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Original Research Article

Hemodynamic comparison between minimally invasive and conventional approaches in off-pump coronary artery bypass grafting: A randomized controlled trial

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ABSTRACT

Background: This study aimed to investigate the hypothesis that minimally invasive coronary artery bypass grafting (CABG) induces fewer hemodynamic alterations compared to conventional approaches, attributing this to reduced heart rotation during grafting. Given the critical role of hemodynamic stability in patient outcomes and the growing popularity of minimally invasive CABG, we sought to assess and compare the hemodynamic responses during left anterior descending artery grafting.

Materials and Methods: This randomized controlled trial was conducted at a tertiary center, enrolling a total of 60 patients, with 30 in each group. Parameters such as heart rate (HR), mean arterial pressure (MAP), central venous pressure (CVP), and perfusion index (PI) were measured at baseline, after octopus stabilization prior to grafting, at 3 minutes during grafting, and at the end of grafting. Additionally, serum lactate levels were assessed at baseline and upon completion of grafting.

Results: The baseline HR was comparable between the groups. However, the trends in HR revealed a significant increase in the conventional group after octopus stabilization (P value = 0.0038), at 3 minutes post-initiation of grafting ($p < 0.001$), and at the completion of grafting (P value = 0.001). MAP and CVP remained comparable at all time points. Notably, PI showed a significant increase in the conventional group during positioning (after octopus stabilization), at 3 minutes post-initiation of grafting, and at the completion of grafting. There were no significant differences in lactate levels between the groups.

Conclusion: Despite no significant differences in MAP, CVP, and lactate levels, our findings highlight significant disparities in HR and PI between the two groups. We conclude that the observed variations in heart rate may be attributed to minimal positional changes in the minimally invasive approach compared to the conventional approach.

1. Introduction

Hemodynamic instability and cardiac arrhythmias during grafting in off-pump Coronary Artery Bypass Grafting (CABG) have been identified as significant contributors to perioperative morbidity and mortality.[1,2] To address these challenges, various interventions and medications have been proposed.[3] Recognizing the substantial impact of intraoperative hemodynamic variations on perioperative outcomes, our study aimed to investigate the influence of different surgical approaches on these changes.

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The history of coronary surgery without extracorporeal circulation dates back over 40 years. However, it wasn't until the late 1990s, marked by significant technological advancements, that it evolved into a standardized and reproducible technique. The terminological nuances associated with minimally invasive techniques have led to confusion, even within off-pump coronary surgery involving median sternotomy, where notable technical variations exist.[4]

In recent years, there has been a growing interest in conducting CABG surgery without relying on cardiopulmonary bypass (CPB). Initial efforts focused on "minimally invasive" direct coronary artery bypass, involving a small left anterior thoracotomy for bypassing the left anterior descending artery with an in situ left internal mammary artery graft. An increasingly adopted alternative is off-pump CABG (OPCAB), performed through the conventional median sternotomy approach, eliminating the need for CPB assistance.[5]

Similarly, a study conducted by Detter C et al. emphasized the feasibility and safety of coronary bypass surgery without CPB, yielding favorable early results. However, they highlighted that minimally invasive direct coronary artery bypass (MIDCAB) grafting is a challenging technique suitable only for selected patients with favorable coronary anatomy. In contrast, the sternotomy approach, as employed in OPCAB, demonstrated well-tolerated exposure of all vessels, facilitating complete revascularization even in high-risk patients.[6]

Our research specifically compared the conventional CABG approach during Left Anterior Descending (LAD) artery grafting with the increasingly popular minimally invasive CABG approach. Our hypothesis suggested that minimally invasive coronary artery bypass grafting induces fewer hemodynamic alterations, primarily attributed to reduced heart rotation during grafting.

2. Objectives

1. Evaluate and compare hemodynamic alterations during grafting between minimally invasive coronary artery bypass grafting (MICA) and conventional off-pump coronary artery bypass grafting (CABG) approaches.
2. Assess and compare key hemodynamic parameters, including heart rate, mean arterial pressure, and central venous pressure, at different stages of the surgical procedure between the MICA and conventional CABG groups.
3. Examine tissue perfusion by analyzing serum lactate levels and perfusion index (PI) as secondary indicators of hemodynamic performance in both surgical approaches.
4. Provide insights into the potential benefits of minimally invasive CABG in minimizing intraoperative hemodynamic fluctuations compared to conventional CABG.

3. Materials and Methods

This randomized controlled trial was conducted at a tertiary care center from December 2020 to March 2021 following institutional ethical committee approval and clinical trial registration. A total of 60 patients undergoing off-pump Coronary Artery Bypass Grafting (CABG) who met the inclusion criteria were enrolled after obtaining written informed consent.

Inclusion criteria comprised patients with an ejection fraction of >35% and those undergoing grafting to the left anterior descending artery. Exclusion criteria included patients with unstable angina, left main disease, poor left ventricular function (EF < 35%), those requiring preoperative inotropes or intra-aortic balloon pump support, uncontrolled hypertension/diabetes, obesity, emergency CABG, and those refusing to participate.

Patients were randomized into two groups, Group C (conventional off-pump CABG) and Group M (Minimally invasive off-pump CABG) using a chit method after consultation with the surgeon regarding the suitability of the minimally invasive approach.

Anesthesia induction followed a standardized institutional protocol. Standard monitors including pulse oximetry, 5-lead electrocardiogram, and non-invasive blood pressure monitor were applied. Peripheral venous and radial artery cannulations were performed under local anesthesia. General anesthesia induction included midazolam, fentanyl, etomidate, and vecuronium bromide. Tracheal intubation was conducted with an appropriate size endotracheal tube. In the minimally invasive group, lung isolation was achieved using a double-lumen tube.

Central venous cannulation via the right internal jugular vein was performed, and monitoring included nasopharyngeal temperature, urine output, and capnography. Patients were positioned with a 20-30° right lateral tilt for the thoracotomy approach. One-lung ventilation was initiated during internal mammary artery harvesting and left anterior descending artery grafting. The surgical procedure was performed by the same surgeon for standardization.

Hemodynamic parameters, including mean arterial pressure, central venous pressure, heart rate, and perfusion index, were measured at baseline (BL), after octopus stabilization before grafting (0), at 3 minutes during grafting,[1] and at the end of grafting.[2]

The primary outcome was to compare intraoperative hemodynamics, measured by heart rate, mean arterial pressure, and central venous pressure between the two groups. The secondary outcome was to compare tissue perfusion, assessed by serum lactate and perfusion index (PI).

Statistical analysis was conducted using SPSS 17.0 software. The sample size was determined by power analysis, requiring 18 patients per group to detect a 20% change in hemodynamic parameters with 80% power at a 5% significance level. Results were expressed as mean ± standard deviation, and statistical significance was set at $p < 0.05$. Independent t-test and chi-square test were used for continuous and categorical data, respectively, and nonparametric tests were applied when appropriate.

4. Results

4.1. Demographics and surgical characteristics

Demographic characteristics, including mean age and gender distribution, were comparable between the two groups. The minimal group had a mean age of 64.57 ± 5.44 years, while the conventional group had a mean age of 66.10 ± 8.032 years. No statistically significant differences were observed in age or gender distribution (Table 1). The average duration of anastomosis was significantly different between the groups, with the conventional group having a shorter duration of 7.30 ± 1.343 minutes compared to 10.67 ± 2.412 minutes in the minimal group ($p < 0.001$).

4.2. Hemodynamic parameters

The mean baseline heart rate was similar in both groups. However, the trends in heart rate demonstrated a statistically significant increase in the conventional group after octopus stabilization ($p = 0.0038$), at three minutes after initiating grafting ($p = 0.000$), and at the completion of grafting ($p = 0.001$) (Table 2). Mean arterial pressure (MAP) and central venous pressure (CVP) were comparable between the two groups at baseline, after positioning, at three minutes, and at the end of grafting (Table 3 A, B).

4.3. Perfusion index

The perfusion index at baseline was comparable between the two groups. However, the minimally invasive group showed a significant increase in perfusion index at positioning ($p < 0.001$), after octopus stabilization, at three minutes after initiating grafting ($p = 0.003$), and at the completion of grafting ($p < 0.001$) (Table 4).

4.4. Serum lactate levels

There were no significant differences in lactate levels between the groups before and after grafting, indicating comparable metabolic outcomes (Table 4).

Summary of the results suggests that while both groups exhibited similar baseline characteristics and perioperative hemodynamics, the conventional group demonstrated a notable increase in heart rate during critical phases of the procedure. Interestingly, the minimally invasive group displayed a significant improvement in perfusion index at various points during the surgery, suggesting potential advantages in tissue perfusion. The duration of anastomosis was notably shorter in the conventional group, warranting further exploration of the surgical efficiency associated with each approach.

5. Discussion

Optimal target-vessel exposure and maintenance of haemodynamics is essential for success of off pump CABG.[7] This study was conducted to compare the effects of haemodynamic changes between two different approaches during LAD artery grafting in off- pump CABG. The haemodynamics during LAD artery grafting in the minimal invasive approach was deep pericardial traction sutures (Figure 1) whereas the conventional approach was studied using a laprotomy pad (Figure 2). There is no comprehensive published data comparing the haemodynamics between the two approaches commonly used during off-pump CABG. LAD artery positioning during off-pump CABG impairs haemodynamic stability, leading to a decrease in stroke volume and increase in central venous pressure, right ventricular end-diastolic pressure, left atrial pressure and left ventricular end diastolic pressure. An increase in left atrial pressure and left end-diastolic pressure may indicate impaired left ventricular performance. Minimal to moderate compression of the left ventricle has also been observed in transoesophageal echocardiography.[8] This compression of the left ventricle differed between conventional sternotomy and thoracotomy as evidenced by the rotational changes of the ventricles used for grafting. These rotational changes and alternations in filling pressure can lead to haemodynamic changes.[9] In our study the main hemodynamic changes occurred only with regards to the heart rate which was higher in conventional group. The central venous pressure and mean arterial pressure were comparable between the two groups at all times of measurement. Although the right ventricular deformation is more in conventional group than minimal group as evidenced by minimal rise in CVP it was not statistically significant. The right ventricle is usually squeezed between the right pericardium and the bulky left ventricular muscle mass in conventional approach thereby creating a low cardiac output situation which seldom occurs in minimally invasive approach. The result of the present study emphasizes the importance of right ventricular compression in hemodynamics during LAD artery anastomosis. Mitral valve distortion occurs during obtuse marginal grafting in conventional sternotomy.[9] Mitral valve distortion is usually very minimal during left anterior descending artery grafting. Whether mitral distortion can differ between conventional and minimally invasive left anterior descending artery grafting has to be assessed by transesophageal echocardiogram or pulmonary artery occlusion pressure. In our study, we did not monitor

Table 1: Demographic parameters and duration of grafting

Variable	Group M Minimal CABG	Group C Conventional CABG	P value
Age (Years)	64.57 ± 5.44	66.10 ± 8.032	0.390
Gender (Numbers)	Male- 22 Female -8	Male- 24 Female- 6	0.542
Duration of grafting (Minutes)	10.67 ± 2.412	7.30 ± 1.343	<0.001*

Values are expressed in Mean ± standard deviation except in row 2 where it is expressed in number of patients. * Statistically significant.
M- Minimal C- Conventional CABG- Coronary artery bypass grafting

Table 2: Comparison of heart rate between minimal CABG and conventional CABG

Time period	Group M Minimal CABG (Beats per minute)	Group C Conventional CABG (Beats per minute)	P value
Baseline	77.63 ± 10.975	73.67 ± 11.52	0.177
Before grafting	76.33 ± 11.208	82.23 ± 10.318	0.038*
At 3min	77.03 ± 10.467	86.90 ± 8.487	<0.001*
Post grafting	78.30 ± 9.760	86.47± 7.886	0.001*

Table 3: Comparison of mean arterial pressure (MAP) and central venous pressure (CVP) between minimal CABG and conventional CABG

	(A) MAP			(B) CVP		
Time period	Group M (mm of Hg)	Group C (mm of Hg)	P value	Group M (mm of Hg)	Group C (mm of Hg)	P value
Baselin e	81.37 ± 8.459	82.60 ±6.678	0.533	5.80 ± 1.472	5.90 ± 1.948	0.17
Before graftin g	80.83 ± 6.879	79.87 ± 5.877	0.561	6.13 ± 1.106	6.77 ± 1.591	0.076
At 3min	79.30 ± 7.149	79.13 ± 8.529	0.935	6.50 ± 1.358	7.43 ± 2.128	0.056
Post graftin g	80.30 ± 6.556	79.70 ± 7.062	0.734	6.20 ± 0.847	6.70 ± 1.368	0.233

Table 4: Comparison of perfusion index and serum lactate between minimal CABG and conventional CABG

Variable	Group M Minimal CABG	Group C Conventional CABG	P value
Perfusion index baseline	4.600 ± 2.1270	4.893 ± 0.7334	0.182
Perfusion index before grafting	3.167± 1.1167	1.567±0.570	<0.001*
Perfusion index (At 3min)	2.200± 1.5179	0.5486	0.003*
Perfusion index (Post grafting)	3.900± 1.5391	1.540±.4789	<0.001*
Lactate in mmol/L (Pre-grafting)	0.840± 0.3856	0.892 ±0.4915	0.140
Lactate in mmol/L (Post-grafting)	1.010± .3448	1.241 ± .5766	0.065

the pulmonary artery pressure but the transesophageal echocardiogram did not show much difference between the two group with regard to mitral valve distortion as measured by grading of mitral regurgitation.

Haemodynamic instability during off pump coronary artery bypass grafting is mainly due to impaired right ventricle diastolic expansion, left ventricular outflow tract compression and impaired myocardial contractility. Diastolic expansion and left ventricular end diastolic volume may be altered in conventional off-pump coronary artery bypass grafting by the anteroposterior compression of noncompliant laparotomy pads. The only hemodynamic change that we observed was the increase in heart rate in the conventional approach group. Impairment of left ventricular performance can also affect right ventricular function.[10]

The observation of a relatively stable hemodynamics in the minimally invasive group may indicate a normal left ventricular performance compared to the conventional group. In the minimally invasive group, the relatively compliant pericardium helps in the normal geometry of the left ventricle. In our study, this was evidenced by a higher perfusion index in the minimally invasive group than the conventional group.

Vessel wall biomechanical factors, intimal hyperplasia and thrombus formation have correlations with haemodynamic changes. Newer devices with various anastomotic geometries have been designed to regulate the blood flow in order to enhance the patency of coronary artery bypass grafting.[11] The longevity and patency of the coronary artery graft can eliminate the need for re-operation and can significantly improve the outcome. The

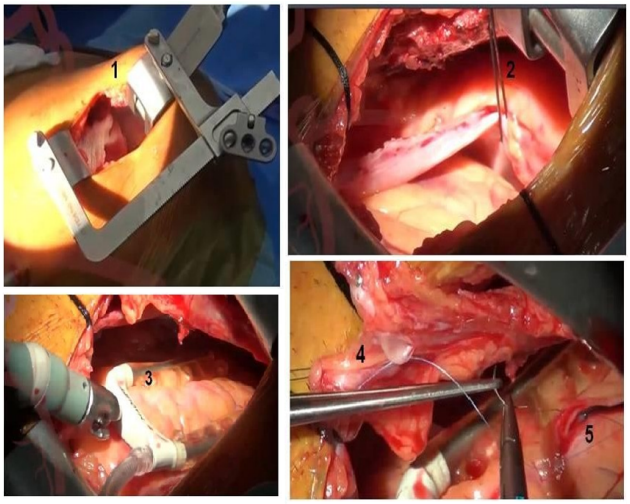

Figure 1: Off pump coronary artery bypass grafting through left thoracotomy (Minimally invasive approach); 1. Left mini thoracotomy. 2. Placement of pericardial stay sutures. 3. Octopus positioning for left anterior descending artery grafting. 4. Left internal mammary artery. 5. Left anterior descending artery with shunt insitu.

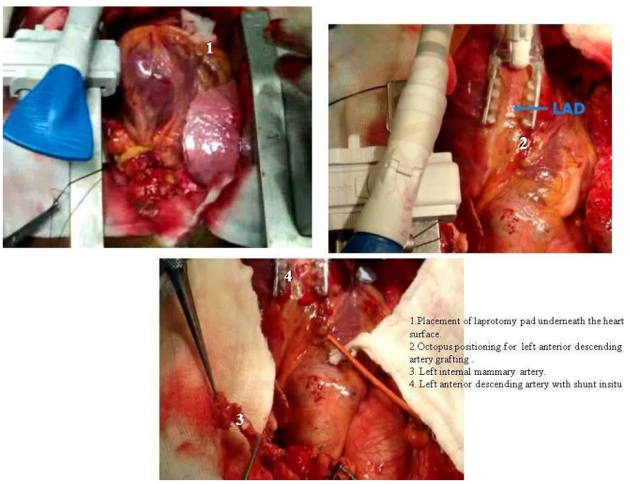

Figure 2: Off pump coronary artery bypass grafting through sternotomy (Conventional approach) 1. Placement of laprotomy pad underneath the heart surface. 2. Octopus positioning for left anterior descending artery grafting. 3. Left internal mammary artery. 4. Left anterior descending artery with shunt insitu

anastomotic angle is very important towards attaining an optimal anastomosis.[12] Alterations in the needle angle during surgery in both the groups and its impact on hemodynamic variables yet to be studied. The increased duration of anastomosis in the minimally invasive group did not alter the outcome as evidenced by perfusion index and lactate level. Minimally invasive coronary artery bypass grafting can be a valuable alternative for patients in need of multivessel coronary artery bypass grafting.[13] Minimally invasive approach was associated with shorter length of hospital stay, less wound infections and faster post-operative recovery than the conventional approach.[14] Duration of surgery, intra-operative inotropes used, duration of ventilation, duration of inotrope use, intraoperative blood loss, postoperative blood loss, analgesic requirement, visual analogue score, time to mobilise, intensive care unit and length of hospital stay (days) are the various parameters compared between conventional and minimal invasive groups.[3] However, this was the first study to compare the haemodynamics during grafting between the two groups on various surgical approaches. Perfusion index and lactate levels were compared between the two groups as surrogate markers for haemodynamic stability. Although the lactate level was not altered the perfusion index was significantly reduced in the conventional group. The haemodynamic alteration of increased heart rate and mild increase in central venous pressure could have contributed to this response.

Coming to the limitations, first the severity of haemodynamic disturbance is related to the site of the anastomosis. Changes are more pronounced during circumflex artery grafting compared with left anterior descending artery grafting[15,16] and these results may not, therefore, be applicable to circumflex artery grafting. Second, the patients might not have been distributed evenly.

Although the patients were randomly allocated to the two groups and the left ventricular ejection fraction was comparable in both groups, the graft timing was higher in the minimally invasive group. Third, the perfusion index is measured only till the end of grafting and not after repositioning the heart back to anatomical position, this might change post grafting and repositioning which was not studied in our current study.

The comparison of haemodynamic changes between different approaches during left anterior descending (LAD) artery grafting in off-pump coronary artery bypass grafting (CABG) illuminates several important considerations regarding surgical technique, hemodynamic stability, and patient outcomes.

1. Haemodynamic stability and surgical approach: Our study emphasizes the critical role of optimal target-vessel exposure and maintenance of haemodynamics during off-pump CABG, particularly during LAD artery grafting. The differences observed in haemodynamic responses between the minimal invasive approach, utilizing deep pericardial traction sutures, and the conventional approach, employing laparotomy pads, highlight the potential impact of surgical technique on patient physiology.[17] While mean arterial pressure (MAP) and central venous pressure (CVP) remained relatively stable across both groups, heart rate (HR) exhibited a significant increase in the conventional group. This disparity suggests that the minimally invasive approach

may offer advantages in preserving haemodynamic stability during LAD artery grafting compared to the conventional approach.[18]

2. Implications of ventricular compression: Our findings underscore the importance of considering ventricular compression and its effects on haemodynamics during off-pump CABG. Although right ventricular deformation appeared more pronounced in the conventional group, as evidenced by a minimal rise in CVP, this difference was not statistically significant. Nonetheless, the observation of a relatively stable hemodynamic profile in the minimally invasive group suggests a potential advantage in mitigating right ventricular compression and its associated hemodynamic consequences. Future studies should further explore the mechanisms underlying these observations and their implications for surgical practice.
3. Left ventricular performance and mitral valve distortion: While our study primarily focused on haemodynamic parameters, the impact of surgical approach on left ventricular performance and mitral valve distortion warrants further investigation. Left ventricular outflow tract compression and alterations in left ventricular diastolic expansion may influence both left ventricular and right ventricular function. Future studies utilizing advanced imaging modalities, such as transesophageal echocardiography, can provide valuable insights into the differential effects of surgical approaches on mitral valve function and overall cardiac performance.[19]
4. Optimal anastomotic geometry and graft patency: The discussion of haemodynamics during off-pump CABG extends beyond immediate perioperative concerns to considerations of long-term graft patency and clinical outcomes. Vessel wall biomechanical factors and anastomotic geometries play crucial roles in regulating blood flow and enhancing the longevity of coronary artery grafts.[20] Future research should explore the impact of needle angle alterations during surgery on haemodynamic variables, with a focus on optimizing anastomotic geometry to improve graft patency and clinical outcomes.
5. Clinical implications and patient-centered outcomes: The findings of our study have important clinical implications for patient care and surgical decision-making. The observed differences in haemodynamic responses between surgical approaches may translate into meaningful differences in patient outcomes, including length of hospital stay, wound infections, and post-operative recovery. The minimally invasive approach, with its potential advantages in preserving haemodynamic stability, may offer a safer alternative for patients undergoing LAD artery grafting in off-pump CABG. However, further research is needed to validate these findings and explore their impact on a broader range of patient-centred outcomes.

6. Limitations and Future Directions

While our study provides valuable insights into haemodynamic changes during off-pump CABG, several limitations should be acknowledged. Firstly, the severity of haemodynamic disturbances may vary depending on the site of the anastomosis, warranting further investigation into different coronary artery territories. Secondly, the distribution of patients between the two groups may not have been entirely even, potentially introducing bias. Lastly, future studies should consider extending the assessment of haemodynamic parameters beyond the completion of grafting to evaluate post-repositioning changes.

7. Conclusion

In conclusion, our study highlights the significance of haemodynamic stability during LAD artery grafting in off-pump CABG and suggests that the minimally invasive approach may offer advantages in preserving haemodynamic parameters compared to the conventional approach. The minimally invasive technique seems to be an equally safer method similar to conventional approach during anastomosis of the left anterior descending artery. While further research is needed to validate these findings and explore their clinical implications, our study contributes to advancing our understanding of optimal surgical techniques and their impact on patient outcomes in off-pump CABG.

8. Source of Funding

None.

9. Conflict of Interest

None.

References

1. Vassiliades TA, Nielsen JL, Lonquist JL. Hemodynamic collapse during off-pump coronary artery bypass grafting. *Ann Thorac Surg*. 2002;73(6):1874–9.
2. Naughton C, Feneck RO, Roxburgh J. Early and late predictors of mortality following on- pump coronary artery bypass graft surgery in the elderly as compared to a younger population. *Eur J Cardiothorac Surg*. 2009;36(4):621–7.
3. Baishya J, George A, Krishnamoorthy J, Muniraju G, Chakravarthy M. Minimally invasive compared to conventional approach for coronary artery bypass grafting improves outcomes. *Ann Card Anaesth*. 2017;20(1):57–60.
4. Cuenca J, Bonome C. Cirugía coronaria sin circulación extracorpórea y otras técnicas mínimamente invasivas [Off-pump coronary artery bypass grafting and other minimally invasive techniques. *Rev Esp Cardiol*. 2005;58(11):1335–48.
5. Shanewise JS, Ramsay JG. Off-pump coronary surgery: how do the anesthetic considerations differ? *Anesthesiol Clin North Am*.

2003;21(3):613–23.
6. Detter C, Reichenspurner H, Boehm DH, Thalhammer M, Raptis P, Schütz A, et al. Minimally invasive direct coronary artery bypass grafting (MIDCAB) and off-pump coronary artery bypass grafting (OPCAB): two techniques for beating heart surgery. *Heart Surg Forum*. 2002;5(2):157–62.
7. Kim DH, Park SY, Cho HB, Park SK, Kang M, Hong YS. Haemodynamic Changes during Left Anterior Descending Artery Exposure in Off-pump Coronary Artery Bypass: Comparison between Use of Moist Laparotomy Pads and Deep Pericardial Traction Sutures for Heart Displacement. *J Int Med Res*. 2011;39(4):1211–8.
8. Mathison M, Edgerton JR, Horswell JL. Analysis of hemodynamic changes during beating heart surgical procedures. *Ann Thorac Surg*. 2000;70(4):1355–60.
9. George SJ, Al-Ruzzeh S, Amrani M. Mitral Annulus Distortion During Beating Heart Surgery: A Potential Cause for Hemodynamic Disturbance-A Three-Dimensional Echocardiography Reconstruction Study. *Ann Thorac Surg*. 2002;73(5):1424–30.
10. Nierich AP, Diephuis J, Jansen EW, Borst C, Knape JT. Heart displacement during off-pump CABG:how well is it tolerated? *Ann Thorac Surg*. 2000;70(2):466–72.
11. Ghista DN, Kabinejadian F. Coronary artery bypass grafting haemodynamic and anastomosis design: A biomedical engineering review. *Biomed Eng Online*. 2013;12:129.
12. Ruel M, Shariff MA, Lapierre H, Goyal N, Dennie C, Sadel SM, et al. Results of the minimally invasive coronary artery bypass grafting angiographic patency study. *J Thorac Cardiovasc Surg*. 2014;147(1):203–8.
13. Doenst T, Diab M, Sponholz C, Bauer M, Färber G. The opportunities and limitations of minimally invasive cardiac surgery. *Dtsch Arztebl Int*. 2017;114(46):777–84.
14. Lapierre H, Chan V, Sohmer B, Mesana TG, Ruel M. Minimally invasive coronary artery bypass grafting via a small thoracotomy versus offpump:A case matched study. *Eur J Cardiothorac Surg*. 2011;40(4):804–10.
15. Matata BM, Sosnowski AW, Galiñanes M. Offpump bypass graft operation significantly reduces oxidative stress and inflammation. *Ann Thorac Surg*. 2000;69(3):785–91.
16. Mueller XM, Chassot PG, Zhou J, Eisa KM, Chappuis C, Tevaearai HT, et al. Hemodynamics optimization during off-pump coronary artery bypass: the 'no compression' technique. *Eur J Cardiothorac Surg*. 2002;22(2):249–54.
17. Smith AB, Nair R, Ayoub M, Saha A, Izzat MB. Haemodynamic disturbances during coronary artery bypass surgery: a comparison between off-pump and on-pump techniques. *Eur J Cardiothorac Surg*. 2007;32(1):83–90.
18. Jones WK, Kirklin JW, Naftel DC, Kirklin JK, Bourge RC, Dyke DB. Comparison of heart rate, central venous pressure, and pulmonary artery wedge pressure as monitors of left ventricular function. *Circulation*. 1985;71(5):940–7.
19. Markar SR, Kutty R, Edmonds L, Sadat U, Nair S. A meta-analysis of minimally invasive versus traditional open vein harvest technique for coronary artery bypass graft surgery. *Interact Cardiovasc Thorac Surg*. 2011;10(2):262–70.
20. Magee MJ, Alexander JH, Hafley G, Ferguson TB, Gibson CM, Harrington RA, et al. Coronary artery bypass graft failure after on-pump and off-pump coronary artery bypass: findings from PREVENT IV. *Ann Thorac Surg*. 2008;85(2):494–9.

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