

*Chapter***115****Off-pump Coronary Artery Bypass:  
The Game Changer****Murali P Vettath****Introduction**

The off-pump coronary artery bypass (OPCAB) has been practiced in very few countries around the world, over the last two decades. But, this has become a preferred surgical technique in this part of the world; whereas in the West, it is still not taken up as a routine to perform coronary artery bypass grafting (CABG) off pump.

The OPCAB still remains a double-edged sword, as even today, in spite of all the technical advancements, it still remains very much an operator-dependent procedure. Though it has been standardized to a great extent, in order to perform this in all the patients who need a bypass, we need quite a bit of dedication and a mindset from the surgeon, anesthesiologist, and the team. Otherwise, the conversion rate on to the heart-lung machine (HLM) will be high. This technique has definitely come up in a big way in most of the Asia-Pacific region and is being spread to the other regions of the world.

In dedicated centers, it has definitely brought down the mortality and morbidity of coronary surgery and also reduced the need to use the pump, both the HLM and the intra-aortic balloon pump to perform a coronary anastomosis. Hence, it has reduced the carbon foot print by reducing the amount of plastic (in terms of oxygenator and custom pack and cannulas) we need to discard after each of the on pump cardiac surgery. Thereby reducing the cost of surgery in our region. In this chapter, I would like to discuss how this technique has evolved over the last two decades in our place and how it has become a routine in our center.

**Coronary Artery Bypass Grafting**

The first successful CABG was performed in 1960 by Robert Goetz using Rosenak (tantalum) rings.<sup>1</sup> The first clinical case of a direct hand-sewn coronary anastomosis was performed by David Sabiston on April 4, 1962, when he anastomosed the saphenous vein graft (SVG) to the right coronary artery (RCA) at Johns Hopkins. Technically, this procedure was performed off-pump using an end-to-end distal anastomosis. History more frequently attributes the first successful hand-sewn anastomosis to the Russian surgeon, Vasili I Kolessov, who in fact performed a left thoracotomy to perform a left internal mammary artery (LIMA) to circumflex coronary artery as an end-to-end anastomosis without cardiopulmonary bypass (CPB) on February 25, 1964. He reported the outcomes of his first 12 bypass surgeries in 1967.<sup>2</sup> In 1968, Dr George Green from the Saint Luke's Hospital in New York City performed the first left internal thoracic artery (LITA) to left anterior descending (LAD) artery anastomosis,<sup>3</sup> which has become the absolute gold standard of the CABG surgery. The CABG surgery as it is known today was born!

In 1967, when Rene Favaloro performed the first CABG with saphenous vein graft in Cleveland clinic, it opened up the era of coronary bypass surgery in the world on arrested heart.<sup>4</sup> But only in 1981 Enio Buffolo from Brazil and Benneti from Argentina rekindled the idea of OPCAB in the Western world.<sup>5,6</sup> But even after that, only after Calafiore published in 1998, did the rest of the world started looking at OPCAB as a possibility to perform OPCAB on all the vessels.<sup>7</sup> Then, with the invention of

stabilizers, and our ability to perform OPCAB on all the walls of the heart, it became a game changer.

## Myocardial Preservation

Adequate myocardial preservation remains the cornerstone of coronary bypass surgery. If we are unable to maintain this, especially in the ischemic myocardium, it is when we have to resort to intra-aortic balloon pump (IABP) or even end up converting to the HLM. Hence, we devised our own strategy –re-engineering in OPCAB - to maintain the myocardial oxygenation even during grafting, without which arrhythmia would develop and cause hemodynamic instability.<sup>8</sup> Since deliberate induction of global ischemia is unnecessary in OPCAB, it is logical to suppose that iatrogenic biochemical injury to the myocardium would not occur. More so, the blunted inflammatory response with avoidance of cardiopulmonary bypass (CPB) is characterized by low production of interleukin 8 (IL-8) which is involved in myocardial injury. In fact, Atkins et al. first suggested that OPCAB preserved cardiac function in 1984.<sup>9</sup> Compared to on-pump CABG, OPCAB is associated with better myocardial energy preservation, less oxidative stress, and minimal myocardial damage.<sup>10</sup>

Reperfusion injury can occur from regional ischemia due to a combination of underlying coronary obstructive pathology, stabilization, and anastomotic techniques, compounded by episodes of hypotension which precede revascularization. The development of intracoronary shunts has minimized it to a great extent.

Hemodynamic instability has been the major concern in performing OPCAB even today. Though we have been able to master the technique of positioning the heart by the use of various technique and devices, this still remains a major concern. Exposure of the coronary artery target sites requires the heart to be lifted, rotated, dislocated, and displaced producing a distortion of cardiac geometry and consequently hemodynamic fluctuations frequently occur. As a result, the early reports of OPCAB described single or double grafts limited to anterior target sites. The corrective measures for these hemodynamic changes include volume loading, Trendelenburg positioning and displacement of the heart into the opened right pleura, use of inotropes, vasopressors, vasodilators, and intra-

aortic balloon pump.<sup>11,12</sup> We had re-engineered our technique of maintaining the hemodynamics by avoiding the Trendelenburg position. And, we practice an anti-Trendelenburg position of the patient, where the patient lies on the table with the head end up. This is very useful in patients with ischemia, where the pulmonary artery (PA) pressure is high. This maneuver reduces the PA pressure, and thereby reduces the left ventricular end-diastolic pressure (LVEDP). This is exactly what the patient would do when he develops chest pain in his room. He sits up and tries to catch his breath. That is what we help him do in the operation theater as he is anesthetized.

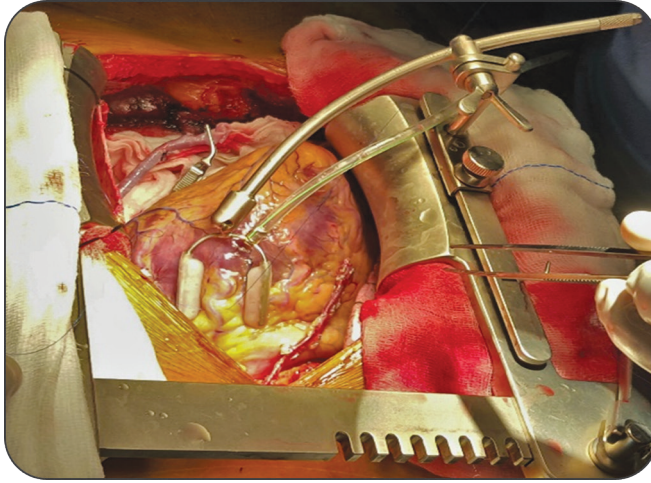
## Distal Anastomosis

The quality of the distal anastomosis is of paramount importance in coronary surgery. Hence, performing vascular anastomoses on small arteries on a beating heart can be a daunting and frustrating adventure. However, with the application of effective target vessel stabilization and efficient visualization systems, the patency of OPCAB has been quite well maintained. The most important issue was to position the heart without hemodynamic compromise. And, to achieve this, we had re-engineered our technique of OPCAB, which we had published earlier.<sup>13</sup> Once the heart is positioned well, we have noticed that even if the surgery takes more time, the hemodynamics would be maintained. In the early days, there were many publications which highlighted incomplete revascularization in OPCAB; but over time, we have noticed that we do not come across any vessel that cannot be grafted using this technique. Today, there is no contraindication for OPCAB, the intramyocardial coronary arteries, small coronary arteries, and diffuse coronary arteries,<sup>14</sup> have all remained a thing of the past (**Fig. 1**).

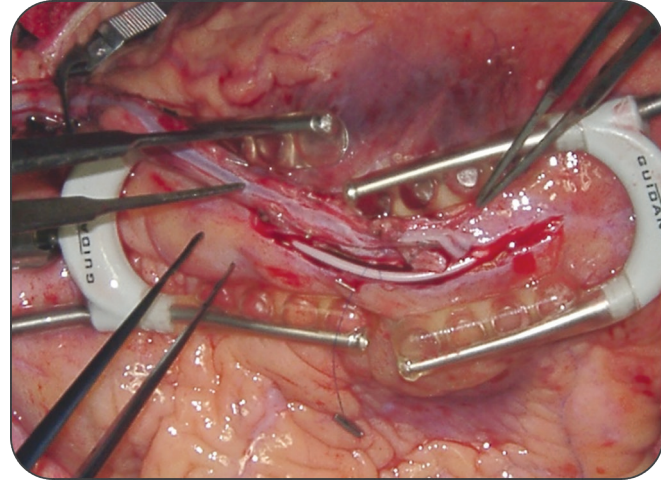
## High-risk Patients

Patients with diffusely diseased coronary arteries, with diseased aorta, low ejection fraction (EF), and patients in renal failure and/or who are on dialysis or after renal transplant, have all been able to undergo OPCAB with least mortality.

Diffusely diseased coronary arteries are seen a large subgroup of patients younger age group and they are



**Fig. 1:** The simple indigenous metallic stabilizer (SIMS) being used to stabilize the coronary artery

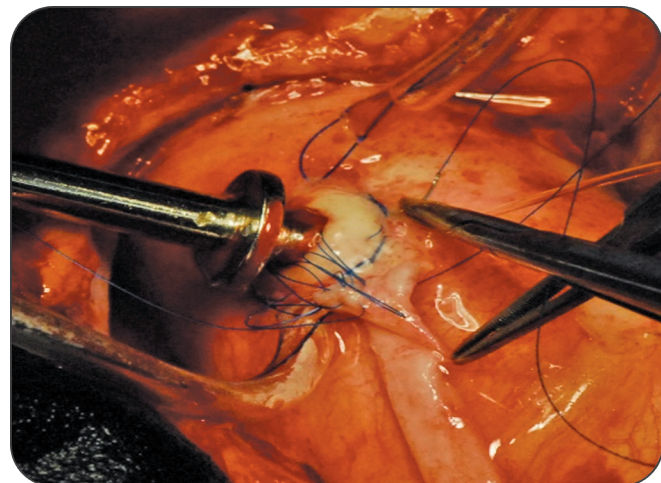


**Fig. 2:** The left internal mammary artery (LIMA) patch being sutured on to the left anterior descending (LAD) artery

usually termed inoperable. The disease is so diffuse that grafting area in the coronary arteries are studded with plaques. We had developed our own technique of Vettath's technique of long mammary patch on LAD without endarterectomy on beating heart. We had performed this on more than 400 patients since the last 18 years. We have also published the same<sup>14,15</sup> in couple of journals. In fact, we have been reviewing these patients with coronary angiograms and the results have been quite gratifying (**Fig. 2**).

In patients with diseased aortas, OPCAB has remained a life saver, as in such patients, going on pump is a recipe for developing stroke. We had developed the Vettath's anastomotic obturator (VAO),<sup>16,17</sup> which is an aortic anastomosis enabling device. This allows the surgeon to avoid the side clamp on the aorta, when a no-clamp technique is required (**Fig. 3**). In patients with aortas with diffuse plaques, where a saphenous vein top end is to be connected, this could be used to make an anastomosis on a zone in the aorta, where there are no plaques. If the aorta is so bad that even a VAO is not possible, then we hook the top end on to the mammary arteries.

Preoperative renal impairment is an independent predictor of poor prognosis after on-pump CABG.<sup>18</sup> OPCAB preserves renal function better than on-pump CABG,<sup>19</sup> and available evidence favors the preferential use



**Fig. 3:** The Vettath's anastomotic obturator (VAO) in use, avoiding the side clamp on the aorta

of OPCAB for patients with chronic renal for a better early clinical outcome. We have developed our own protocol for such patients wherein we are able to maintain the mean arterial pressure of 75 mmHg all through during the surgery, so that the renal output is maintained. Hence, in OPCAB, we are able to perform surgery on patients with renal failure without going on dialysis in most of these patients. Even in patients on dialysis, this technique is very useful, as going on pump is very messy in such patients.

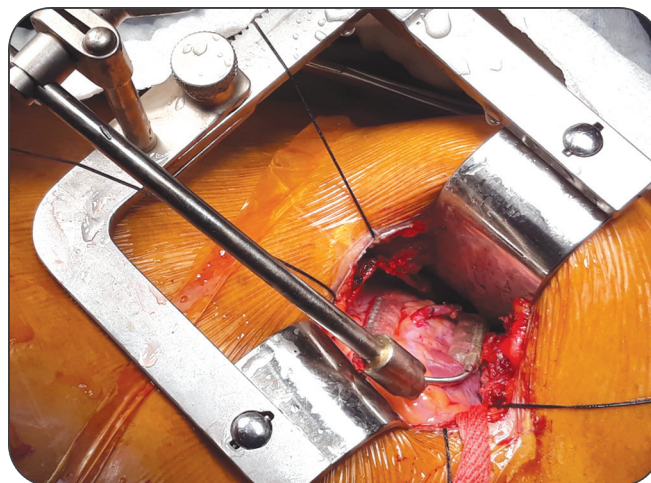
## Role of Intra-aortic Balloon Pump in Off-Pump Coronary Artery Bypass

The use of intra-aortic balloon pump (IABP) either preoperatively or intraoperatively, to reduce operative risk and to facilitate posterior vessel OPCAB has been well documented. IABP has been useful in high-risk patients with left main coronary artery disease (>75% stenosis), intractable resting angina, post-infarction angina, left ventricular dysfunction (ejection fraction <35%), or unstable angina.<sup>20,21</sup> We had modified the use of IABP in our center. Earlier, any patient who has a hemodynamic compromise or has an inclination to crash, gets an IABP inserted. We had the IABP inserted in the early days when we had the patient included in one of the high-risk groups such as left main coronary artery disease (>75% stenosis), intractable resting angina, ST depression more than 2.5 mm, post-infarction angina, left ventricular dysfunction (ejection fraction <35%), or unstable angina.

We had noticed that the use of IABP was not high in the left main disease group and low ejection fraction group, but was high in patients with ongoing ischemia. Hence, we re-engineered our use of IABP such that every patient undergoing OPCAB gets a femoral arterial line and this is used for monitoring along with the radial arterial line. When a patient becomes ischemic during lifting the heart and while positioning for lateral wall grafting, then the heart is repositioned, and a sheath-less IABP inserted. This is then used till the distal anastomosis is over. Once the anastomosis is complete and the heart repositioned for top end anastomosis, then the IABP is kept on standby mode. Then, after the top end anastomosis is over, the heparin is reversed. Once the reversal is over and when the patient remains hemodynamically stable, we remove the IABP on the table, after inserting another femoral arterial line in the other groin. This technique has been very useful. In fact, this technique is published.<sup>21</sup> Hence, we have had no patient in the cardiac surgical ICU with an IABP over the last ten years.

## Minimally Invasive Coronary Surgery

Minimally invasive coronary surgery (MICS) has nowadays been added to our surgical volumes; but due to the diffuse nature of coronary disease, it has still not been able to pick up the momentum as it should have. With the increasing



**Fig. 4:** The left internal mammary artery (LIMA) to left anterior descending (LAD) artery anastomosis via a small thoracotomy

number of coronary angioplasties being performed and with patients opting for more and more minimally invasive procedure, the role of hybrid revascularization is a procedure worth contemplating. Though we have also done our share of MICS with grafting to single and triple vessel disease, though with minimal numbers. As most of the time, when our patient needs at least four or five grafts and the average is 4 grafts over the last 15 years, it is more time consuming and it is not worth the risk, in our hands.

What we have noticed that over the last couple of years, with the coronary angioplasties being performed on mostly all coronaries including left main and triple vessel disease, we as coronary surgeons end up getting patients with diffusely diseased coronary arteries with no clear landing zones for our coronary anastomosis. And, what the patient ends up is a having a higher restenosis rate, as the run off the grafted vessel is very low. This in turn ends up in patients having early restenosis, and disrepute to the surgical technique. Hence, as the surgeons are not the gate keepers, we as a policy perform OPCAB only on patients when the cardiologist feels it is not up to them to stent all the lesions. Thereby, at least the patients would not feel that they could have gone for a stent (Fig. 4).

## Results

The OPCAB has in fact reduced the inherent mortality and morbidity of coronary surgery using HLM. Though

the on-pump-off-pump trial<sup>23</sup> had not shown significant difference in the results. We were very sure it would be like that as the experience of individual surgeons does matter in OPCAB. As most of the surgeons involved in the trial were not experienced surgeons. And, the rate of conversion rate to on pump from the allotted OPCAB was very high, though the trial did not mention that in the statistics. We had published our mid-term results of our 15 years of OPCAB, and more than 4,300 patients (single surgeon) which showed a mortality of less than 1% in the whole group of population. In fact, our stroke rates and renal failure were also less than 1%.<sup>24</sup> This is just to show that OPCAB in dedicated group will definitely remain a good surgical option if angioplasty is not possible.

## Conclusion

The OPCAB has generated renewed, widespread, and sustained interest in the present generation of cardiac surgeons. The resurgence of OPCAB has also ignited a keen enthusiasm in the refinement of CPB techniques and the management of on-pump CABG patients. In most practices, OPCAB is paradoxically dependent on, and guaranteed by the presence of the CPB machine. We would like to stress here that OPCAB is not for everyone. Like any cardiac surgery, OPCAB is very much dependent on the cardiac anesthesiologist who works as a part of the surgical team and is a prime factor in achieving the results in this type of surgery. From the time of induction to extubation, we have developed techniques and technology, fabricated devices and equipment to aid in our practice and standardizing this technique of coronary revascularization. Hope this will remain a game changer from the conventional on-pump CABG and remain as the technique of choice for more surgeons in this field. But with refinement of angioplasty techniques, definitely minimally invasive technique should come up to at least provide an equal chance for surgery to be part of the surgical options for coronary revascularization.

OPCAB video link in YouTube: <https://www.youtube.com/playlist?list=PLmVb6npEfabinhlatq81YLBz8WIHo8bu1>

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## SECTION 14

### Cardiac Surgery

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