

Coronary Artery Bypass Graft Surgery: The Fourth School of Thought?

Mohd Zamrin Dimon

Faculty of Medicine, Universiti Teknologi MARA, Selangor, Malaysia

Coronary artery bypass graft (CABG) is one of the most common surgical procedure to be performed in patients with coronary artery blockages in the world. It was initially performed while the heart was still beating, which is recognized as the off-pump technique (OPCAB). However, after the invention of the cardiopulmonary bypass (CPB) machine, CABG surgery began to be performed while the heart is arrested. The CPB machine, temporarily acting as a heart pump, allowed the establishment of an extracorporeal circulation. This, subsequently, became known as the on-pump technique. It has now become the gold standard of CABG surgery; with significant improvement in overall patient outcome.

However, the usage of CPB machine is not without complications. The deleterious effect of contact of blood with the artificial extracorporeal circuit could result in systemic inflammatory response and coagulopathy and end-organ failure. Suboptimal endocardial and myocardial protection and stroke could also occur due to aortic manipulation during aortic cross clamping and proximal aortic anastomosis. The massive systemic inflammatory response due to prolonged extracorporeal circulation also renders this technique unsuitable for the high-risk patients, especially those with acute myocardial infarction, poor left ventricular function, renal impairment and patients with a high Euroscore [1].

To overcome this, the off-pump technique was re-popularized in the mid 1990's with much improvement on the technology and better hemodynamic control. For the past 30 years, a lot of debate and studies

had been conducted to compare the short- and long-term outcomes between the off-pump and on-pump techniques. Various clinical trials showed conflicting evidence on the efficacy and benefit of off-pump CABG when compared to on-pump CABG. Since the pinnacle of the OPCAB technique in mid-2002, to date, the adoption of OPCAB surgery in USA and Europe is about 15-25%, compared to that in some developing countries in Asia, especially in China, Japan and India, where it ranges from 70 to 100% (partly contributed by the availability of the novel devices, innovative strategies of conducting OPCAB especially on coronary exposure without compromising the hemodynamics [1,5].

The advantage of OPCAB is significant in patients at high risk of complications if put on CPB. Various studies have demonstrated that those patients who are at high-risk benefit substantially from this procedure, particularly those with impaired left ventricular function, advanced age, left main stem disease, chronic renal failure, sleep apnea syndrome, acute myocardial infarction (AMI), atheromatous disease of the aorta and end-organ failure. OPCAB is shown to be beneficial in terms of blood transfusion requirement, reduced acute kidney injury, reduced atrial fibrillation, reduced re-operation for bleeding and respiratory complications [2,8]. The OPCAB technique has been reported to be effective and comparable to on-pump procedures performed in patients with Left Main Stem (LMS) disease [9]. However, it has been shown to have similar overall mortality and stroke rate compared to on-pump procedures. In the German off-pump CABG in Elderly (GOPCABE) trial, which included patients of



more than 75 years of age, there were no differences in the end points of death, stroke, AMI or new kidney injury [3].

One of the major concerns about the off-pump technique is on the completeness of the revascularization of the blocked coronary artery especially on the circumflex territories, which are at the posterior aspect of the heart. Even though a few randomized controlled trials (RCTs) showed no difference on the short- and mid-term results between the on- and off-pump techniques, there are some data, albeit limited, that showed some inferiority in the latter technique in regard to the long-term outcomes. Some authors have attributed this to the partial completeness of the revascularization process. This has led to more repeat revascularizations in patients who have been subjected to OPCAB surgery [4-7]. Another critique on the technique of OPCAB is about the quality of the anastomosis, as it is done while the heart is still beating and only selected part of the myocardium is not moving. This has been refuted with the introduction of transit time flow meter (TTFM) measurement of the quality of graft anastomosis.

Over the years, there have been three schools of thought among cardiothoracic surgeons with regard to the practice of CABG. The first group consists of the 'pure' off-pump surgeons, the second is the 'pure' on-pump surgeons and the third is the '*selectivists*' group. The '*selectivists*' is a group of surgeons who selectively opt for either the on-pump or off-pump technique depending on the patient profile [6]. Historically, the shift towards OPCAB especially among the surgeons in Asia, India and developing countries is partly due to financial reasons, as the cost of the OPCAB is much less compared to on-pump. This is, of course, in addition to avoiding the deleterious complications of CPB as mentioned above [6]. Of note, these are normally young and enthusiastic surgeons who are in pursuit of innovation and revolutionary techniques. In contrast, the absolute on-pump surgeons remain skeptical on the new technique and argue that the comfort of performing the operation on a still heart translates into more complete revascularization and superior long-term outcome through better graft patency.

The ultimate aim of the surgery is to provide the best short- and long-term outcomes to the patients. Therefore, one of the most important selection criteria

for deciding the best surgical technique is on the possibility of giving the most viable complete revascularization appropriate to the patient condition.

In my personal view, I have progressed from almost 100% OPCAB in my early years of practice, to be among the '*selectivists*' group. This is mainly attributed to increasing data on long-term outcomes from various reviews and RCTs. Another factor that influenced my option within the last decade, is the change in the patient referrals, mainly from cardiologists. Aggressive interventional practices of the cardiologists have led to more high-risk patients with severely diffuse coronary disease and higher syntax score. Bypass surgeries on them are absolutely more challenging when performing CABG with the OPCAB technique. In my current routine practice, for all OPCAB surgeries, the grafts are assessed intra-operatively using graft flow measurement with TTFM (VeriQ System, Medistim, Oslo, Norway). The usefulness of graft flow measurement is mentioned in the European Society of Cardiology and European Association for Cardio-Thoracic Surgery (ESC-EACTS) guidelines [10]. Graft flow measurements were performed just before chest closure and after hemodynamic stabilization. The parameters evaluated with the TTFM are mean bypass graft flow, pulsatility index, diastolic filling, and systolic reverse flow. These measurements have reduced the possibility of graft failure, as immediate redo graft revascularization could be performed if necessary, depending on the TTFM reading. This has significantly assisted the surgeons in improving the overall short- and long-term outcome of the OPCAB procedure [11].

With the introduction of Minimally Invasive CABG technique, which is performed through a small opening at the left intercostal space, we have identified that using a hybrid technique, i.e. on-pump beating heart CABG (ON-BH CABG), the outcome has been promising. This was supported by the meta-analysis performed by Chikara et al [12], which concluded that there was a significantly lower perioperative morbidity associated with ON-BH CABG, including myocardial infarction, renal failure and low output syndrome, albeit with no significant difference in primary outcomes. Current evidence indicates that ON-BH CABG is associated with significantly lower early morbidity and mortality [12].

Therefore, the ON-BH CABG could be an attractive alternative for high-risk patient populations. This potentially could be the '4th school of thought' among the various treatment modalities for patients requiring CABG surgery in the future.

REFERENCES

1. Nandor M, Shahzad GR. Off-pump coronary artery bypass grafting. *AME Medical Journal*. 2020;5:21. doi: <http://dx.doi.org/10.21037/amj.2020.03.11>
2. Ooi JSM, Abdul Rahman MR, Shah SA, Dimon MZ. Renal outcome following on and off-pump coronary artery bypass grafts surgery. *Asian Cardiovascular and Thoracic Annals*. 2008; 16(6): 468-72
3. Diegeler A, Börgermann J, Kappert U, Breuer M, Böning A, Ursulescu A, Rastan A, Holzhey D, Treede H, Rieß FC, Veeckmann P. Off-pump versus on-pump coronary-artery bypass grafting in elderly patients. *New England Journal of Medicine*. 2013;368(13):1189-98. doi: 10.1056/NEJMoa1211666
4. Patel NN, Angelini GD. Off-pump coronary artery bypass grafting: for the many or the few? *J Thorac Cardiovasc Surg*. 2010;140:951-3
5. Gaudino M, Angelini GD, Antoniadis C, Bakaeen F, Benedetto U, Calafiore AM, Di Franco A, Di Mauro M, Fremes SE, Girardi LN, Glineur D. Off-pump coronary artery bypass grafting: 30 years of debate. *Journal of the American Heart Association*. 2018;7(16):e009934. doi: 10.1161/JAHA.118.009934
6. Fudulu D, Benedetto U, Pecchinenda GG, Chivasso P, Bruno VD, Rapetto F, Bryan A, Angelini GD. Current outcomes of off-pump versus on-pump coronary artery bypass grafting: evidence from randomized controlled trials. *Journal of thoracic disease*. 2016;8 (Supl 10):S758-S771. doi:<http://dx.doi.org/10.21037/jtd.2016.10.80>
7. Guan Z, Guan X, Gu K, Lin X, Lin J, Zhou W, Xu M, Wan F, Zhang Z, Song C. Short-term outcomes of on-vs off-pump coronary artery bypass grafting in patients with left ventricular dysfunction: a systematic review and meta-analysis. *Journal of cardiothoracic surgery*. 2020;15:1-12. doi: <http://doi.org/s13019-020-01115-0>
8. Matkovic M, Tutus V, Bilbija I, Lazovic JM, Savic M, Cubrilo M, Aleksic N, Atanasijevic I, Andrijasevic V, Putnik S. Long Term Outcomes of The Off-Pump and On-Pump Coronary Artery Bypass Grafting in a High-Volume Center. *Scientific reports*. 2019;9(1):1-6. doi: <http://doi.org/10.1038/s41598-019-45093-3>
9. Ishamuddin IM, Zamrin DM, Joanna OS, Ramzisham AR, Hairolfai H. Off-pump Coronary Artery Bypass Graft Surgery in patients with Left Main Stem Disease. *Clinica Terapeutica*. 2011 Jan 1;162(6):527-31.
10. Wijns W, Kolh P, Danchin N, Di Mario C, Falk V, Folliguet T, Garg S, Huber K, James S, Knuuti J. Guidelines on myocardial revascularization: the task force on myocardial revascularization of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS). *European heart journal*. 2010 Oct 1;31(20):2501-55.
11. Honda K, Okamura Y, Nishimura Y, Uchita S, Yuzaki M, Kaneko M, Yamamoto N, Kubo T, Akasaka T. Graft flow assessment using a transit time flow meter in fractional flow reserve-guided coronary artery bypass surgery. *The Journal of thoracic and cardiovascular surgery*. 2015;149(6):1622-8. doi: <http://dx.doi.org/10.1016/j.jtcvs.2015.02.050>
12. 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. *European Journal of Cardio-Thoracic Surgery*. 2016 Nov 1;50(5):813-21. doi:10.1093/ejcts/ezw129