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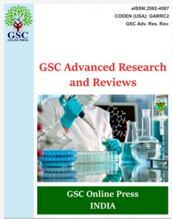

(Review Article)

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On-pump beating-heart coronary artery bypass grafting: Single Center Experience and Literature Review

Konstantinos Triantafillou *

Department of Cardiac Surgery, Hippokration General Hospital, Athens, Greece.

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Abstract

Purpose: In this retrospective, observational, non-randomized study, we present the results of our department in on-pump beating-heart coronary artery bypass grafting and we review the relevant medical literature.

Methods: All data related to patients who underwent on-pump beating-heart coronary artery bypass grafting at our center for three consecutive years were collected. These patients were classified into two groups: isolated bypass grafts or combined with aortic valve replacement. All data related to preoperative characteristics, procedural characteristics, and clinical outcomes are presented separately for the two groups.

Results: During the study period, 175 patients underwent on-pump beating-heart bypass grafting alone and 32 combined with aortic valve replacement. Despite higher than average Euroscore in both groups, mortality, and morbidity were satisfactory while the rate of complete revascularization was higher than previously reported for classic off-pump surgery.

Conclusion: On-pump beating heart coronary artery bypass grafting offers an excellent alternative in the surgical treatment of coronary artery disease. Patient selection is very important, and in the hands of skilled surgeons, it may prevent intraoperative complications and offer the appropriate revascularization, especially for high-risk patients.

Keywords: Coronary Artery Disease; Bypass Surgery; On-pump beating heart; Aortic Valve Replacement

1. Introduction

Coronary Artery Disease (CAD) is one of the leading causes of death worldwide [1,2]. Despite significant advances in both medical and interventional treatment, Coronary Artery Bypass Graft (CABG) remains the gold standard treatment for patients with severe CAD [3]. CABG has been improved over time to produce outstanding short- and long-term results for the treatment of multi-vessel CAD [1,2]. However, cardiopulmonary bypass (CPB) and cardioplegic arrest may be the cause of cardiac and systemic complications [3-6]. On the other hand, off-pump CABG has raised concerns about the completeness of revascularization and the long-term outcomes [7]. In addition, transitory haemodynamic instability caused by surgical manipulations may necessitate an urgent conversion to an on-pump conventional CABG, significantly complicating the procedure [1,2]. More than 20 years ago, Perrault et al. [8] proposed the "CPB-assisted strategy", which gradually became an alternative option in the management of high-risk patients. On-pump Beating-Heart CABG (OPBHC) is used in our center on a routine basis. In this paper, we report the results from the treatment of patients with OPBHC for three consecutive years. We also report the results of combined OPBHC and Aortic Valve Replacement (AVR) during the same period. To our knowledge, the latter technique has not been previously described. In the second part of the paper, we review the current literature on OPBHC.

* Corresponding author: Konstantinos Triantafillou

2. Methods

In this retrospective, observational, non-randomized study, we included all patients undergoing OPBHC at our center between 2018 and 2020. These operations were performed by two different surgical teams during the above-mentioned time frame. Patients underwent either OPBHC or combined OPBHC and AVR. We have recorded all data related to these patients and classified them into three groups:

- Preoperative characteristics of the patients (demographics and medical history)
- Procedural characteristics (operative times, completeness of revascularization, number of grafts)
- Clinical outcomes (duration of ventilation, duration of intensive care unit, duration of in-hospital stay, acute renal failure, stroke, arrhythmias, wound infections, death, re-exploration).

2.1. Technique

After the median sternotomy is completed, the left internal mammary artery is prepared, and routine aortic and venous cannulation is performed. Additionally, when AVR is scheduled a left ventricular vent is placed via the right superior pulmonary vein. Subsequently, heparin is administered and CPB is established. During the period of CPB, the anesthetic team is focused on the maintenance of the beating state of the heart. Thus, electrolyte balance and adequate perfusion are closely monitored. The mean arterial blood pressure is maintained between 50–80 mm Hg at a flow rate of 2.2–3.4 L/m2/min, while the haematocrit is kept at 18–24% during mild hypothermia and >22% during normothermia. The perfusate temperature is being adjusted to maintain a temperature between 33–34 °C for OPBHC and 30-33°C for OPBHC+AVR. When AVR is required, aorta is cross-clamped after distal anastomoses are completed and cold blood cardioplegia is administered at 20-minute intervals. Finally, proximal anastomoses are performed with the heart in a beating state.

3. Results

The majority of patients were males between the ages of 60 and 70. Almost one-third of these patients underwent urgent or emergency surgery as a result of hemodynamic instability, recent Myocardial Infarction (MI), unstable angina, and severe Left Main Stem Disease (LMSD). The rest of the demographic characteristics and comorbidities of the population are displayed in Table 1. As expected the patients who underwent combined AVR and CABG had substantially longer operating times. None of the patients who underwent isolated CABG required aortic cross-clamping. The rate of complete revascularization in our patients was higher than previously reported results for off-pump surgery since the performed/intended grafts ratio in the two groups was 351/396 and 43/48 respectively (Table 2). Despite higher than average Euroscore in the two groups (2.1 and 3.9 respectively) recovery was generally satisfactory in most patients with only 4 deaths in total. The average length of ICU stay was 2-3 days while the total in-hospital stay was 5-7 days. Re-exploration for bleeding was required in 5.1 % of OPBHC and 12.5 % of OPBHC+AVR patients while only one patient experienced a stroke. Acute renal failure requiring dialysis was recorded in 9.3% of OPBHC+AVR while in the OPBHC group was only 2.8%. Finally, arrhythmias were the most frequent problems seen in both groups (36% and 43%, respectively) (Table 3). However, this was mainly driven by the high incidence of postoperative atrial fibrillation which is expected in the first days postoperatively.

Table 1 Patient characteristics

	OPBHC	OPBHC+AVR
Population	175	32
Male/Female	105/70	18/14
Age (in years)	62.8±0.88	69.42±0.69
BMI	27.8±0.63	27.6±0.24
Smokers	68 (38.8 %)	10 (31.2%)
Hypertension	102(58.2%)	12 (37.5%)
Diabetes Mellitus	46(26.2%)	8(25%)
Chronic Kidney Disease	20(11.4%)	2(6.2%)
COPD	32(18.2%)	6(18.7%)
Peripheral Vascular Disease	39(22.2%)	8(25%)
Mean Ejection Fraction	42%	55%
Recent MI	41(23.4%)	2(6.2%)
Unstable angina	23(13.1%)	-
Urgent	43(24.5%)	4(12.5%)
Emergency	7(4%)	-
Extent of CAD		
LMSD	23(13.1%)	2(6.2%)
SVD	17 (9.7%)	22(68.7%)
DVD	58 (33.1%)	5(15.6%)
TVD	77(44%)	3(9.3%)
EUROSCORE II	2.1 %	3.9%

AVR: Aortic Valve Replacement; BMI: Body Mass Index; COPD: Chronic Obstructive Pulmonary Disease; LMSD: Left Main Stem Disease; SVD: Single Vessel Disease; DVD: Double Vessel Disease; OPBHC: On-pump Beating-Heart Coronary Artery Bypass Graft; TVD: Triple Vessel Disease; MI: Myocardial Infarction;

Table 2 Procedural characteristics

	OPBHC	OPBHC+AVR
Total operating time (average in mins)	192	232
By-pass time (average in mins)	63	87
Cross clamp time (average in mins)	-	40
Total grafts (average)	2.3	1.3
Number of grafts		
Single graft	21	24
Two grafts	77	5
Three grafts	75	3
Four grafts	2	-
Performed/Intended grafts	351/396	43/48

Table 3 Clinical outcomes

	OPBHC	OPBHC+AVR
Duration of ventilation (in hours)	6.2	8.4
Duration of ICU stay (in days)	1.8	3.2
Duration of in-hospital stay (in days)	5.2	7.3
Re-exploration	9(5.1%)	4(12.5%)
Acute renal failure	5(2.8%)	3(9.3%)
Stroke	1(0.5%)	-
Arrhythmias	63(36%)	14(43%)
Wound infection	11(6.2%)	3(9.4%)

AVR: Aortic Valve Replacement; ICU: Intensive Cara Unit; OPBHC: On-pump Beating-Heart Coronary Artery Bypass Graft;

4. Discussion

In high-risk patients, the OPBHC procedure provides an efficient way to perform surgical revascularization [10-28]. Elective use of OPBHC might be the suitable approach when hemodynamic stability and adequate end-organ perfusion are the primary concerns. Cardiogenic shock, early graft failure requiring reoperation, redo CABG surgery, reduced LVEF, and technically challenging off-pump operations (such as those involving poor-quality coronary arteries) may all benefit from the OPBHC technique.

OPBHC has been proposed as a safe and effective procedure in high-risk patients who have recently experienced MI and need urgent surgical revascularization [9], even in cases of cardiogenic shock. It avoids cardioplegic arrest and aortic cross-clamping and provides adequate end-organ perfusion with reduced inotrope requirement. In high-risk patients, the OPBHC procedure provides an efficient way to perform surgical revascularization [10-14,16-18,20-22,24-30]. This evidence suggests that OPBHC may be the treatment of choice for patients who have experienced a cardiogenic shock after acute MI. Cardiogenic shock following acute MI occurs in 10% to 20% of patients and is the leading cause of in-hospital mortality [31-35]. Even though urgent CABGs performed after an acute MI carries a higher mortality risk than percutaneous procedures, it is unavoidable in cases of percutaneous intervention failure or complication, unfavorable coronary anatomy for percutaneous coronary intervention (PCI), or persistent myocardial ischemia that is resistant to medical or percutaneous therapy [13,28,31,32]. In these cases, cardioplegic arrest and ischemia–reperfusion syndrome, are poorly tolerated by the injured myocardium [13,32] leading to a deterioration of cardiac function and unfavorable clinical outcomes [13,32]. The findings of the GUSTO1 and SHOCK studies support urgent intervention [35]. The SHOCK trial analysis demonstrated that CABG had comparable results to PCI despite dealing with more complex CAD and higher-risk patients [31,35-37]. This can be explained by the higher rate of complete revascularization in surgical patients (87% in CABG vs 23% in PCI) or the different mechanism of revascularization between the two techniques. However, in most registries, less than 5% of patients were referred for surgery in this instance [31,38].

Off-pump CABG in patients with hemodynamic instability or recurrent arrhythmias may also require higher doses of inotropes or vasopressors further increasing the risk of end-organ damage. Additionally, acute refractory hypotension can be induced by heart compression and target artery occlusion. Emergent intraoperative conversion to on-pump CABG is unavoidable on these occasions with this incidence ranging from 5% to 7% [10]. Conversion leads to a mortality rate as high as 40% and an up to seven-fold greater risk of death [10]. OPBHC can eliminate the risks associated with an emergency establishment of CPB, notwithstanding its rarity (incidence ranges from 5% to 7%) [10]. Additionally, OPBHC with complete cardiopulmonary assistance lowers ventricular volume loading. This would make it possible to gently mobilize the heart while maintaining adequate coronary flow and myocardial protection [16,34]. Furthermore, this method might make it easier to graft the heart's inferior and lateral walls, which would explain why OPBHC had higher rates of complete revascularization than off-pump CABG and shorter CPB times than on-pump CABG [30].

Aortic cannulation in patients with extensive aortic calcifications is considered to be a risk factor for embolization. However, aortic cross-clamping appears to be the major determinant of this complication [4,39]. Therefore, the absence of aortic cross-clamping may directly reduce the stroke risk for OPBHC technique compared to standard on-pump CABG. However, off-pump CABG remains the treatment of choice in patients with a history of stroke or with porcelain aorta since it is related to better neurological outcomes than on-pump CABG [4,40]. The incidence of postoperative stroke is comparable between OPBHC and off-pump CABG, indicating that the sole effect of aortic cannulation may be negligible. On the other hand, the dynamics of aortic side-clamping for proximal anastomosis, differ remarkably between the two techniques. OPBHC promotes a "softer" aortic lateral clamping, whereas, in standard off-pump CABG, the same maneuver may result in a more traumatic side clamping. Finally, the "no touch" approach [41,42] prevents the need for aortic side-clamping and in theory, is the ideal technique in patients with markedly calcified ascending aorta [42]. Consequently, there are plenty of options in the treatment of patients at high risk for stroke and OPBHC may be one of them.

It's still under discussion the treatment of choice in patients with poor LV function. For these patients, the traditional on-pump CABG has been shown to have increased mortality and morbidity [3]. On the other hand, during off-pump surgery, patients with poor LV function are at great risk for intraoperative hemodynamic deterioration and incomplete revascularization [18]. Traditional on-pump CABG is also related to more frequent use of postoperative intra-aortic balloon pump (IABP) and higher post-operative inotropic support [28] in these patients. The shorter duration of CPB, the improved hemodynamics and myocardial perfusion, and the decreased myocardial stunning could all be contributing factors to the reduced postoperative IABP use in OPBHC patients, which could clinically translate into a decreased incidence of perioperative MI following OPBHC.

The idea of adopting OPBHC in elective patients opens another interesting debate and it is supported by some studies [7,15,19,23]. It is a reasonable strategy to prevent hemodynamic deterioration and ensure appropriate end-organ supply [13,16,17,27-29]. However, this concept should be further examined in future clinical trials. As demonstrated in the present study, in our center, OPBHC is routinely used for isolated CABGs or combined with AVR. From our experience, OPBHC in elective patients is a safe technique with exceptional results.

Limitations

This study has certain limitations. It is a retrospective observational study from a single center. There is no control group and the clinical outcomes are limited to the time the patients were in the hospital. Finally, the OPBHC+AVR group is small, thus larger studies will be needed to draw firm conclusions.

5. Conclusion

OPBHC enables the maintenance of coronary flow while lowering cardiac preload and after-load, hence lowering myocardial oxygen demand and ensuring a steady supply of oxygen. This offers intraoperative hemodynamic stability without the need for cardioplegic cardiac arrest or aortic cross-clamp. Patient selection is very important, and in the hands of skilled surgeons, OPBHC may prevent intraoperative complications and offers the appropriate revascularization even for high-risk patients.

Compliance with ethical standards

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Statement and Declarations

- The authors have no relevant financial or non-financial interests to disclose.
- All authors contributed to the study’s conception and design.
- All authors read and approved the final manuscript

References

[1] Neumann FJ, Sousa-Uva M, Ahlsson A, et al. Group ESCSD. 2018 ESC/EACTS guidelines on myocardial revascularization. Eur Heart J. 2019;40:87-165.

[2] Knuuti J, Wijns W, Saraste A, et al. Group ESCSD. 2019 ESC Guidelines for the diagnosis and management of chronic coronary syndromes. Eur Heart J. 2020;41(3):407-477

[3] Gaudino M, Angelini GD, Antoniades C, et al. Off-pump coronary artery bypass grafting: 30 years of debate. J Am Heart Assoc. 2018;7:e009934.

[4] Gaudino M, Angiolillo DJ, Di Franco A, et al. Stroke after coronary artery bypass grafting and percutaneous coronary intervention: incidence, pathogenesis, and outcomes. J Am Heart Assoc. 2019;8:e013032.

[5] Gaudino M, Rahouma M, Di Mauro M, et al. Early versus delayed stroke after cardiac surgery: a systematic review and meta-analysis. J Am Heart Assoc. 2019;8:e012447.

[6] Lorusso R, Moscarelli M, Di Franco A, et al. Association between coronary artery bypass surgical techniques and postoperative stroke. J Am Heart Assoc. 2019;8:e013650.

[7] Kim HJ, Oh YN, Ju MH, et al. On-pump beating heart versus conventional coronary artery bypass grafting: comparative study on early and long-term clinical outcomes. J Thorac Dis. 2018;10:2656-2665.

[8] Perrault LP, Menasche P, Peynet J, et al. On-pump, beating-heart coronary artery operations in high-risk patients: an acceptable trade-off? Ann Thorac Surg. 1997;64:1368-1373.

[9] Edgerton JR, Herbert MA, Jones KK, et al. On-pump beating heart surgery offers an alternative for unstable patients undergoing coronary artery bypass grafting. Heart Surg Forum. 2004;7:8-15.

[10] Wang W, Wang Y, Piao H, et al. Early and medium outcomes of on-pump beating-heart versus off-pump CABG in patients with moderate left ventricular dysfunction. Braz J Cardiovasc Surg. 2019;34:62-69.

[11] Rao YM, Potdar S, Das D, et al. On-pump beating heart versus off-pump myocardial revascularization-a propensity-matched comparison. Indian J Thorac Cardiovasc Surg. 2021;37(6):639-646. doi:10.1007/s12055-021-01209-x

[12] Sepehripour, A. H., Chaudhry, U. A., Harling, L., & Athanasiou, T. (2015). Off-pump or on-pump beating heart: which technique offers better outcomes following coronary revascularization?. Interactive cardiovascular and thoracic surgery, 20(4), 546–549. https://doi.org/10.1093/icvts/ivu451

[13] Zhu MZL, Huq MM, Billah BM, et al. On-pump beating heart versus conventional coronary artery bypass grafting early after myocardial infarction: a propensity-score matched analysis from the ANZSCTS database. Heart Lung Circ. 2019;28:1267-1276.

[14] Masuda M, Okumura M, Doki Y, et al. Thoracic and cardiovascular surgery in Japan during 2014: annual report by The Japanese Association for Thoracic Surgery. Gen Thorac Cardiovasc Surg. 2016;64:665-697.

[15] Mizutani S, Matsuura A, Miyahara K, et al. On-pump beating-heart coronary artery bypass: a propensity matched analysis. Ann Thorac Surg. 2007;83:1368-1373.

[16] Miyahara K, Matsuura A, Takemura H, et al. On-pump beating-heart coronary artery bypass grafting after acute myocardial infarction has lower mortality and morbidity. J Thorac Cardiovasc Surg. 2008;135:521-526.

[17] Izumi Y, Magishi K, Ishikawa N, Kimura F. On-pump beating-heart coronary artery bypass grafting for acute myocardial infarction. Ann Thorac Surg. 2006;81:573-576.

[18] Xia L, Ji Q, Song K, et al. Early clinical outcomes of on-pump beating-heart versus off-pump technique for surgical revascularization in patients with severe left ventricular dysfunction: the experience of a single center. J Cardiothorac Surg. 2017;12:11.

[19] Antunes PE, Ferrao de Oliveira J, Prieto D, et al. Coronary artery bypass surgery without cardioplegia: hospital results in 8515 patientsdagger. Eur J Cardiothorac Surg. 2016;49:918-925.

[20] Erkut B, Dag O, Kaygin MA, et al. On-pump beating-heart versus conventional coronary artery bypass grafting for revascularization in patients with severe left ventricular dysfunction: early outcomes. Can J Surg. 2013;56:398-404.

[21] Tsai YT, Lin FY, Lai CH, Lin YC, Lin CY, Tsai CS. On-pump beating-heart coronary artery bypass provides efficacious short- and long-term outcomes in hemodialysis patients. Nephrol Dial Transplant. 2012;27:2059-2065.

[22] Munos E, Calderon J, Pillois X, et al. Beating-heart coronary artery bypass surgery with the help of mini extracorporeal circulation for very high-risk patients. Perfusion. 2011;26:123-131.

[23] Narayan P, Rogers CA, Bayliss KM, et al. On-pump coronary surgery with and without cardioplegic arrest: comparison of inflammation, myocardial, cerebral and renal injury and early and late health outcome in a single-centre randomised controlled trial. Eur J Cardiothorac Surg. 2011;39:675-683.

[24] Darwazah AK, Bader V, Isleem I, Helwa K. Myocardial revascularization using on-pump beating heart among patients with left ventricular dysfunction. J Cardiothorac Surg. 2010;5:109.

[25] Prifti E, Bonacchi M, Giunti G, et al. Does on-pump/beating-heart coronary artery bypass grafting offer better outcome in end-stage coronary artery disease patients? J Card Surg. 2000;15:403-410.

[26] Pegg TJ, Selvanayagam JB, Francis JM, et al. A randomized trial of on-pump beating heart and conventional cardioplegic arrest in coronary artery bypass surgery patients with impaired left ventricular function using cardiac magnetic resonance imaging and biochemical markers. Circulation. 2008;118:2130-2138.

[27] Ferrari E, Stalder N, von Segesser LK. On-pump beating heart coronary surgery for high risk patients requiring emergency multiple coronary artery bypass grafting. J Cardiothorac Surg. 2008;3:38.

[28] Rastan AJ, Eckenstein JI, Hentschel B, et al. Emergency coronary artery bypass graft surgery for acute coronary syndrome: beating heart versus conventional cardioplegic cardiac arrest strategies. Circulation. 2006;114:I477-I485.

[29] Ueki C, Sakaguchi G, Akimoto T, Ohashi Y, Sato H. On-pump beating-heart technique is associated with lower morbidity and mortality following coronary artery bypass grafting: a meta-analysis. Eur J Cardiothorac Surg. 2016;50:813-821.

[30] Chaudhry UA, Harling L, Sepehripour AH, et al. Beating-heart versus conventional on-pump coronary artery bypass grafting: a meta-analysis of clinical outcomes. Ann Thorac Surg. 2015;100:2251-2260.

[31] Liakopoulos OJ, Schlachtenberger G, Wendt D, et al. Early clinical outcomes of surgical myocardial revascularization for acute coronary syndromes complicated by cardiogenic shock: a report from the North-Rhine-Westphalia Surgical Myocardial Infarction Registry. J Am Heart Assoc. 2019;8:e012049.

[32] Weiss ES, Chang DD, Joyce DL, Nwakanma LU, Yuh DD. Optimal timing of coronary artery bypass after acute myocardial infarction: a review of California discharge data. J Thorac Cardiovasc Surg. 2008;135:503-511.

[33] Mukherjee D, Ashrafian H, Kourliouros A, Ahmed K, Darzi A, Athanasiou T. Intra-operative conversion is a cause of masked mortality in off-pump coronary artery bypass: a meta-analysis. Eur J Cardiothorac Surg. 2012;41:291-299.

[34] Borowski A, Korb H. Myocardial infarction in coronary bypass surgery using on-pump, beating heart technique with pressure- and volume-controlled coronary perfusion. J Card Surg. 2002;17:272-278.

[35] Moscarelli M, Harling L, Attaran S, Ashrafian H, Casula RP, Athanasiou T. Surgical revascularisation of the acute coronary artery syndrome. Expert Rev Cardiovasc Ther. 2014;12:393-402.

[36] White HD, Assmann SF, Sanborn TA, et al. Comparison of percutaneous coronary intervention and coronary artery bypass grafting after acute myocardial infarction complicated by cardiogenic shock: results from the should we emergently revascularize occluded coronaries for cardiogenic shock (SHOCK) trial. Circulation. 2005;112:1992-2001.

[37] Mehta RH, Lopes RD, Ballotta A, et al. Percutaneous coronary intervention or coronary artery bypass surgery for cardiogenic shock and multivessel coronary artery disease? Am Heart J. 2010;159:141-147.

[38] Kolte D, Khera S, Aronow WS, et al. Trends in incidence, management, and outcomes of cardiogenic shock complicating ST-elevation myocardial infarction in the United States. J Am Heart Assoc. 2014;3:e000590.

[39] Andersen ND, Hart SA, Devendra GP, et al. Atheromatous disease of the aorta and perioperative stroke. J Thorac Cardiovasc Surg. 2018;155:508-516.

[40] Dominici C, Salsano A, Nenna A, et al. Neurological outcomes after on-pump vs off-pump CABG in patients with cerebrovascular disease. J Card Surg. 2019;34:941-947.

[41] Amabile A, Torregrossa G, Williams E, Puskas J. Mastering off-pump, total arterial coronary artery bypass grafting: a step-by-step approach [published online ahead of print January 17, 2020]. Multimed Man Cardiothorac Surg. 2020. https://doi.org/10.1510/mmcts.2020.003

[42] Prapas S, Calafiore AM, Katsavrias KP, et al. Anaortic coronary surgery using the Pi-circuit is associated with a low incidence of perioperative neurological complications. Eur J Cardiothorac Surg. 2018;54:884-888