Heart, Lung and Circulation (2019) **28,** 1141–1143
1443-9506/04/$36.00
https://doi.org/10.1016/j.hlc.2019.05.173

EDITORIAL

On and Off Pump: The Marriage of Opposites With Potential Long-Term Rewards

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Keywords CABG • Off pump • ONBEAT • Acute MI

There are at least three different methods of surgical coronary revascularisation—on-pump with an arrested heart, on-pump without arrest of the heart, and off-pump surgery. The on-pump beating (ONBEAT) coronary bypass surgery embodies an amalgamation of conventional on-pump coronary surgery (CABG) and off-pump technique (OPCAB). The principal benefits emerging from the ONBEAT technique are the avoidance of cardioplegic arrest and the haemodynamic stability ensured throughout the procedure, notably in unstable high-risk patients. In this Issue of *Heart, Lung and Circulation,* the study by Zhu et al. reports the Australian clinical experience with the on-pump beating heart coronary surgery for emergency multiple myocardial revascularisation — the ONBEAT methods led to both good short-term and good long-term survival, although no better than conventional CABG in this retrospective, propensity-matched database study [1].

The better short-term outcomes in this subgroup of sick patients undergoing on-pump beating coronary surgery have been described previously in several studies. In 2006, Izumi et al. [2], in 2008, Miyahara and colleagues [3], and, in 2009, Fattouch et al.[4], all compared the results of emergent CABG surgery in patients with acute ST-elevation myocardial infarction (MI). The difference in the mean peak Creative kinase-myocardial band (CK-MB) and troponin release was markedly higher in the traditional CABG patients; they also reported a lower incidence of low-cardiac output postoperatively and a lower incidence of postoperative bleeding requiring reoperation in the off-pump and on-pump beating-heart groups compared with the conventional CABG group. Two additional findings in these earlier studies were that, more patients needed intra-aortic balloon pump (IABP) support in the conventional CABG group following revascularisation [3], and fewer patients developed postoperative renal insufficiency in the ONBEAT group [2,3]. As such, these authors hypothesised that the on-pump beating heart approach eliminates or reduces intraoperative global myocardial ischaemia compared to the arrested heart.

However, these studies [2,3] were small, retrospective, and in both studies the ONBEAT group was compared with conventional CABG patients from an earlier period.

In this editorial, we would like to shed some light on the possible explanation for the findings in this current analysis.

The difference between these two techniques involves one major component: ''the use of cardioplegic arrest''. In spite of current perioperative myocardial protection techniques, over 50% of patients submitted to coronary artery bypass (CAB) may release cardiac enzymes [5], and mortality is related to the intensity of enzyme release [6].

Although, over the past decade there has been a sizeable improvement in cardiac surgery mortality, postoperative

DOI of original article: https://doi.org/10.1016/j.hlc.2018.06.1051
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myocardial dysfunction remains the most common serious complication of CABG, which is correlated with increased morbidity, short- and long-term mortality, and health-dollar consumption [7,8].

Cardioplegic arrest often leads to decreased ventricular function, and this manifests as a reduction in systemic oxygen delivery and peripheral organ ischaemia and hypoxia, which commonly results from ischaemic/reperfusion injury. The duration of cardiac dysfunctions may vary from temporary (up to 24 hours), in the case of myocardical stunning, to permanent, in cases of overwhelming ischaemia and myocardial infarction [9].

A recent meta-analysis by Zeng et al. examined 2,866 patients from 12 randomised controlled studies comparing cardioplegia techniques — cold blood versus cold crystalloid [10. The meta-analysis reported no differences in the overall incidences of spontaneous sinus rhythm, 30-day mortality, atrial fibrillation, or stroke. There is no consensus on the optimal dose of such solutions or on the addition of substrates [10–12].

The ONBEAT technique is reported to be an acceptable trade-off between conventional CABG and off-pump CABG [2].

The ONBEAT technique is theoretically elegant in its conception: it eliminates cardioplegic arrest. Patients undergoing OPCAB have less postoperative troponin release as a result of ischaemic preconditioning [4]. This protective technique may be very helpful in diminishing myocardial dysfunction in the setting of acute myocardial infarction.

Ischaemic preconditioning is an endogenous protective reaction against myocardial damage [13–15]. This was reported over 30 years ago by Murry et al., who have observed an up to 75% decrease in infarction size after 40-minute occlusion of the left circumflex artery in an animal model, when previous minor 5-minute occlusions of the same artery were performed [16]. This was also observed in isolated cardiomyocytes, from different animal species [17]. This protection could also decrease the incidence of reversible myocardial dysfunction. Ghosh and Galinanes reported the positive impact of ischaemic preconditioning during procedures with and without cardiopulmonary bypass (CPB) [18].

Theoretically, OPCAB supported by inotropic drugs and an aortic balloon pump can be a suitable solution for high-risk emergency CABG, despite the fact that, in cases of cardiogenic shock, the extensive mobilisation and manipulation of the heart can lead to severe haemodynamic instability [4]. The ONBEAT technique, when not strictly contraindicated (i.e. a calcified aorta), can lead to acceptable short and mid-term results and remains an attractive alternative to CABG and OPCAB in emergency cases [2].

In theory, ONBEAT can eliminate the problem of incomplete revascularization and haemodynamic instability, which are associated with OPCAB, and are reported by some authors to be an acceptable trade-off between conventional CABG and OPCAB [3].

It is well known that insufficient intraoperative myocardial protection compromises the postoperative outcome, leading to the longstanding axiom that ''the convenience of a bloodless and motionless operating field comes at the price of myocardial damage, characterized as ischemia-reperfusion injury''.

Recently, beating-heart and non-cardioplegic CABG without cross-clamping have been used as alternative surgical techniques in high-risk patients. Patients with left ventricular dysfunction who have extensive areas of hibernating myocardium might be expected to derive the greatest benefits from CABG in terms of left ventricular function improvement [1].

Various studies have shown that an OPCAB technique is safe and has satisfactory short-term clinical outcomes compared with conventional CABG [4]. Despite the efficiency and safety of off-pump techniques over CABG, some critics may argue that patients treated with an off-pump technique are undergoing incomplete revascularisation. By using ONBEATING, complete revascularisation is achievable [2], and this may explain the excellent late survival in this subgroup in the current analysis.

Despite improvements in operative techniques and methods of myocardial protection, postoperative left ventricular dysfunction continues to be common in patients undergoing cardiopulmonary bypass surgery. Owing to the increased cardiac and haemodynamic instability, incomplete revascularisation and repeated surgical interventions associated with the off-pump technique, the alternative technique that does not involve aortic cross-clamping with CPB has stood the test of time. Analysis of the real life ANZSCTS registry data has shown that the on-pump beating-heart technique reduces both mortality and morbidity in patients with acute myocardial infarction.

References

[1] Zhu MZL, Huq MM, Billah BM, Tran L, Reid CM, Varatharajah K, et al. On-pump beating versus conventional coronary artery bypass grafting early after myocardial infarction: a propensity-score matched analysis from the ANZSCTS database. Heart Lung Circ 2019;28(8).

[2] 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(2):573–6.

[3] Miyahara K, Matsuura A, Takemura H, Saito S, Sawaki S, Yoshioka T, 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(3):521–6.

[4] Fattouch K, Guccione F, Dioguardi P, Sampognaro R, Corrado E, Caruso M, et al. Off-pump versus on-pump myocardial revascularization in patients with ST-segment elevation myocardial infarction: a randomized trial. J Thorac Cardiovasc Surg 2009;137(3):650–6. discussion 6–7.

[5] Costa MA, Carere RG, Lichtenstein SV, Foley DP, de Valk V, Lindenboom W, et al. Incidence, predictors, and significance of abnormal cardiac enzyme rise in patients treated with bypass surgery in the arterial revascularization therapies study (ARTS). Circulation 2001;104 (22):2689–93.

[6] Mentzer Jr RM. Does size matter? What is your infarct rate after coronary artery bypass grafting?. J Thorac Cardiovasc Surg 2003;126(2):326–8.

[7] Galinanes M, Bernocchi P, Argano V, Cargnoni A, Ferrari R, Hearse DJ. Dichotomy in the post-ischemic metabolic and functional recovery profiles of isolated blood-versus buffer-perfused heart. J Mol Cell Cardiol 1996;28(3):531–9.

[8] Ikonomidis JS, Rao V, Weisel RD, Hayashida N, Shirai T. Myocardial protection for coronary bypass grafting: the Toronto Hospital perspective. Ann Thorac Surg 1995;60(3):824–32.

[9] Bolli R. Mechanism of myocardial ''stunning''. Circulation 1990;82 (3):723–38.
[10] Zeng J, He W, Qu Z, Tang Y, Zhou Q, Zhang B. Cold blood versus crystalloid cardioplegia for myocardial protection in adult cardiac surgery: a meta-analysis of randomized controlled studies. J Cardiothorac Vasc Anesth 2014;28(3):674–81.
[11] Nicolini F, Beghi C, Muscari C, Agostinelli A, Maria Budillon A, Spaggiari I, et al. Myocardial protection in adult cardiac surgery: current options and future challenges. Eur J Cardiothorac Surg 2003;24(6):986–93.
[12] Hayashida N, Ikonomidis JS, Weisel RD, Shirai T, Ivanov J, Carson S, et al. Adequate distribution of warm cardioplegic solution. J Thorac Cardiovasc Surg 1995;110(3):800–12.
[13] Galinanes M, Argano V, Hearse DJ. Can ischemic preconditioning ensure optimal myocardial protection when delivery of cardioplegia is impaired. Circulation 1995;92((9 Suppl):II):389–94.
[14] Kolocassides KG, Galinanes M, Hearse DJ. Ischemic preconditioning, cardioplegia or both? J Mol Cell Cardiol 1994;26(11):1411–4.
[15] Galinanes M, Hearse DJ. Assessment of ischemic injury and protective interventions: the Langendorff versus the working rat heart preparation. Can J Cardiol 1990;6(2):83–91.
[16] Murry CE, Jennings RB, Reimer KA. Preconditioning with ischemia: a delay of lethal cell injury in ischemic myocardium. Circulation 1986;74 (5):1124–36.
[17] Galinanes M, Hearse DJ. Species differences in susceptibility to ischemic injury and responsiveness to myocardial protection. Cardioscience 1990;1(2):127–43.
[18] Ghosh S, Galinanes M. Protection of the human heart with ischemic preconditioning during cardiac surgery: role of cardiopulmonary bypass. J Thorac Cardiovasc Surg 2003;126(1):133–42.