

Study	**ICU Stay (hours) for MIDCAB**	**ICU Stay (hours) for CCAB**	**Total p-value**
Poston et al. (2008)	21.9	50.6	
Bachinsky et al. (2012)	28.5	57.9	
Walther et al. (1999)	22	31	
Cavallaro et al. (2015)	NR	NR	
Leyvi et al. (2014)	NR	NR	
Alturi et al. (2009)	NR	NR	
Halkos et al. (2014)	24	-	
Yang et al. (2015)	50.4	-	
Sabashnikov et al. (2014)	25.5	-	
Prasad et al. (2001)	26.4	-	
Bayramoglu et al. (2013)	14	-	
Kofler et al. (2017)	21	-	
Repossini et al. (2019)	21.8	-	
Giambruno et al. (2017)	28.8	-	
Mean ± SD	**25.85 ± 9.13**	**46.50 ± 13.91**	**0.067**

Consistent results were recorded within each group, with the MIDCAB group displaying overall lower duration in the ICU than the CCAB group. However, the p-value (0.067) obtained proved insignificant difference between the ICU stay of the two groups, most likely due to the lack of research articles reporting data on ICU stay for conventional CABG. Clearly, the averages indicate that robotic assistance for CABG yields less time spent in the ICU post-operation, hence the only source of error that can be conveniently detected is the lacking articles for the CCAB group. Three of the six studies that examined patients undergoing conventional CABG did not report data for the average length of stay in the ICU including Cavallaro et al. (2015), Leyvi et al. (2014), and Alturi et al. (2009). Most likely due to this limitation, the analysis of the data when comparing ICU stay for these two data set concluded insignificant difference between the two types of CABG surgery.

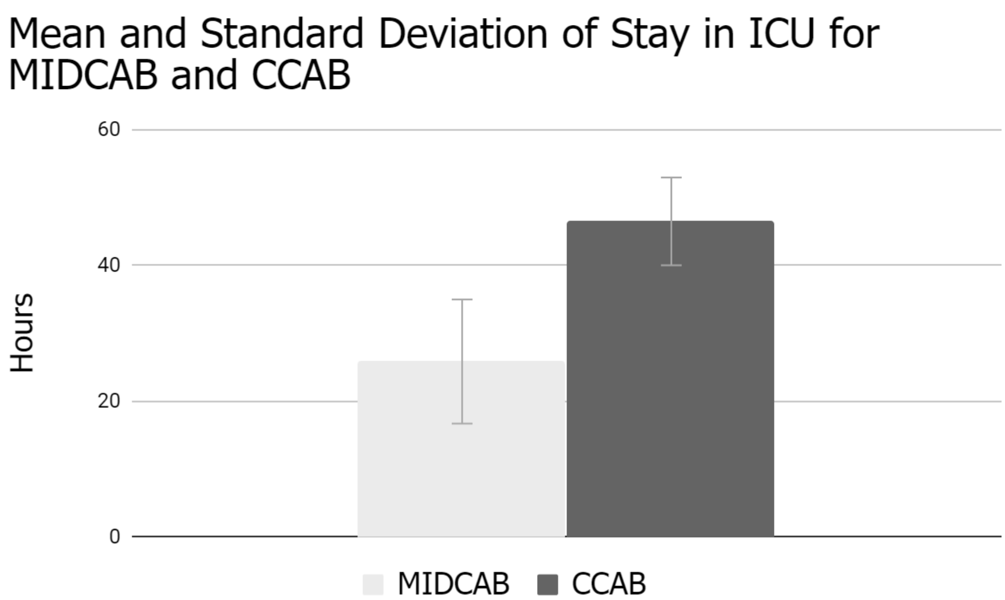


Fig 4. Comparison of averages and standard deviations of stay in ICU for patients in the MIDCAB group and CCAB group.

Statistical analysis provided a p-value of 0.067, indicating insignificant difference for stay in ICU for the two approaches. As shown in Fig 4, the average times differ by a considerable amount, with the average time in the CCAB group being 20.65 hours more than the average ICU time recorded in the MIDCAB group. These findings suggest a possible source of error due to the lacking number of articles in the CCAB group.

Table 3. Studies reporting the LOS in hospital in days after either MIDCAB surgery or conventional surgery, and the overall p-value after conducting the statistical analysis.
Abbreviations: LOS- Length of Stay, MIDCAB- Minimally Invasive Direct Coronary Artery Bypass, CCAB- Conventional Coronary Artery Bypass

Study	**LOS in Hospital (days) for MIDCAB**	**LOS in Hospital (days) for CCAB**	**Total p-value**
Poston et al. (2008)	3.77	6.38	
Bachinsky et al. (2012)	5.1	8.2	
Walther et al. (1999)	10.8	10.8	
Cavallaro et al. (2015)	6.3	9.0	
Leyvi et al. (2014)	6.0	9.0	
Alturi et al. (2009)	4.5	8.0	
Halkos et al. (2014)	4	-	
Yang et al. (2015)	NR	-	
Sabashnikov et al. (2014)	7.17	-	
Prasad et al. (2001)	4.1	-	
Bayramoglu et al. (2013)	5.0	-	
Kofler et al. (2017)	6.0	-	
Repossini et al. (2019)	5.4	-	
Giambruno et al. (2017)	4.8	-	

Mean ± SD	**5.61 ± 1.85**	**8.57 ± 1.45**	**0.001**

All except one of the fourteen studies examining patients undergoing MIDCAB surgery reported average length of stay in the hospital, while six out of six articles reported average length of hospital stay for patients undergoing the CCAB procedure. A significant difference was identified in the total length of stay in the hospital throughout each procedure, indicated by the p-value of 0.001, and the results strongly favored the MIDCAB procedure over the CCAB approach.

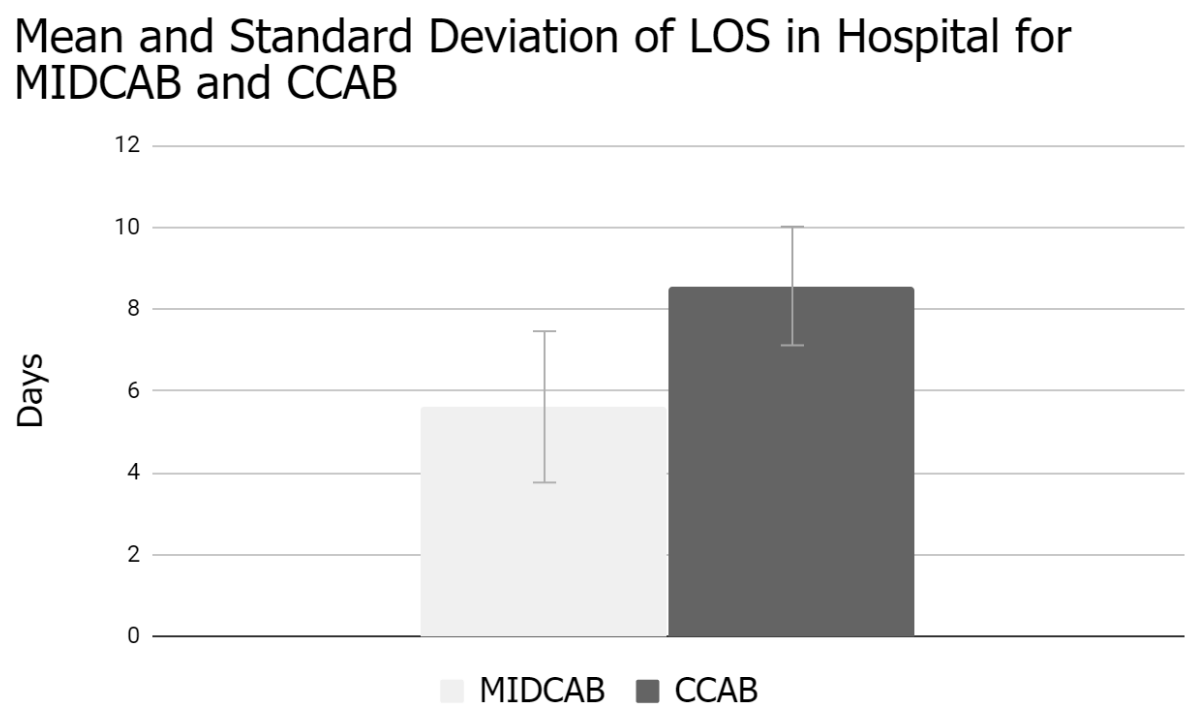


Fig. 5 Comparison of averages and standard deviations of LOS in hospital for patients in the MIDCAB group and CCAB group.

Statistical analysis of this data and the p-value (0.001) proved a significant difference in the average length of stay at the hospital, favoring robotic coronary bypass over the traditional open-heart procedure.

Table 4. Studies reporting the 30-day mortality rates in percent after either MIDCAB surgery or conventional surgery, and the overall p-value after conducting the statistical analysis.
Abbreviations: MIDCAB- Minimally Invasive Direct Coronary Artery Bypass, CCAB- Conventional Coronary Artery Bypass

Study	30-day Mortality (%) for MIDCAB	30-day Mortality (%) for CCAB	Total p-value
Poston et al. (2008)	0	2.0	
Bachinsky et al. (2012)	0	4.0	
Walther et al. (1999)	NR	NR	
Cavallaro et al. (2015)	0.6	1.8	
Leyvi et al. (2014)	0	2.04	
Alturi et al. (2009)	0	1.15	
Halkos et al. (2014)	1.3	-	
Yang et al. (2015)	0	-	
Sabashnikov et al. (2014)	0.7	-	
Prasad et al. (2001)	NR	-	
Bayramoglu et al. (2013)	NR	-	
Kofler et al. (2017)	0	-	
Repossini et al. (2019)	0.8	-	
Giambruno et al. (2017)	0.3	-	
Mean ± SD	**0.34 ± 0.45**	**2.20 ± 1.07**	**0.006**

Eleven out of fourteen studies provided average 30-day mortality in the group of patients undergoing the MIDCAB procedure, while five out of six studies provided average 30-day mortality for patients in the CCAB group. After comparing mortality rates of the two treatments, the results unanimously favored robotically-assisted MIDCAB over the conventional procedure.

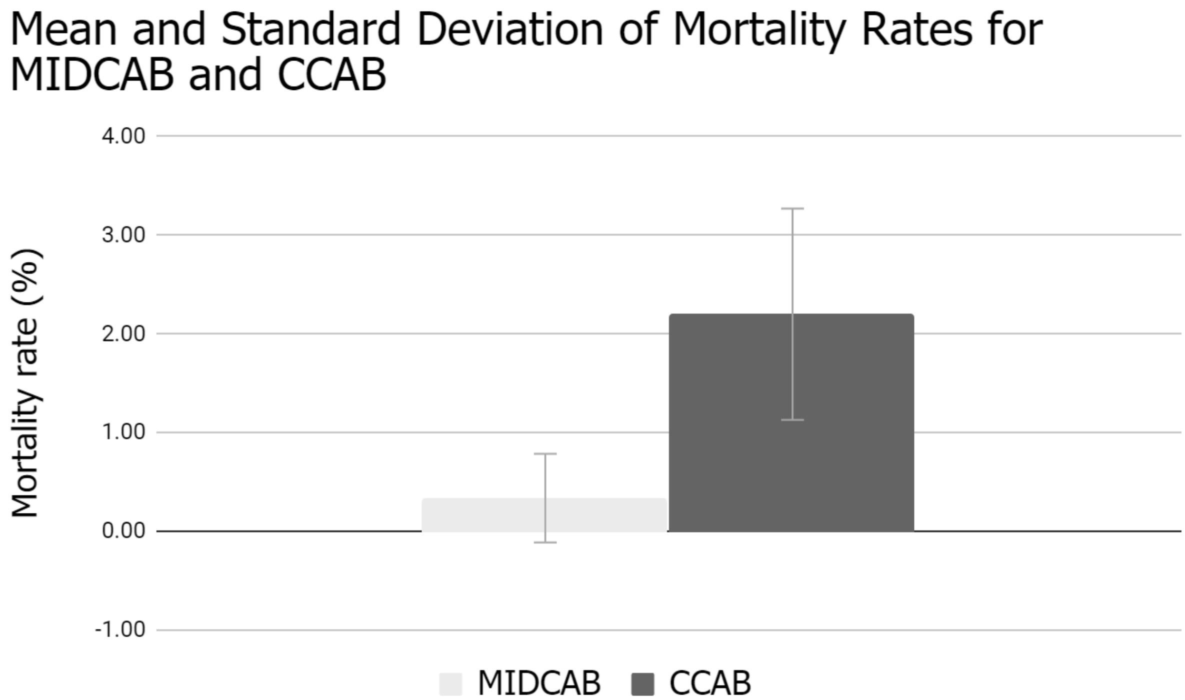


Fig. 6 Comparison of averages and standard deviations of 30-day mortality percentages for patients in the MIDCAB group and CCAB group.

Statistical analysis of this data and the p-value (0.006) proved a significant difference in mortality within 30 days of surgery, favoring robotic coronary bypass over the traditional open-heart procedure.

Discussion

In a comparison of the length of stay in the ICU and the hospital and 30-day mortality rates for two methods of coronary bypass, it is evident that robotically-assisted to perform minimally invasive CABG is overall more favorable for patients than CCAB. Evidently, this study reported one insignificant p-value for the stay in the ICU, however, a significant difference was noticed in length of hospital stay and 30-day mortality, favoring MIDCAB surgery over the conventional procedure.

There is insignificant difference in the average time spent in the ICU between the two patient groups, indicated by the p-value of 0.067, even though the difference in the average times for the two groups was 20.65 hours (Table 2). As shown in Fig 4, the highest range value representing time spent in the MIDCAB group based on the standard deviation is still lower than the lowest range value for the standard deviation of the CCAB group, hence it can be stated that the data is inaccurate because of lacking number of studies in the conventional group.

As shown in Table 3 and Table 4, there was significant difference in days spent in the hospital and death within 30 days of the operation between the MIDCAB group and the CCAB group. Based on a one-tailed t-test for these particular data sets, the p-values reported were 0.001 and 0.006 for hospital stay and mortality, respectively, indicating that patients undergoing robotic coronary bypass spent fewer days in the hospital after treatment and more patients lived until the first follow-up of 30 days post surgery.

When comparing the averages and standard deviations of hospital stay between the two groups, the average length of hospital stay for the MIDCAB group was 5.61 ± 1.85 days and 8.57 ± 1.45 days for the CCAB group, reporting a difference of 2.96 days when disregarding the standard deviations. One particular cause of reduced hospital stay in MIDCAB patients is smaller incisions and reduced dexterity, consequently preventing postoperative complications and surgeon errors. One potential factor that could be compared is patient recovery time, the time it takes for patients to perform physical activity and complete typical tasks after undergoing surgery, however, the data reported for hospital stay in this study suggests that MIDCAB patients are most likely to recover faster than patients in the open-heart CABG group.

Next, the differences in the percentages of mortalities that occurred within 30 days of each type of surgery were 1.86 % while ignoring the standard deviations, the MIDCAB group reporting 0.34 ± 0.45 % and the CCAB group reporting 2.20 ± 1.07 %. As previously stated, there was a significant difference in mortality between the two groups, and clearly, robotic coronary bypass reduced patient deaths by a great margin. Although the percent difference may seem relatively small, numerous patient deaths can be prevented by implementing robotic CABG considering that approximately 600,000 deaths are caused due to coronary artery disease annually. One reason for reduced mortality in the MIDCAB group is also related to smaller incisions, thus reducing blood loss, trauma and pain during and post-treatment. All these findings provide sufficient evidence to reject the null hypothesis, indicating that robotically-assisted coronary bypass is the favorable approach for CABG.

Limitations

The major difference in the number of patients and number of studies between MIDCAB and CCAB was the prime limitation of this study. Although t-tests evaluate significance based on means, the weight of each study was not taken into consideration when calculating the means, standard deviations, and the p-value. Thus, the high population of patients undergoing the conventional procedure (n=481,546) in Cavallaro et al. did not proportionally influence the resulting data. Additionally, the difference in methods of procedure between each study and previous background of patients (diabetes, family history, smoking history, myocardial infarctions, and previous illnesses) may have also affected the data.

The lack of articles including data on the factors considered in this study was also a critical limitation. Only 3 articles examined the length of stay in the ICU for CCAB patients, while 11 articles were used in the MIDCAB group to conduct the t-test. An insignificant p-value was obtained despite consistently lower ICU stays postoperation in the MIDCAB group.

Conclusion

This systematic literature review provided evidence to accept the alternative hypothesis for two of the three factors examined. Overall, it was evident that robotically-assisted MIDCAB was the optimal procedure as it reduced mortality rates and lowered the duration in the hospital. Although the p-value for stay in ICU showed an insignificant difference, it was noticeable that the average time spent in the ICU was lower in the MIDCAB group (25.85 hours) than in the CCAB group (46.5 hours), with a total difference of 20.65 hours between the two. As stated previously, the p-value obtained from the t-test of stay in ICU was most likely a source of error due to lack in data and an incomparable number of studies in the two groups.

The p-values and information acquired in this literature review suggest that implementing robotic-assistance and robotic surgical systems in CABG is overall more efficient than the traditional, open-heart procedure for CABG because it reduces the length of time spent in the hospital and lowers mortality over a 30-day period by a significant amount. Although the implementation of robotics in coronary bypass may not reduce all postoperative complications, it does provide a viable alternative of treatment, with exponential room for growth in robotic technology and combinations of various treatments to yield the most favorable results.

Further Work

To further contribute to future studies, additional research and experimentation should be conducted to compare robotically-assisted coronary bypass surgery and traditional open-heart surgery to be compared and analyzed. Although there is current research on the different approaches of coronary bypass individually, studies should discuss and compare the two methods in one paper, analyzing the two groups with similar methods of procedure, patient selection criteria, and other relevant variables to produce accurate results with minimal influence from extraneous factors.

Although this study only examined the differences in length of stay in ICU and hospital, and the 30-day mortality rates post operation, other factors should also be considered to evaluate the optimal method of CABG. To contribute to this study, future work should compare post-treatment wound infections and complications, blood loss, strokes, need for reoperation, and costs of treatment, while accounting for variable differences in ages, weight and body mass index (BMI), left ventricular ejection fraction (LVEF) gender, diabetes, previous diseases and complications, past treatments and more, as examined in Levyi et al. Analyzing such factors would provide a well-rounded study that precisely compares all characteristics of each method, allowing surgeons and patients to choose the favorable method for their specific case. For instance, despite the benefits and efficacy of robotic MIDCAB, costs of robotically-assisted CABG could be greater than the conventional counterpart, hence denying surgery to patients who cannot afford the costs of the operation.

Most research collected for this review evaluated mortality over a 30-day period after the operation, while some examined their patients over longer durations. To determine which procedure provides the longer-lasting treatment and longer relief from repeat revascularization, follow-up tests should be conducted over several months or years. In some patients, a combination of medications, PCI and robotically-assisted MIDCAB may yield the most favorable results, hence such varying conditions should be analyzed in future studies. With consideration of these factors, more reliable and accurate data could be gathered to precisely determine the optimal approach.

More broadly, robotic assistance can be compared to traditional methods in other cardiac surgeries such as mitral valve replacement, a minimally invasive procedure to replace a malfunctioning mitral valve, and aortic valve replacement, a procedure to replace a narrowed aortic valve. Previously, these two cardiac surgeries were also considered for the topic of this paper, but coronary artery bypass was included based on greater available information and data. In some cases, patients may need a combination of CABG and one of the two replacement surgeries as treatment. Moreover, developing robotic procedures could be compared to current treatments for lung surgery, prostate surgery, kidney surgery, gallbladder surgery, and other procedures. Such research will determine the feasibility of robotic implementation in surgeries, ultimately improving treatments and reducing the burden accompanying surgery.

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