The current role and future perspectives of minimally invasive coronary artery bypass grafting

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Coronary artery bypass graft (CABG) surgery performed through a left anterior small thoracotomy (LAST) without utilization of cardiopulmonary bypass (CPB) has become an increasingly popular technique worldwide since the first reports of the use of off-pump techniques and minimally invasive access in CABG surgery were published (1). Constant improvements in the composition of coronary stents and advancements in the techniques of percutaneous coronary intervention (PCI) have been chiefly responsible in inspiring cardiac surgeons to reduce the invasiveness of surgical revascularization techniques, resulting in the development of minimally invasive cardiac surgical (MICS) procedures.

The three main factors of conventional CABG that are predominantly responsible for its invasiveness are the use of CPB, manipulation of the ascending aorta, and sternotomy. Therefore, the essential steps in reducing the invasiveness of CABG surgery would include: (I) avoiding CPB, thereby decreasing the systemic inflammatory response, preventing hemodilution, reducing blood transfusions, and lowering the risk of stroke, neurocognitive disturbances, acute kidney injury, respiratory insufficiency and atrial fibrillation (2). (II) Avoiding aortic manipulation by refraining from partial or total clamping of the ascending aorta does reduce the stroke rate to that observed following PCI (3). (III) Avoiding a sternotomy, which eliminates the risk of sternal wound complications irrespective of the presence of risk factors such as diabetes mellitus, chronic obstructive pulmonary disease, use of bilateral internal thoracic arteries (ITAs), steroid use, osteomyelitis etc., facilitates early extubation, thereby reducing respiratory complications and intensive care unit and hospital stay, and quick recovery and return to work and provides better cosmesis as an added benefit (4).

The present article describes the currently available techniques of minimally invasive coronary surgery in brief, their role in clinical practice today and their potential for changing practice in the future.

Current therapies

Minimally invasive direct coronary artery bypass (MIDCAB)

In the field of coronary surgery, the MIDCAB procedure, which involves the use of the left internal thoracic artery (LITA) to graft the left anterior descending (LAD) artery through a LAST approach has become an excellent alternative to full sternotomy for surgical revascularization for proximal LAD disease. It is probably one of the commonest MICS procedures performed all over the world today (5-7). Following LITA harvest, which is facilitated by specialized retractors, the LITA-LAD anastomosis

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is performed without CPB on a beating heart with the use of mechanical pressure stabilizers. Conventionally, MIDCABs are performed by direct vision, without the use of a scope. However, some modifications of the procedure such as Endoscopic Atraumatic Coronary Artery Bypass (EACAB) and Robotic Assisted Coronary Artery Bypass (RACAB) have been developed, but have not gained widespread adoption. EACAB involves harvest of the LITA with the help of an endoscope and a harmonic scalpel (8), whereas in RACAB the LITA is harvested with robotic assistance that provides high-definition exposure and 3-D telemanipulation, which facilitates the harvesting of the LITA without distorting the thorax (9). However, following LITA harvest, a hand-made anastomosis is performed through a small thoracotomy incision similar to that performed during the conventional MIDCAB procedure. The main advantages of using a thoracoscope or robot assistance are lesser chest wall retraction during LITA harvest resulting in lesser postoperative pain, and better visibility and ease of harvesting the LITA, particularly its distal segment, which could be challenging when using direct vision. This translates into less trauma, lower transfusion rates, and faster recovery. An additional benefit of using robotic assistance is the ability to identify the segment of the LAD that is best suitable for performing the anastomosis, thus, helping the surgeon identify the precise site of entry into the thorax (9,10). Conventional MIDCAB procedures have been associated with excellent long-term outcomes (11) and have been shown to be comparable to both conventional CABG and PCI (12,13). EACAB has also been associated with excellent perioperative outcomes, with rates of conversion to sternotomy and LITA injury lower than 1% (8). Similarly, RACAB also provides excellent results with low perioperative mortality and bleeding and acceptable patency rates (14).

MICS-CABG

MICS-CABG, which was described in 2003, is an extension of the MIDCAB procedure that involves multi-vessel grafting performed through a left antero-lateral thoracotomy, which is performed 2–3 cm more lateral than the MIDCAB incision (12). The feasibility and safety of this procedure have been well-demonstrated (13), and so has its efficacy with respect to patency of grafts (15). The vast majority of the patients received a LITA and vein grafts, with use of radial arteries in some. Most surgeries were performed without CPB, but with partial clamping of the aorta. The last decade has witnessed further improvisation in MICS-CABG procedures through the use of bilateral ITAs as composite grafts without manipulation of the aorta. Such techniques have gained momentum and are associated with excellent early and mid-term outcomes and graft patency (16). The major advantage of this technique is the complete elimination of sternal wound complications, despite utilization of bilateral ITAs. MICS-CABG is also associated with excellent 10-year survival and freedom from major adverse cardiovascular events (17). Although, a larger number of surgeons are now adopting MICS-CABG procedures, the lack of large randomized trials, structured training programs, increased complexity of these operations and a steep learning curve to achieve expertise have hindered widespread acceptance.

Totally endoscopic coronary artery bypass (TECAB)

First performed by Loulmet and colleagues in 1999 (18), TECAB is the least invasive minimal access CABG procedure that is performed through multiple ports without a surgical incision. One port for the camera and 2 working ports are introduced in the midclavicular/anterior axillary line, through the 2nd, 4th and 6th intercostal spaces. The surgical instruments are introduced through the working ports by the surgical assistant, whereas the surgeon sits at the console and performs the procedure. After conduit harvest, two more ports are added; a subcostal port just lateral to the xiphoid process to introduce the robotic stabilizer (Intuitive da Vinci® Robotic Stabilizer) and another working port in the second intercostal space. Thereafter, the surgeon completes the LITA to LAD anastomosis with robotic surgical instruments or a Flex A distal anastomotic device (Cardica) (19).

TECAB is most beneficial as it eliminates tremors, provides excellent vision and magnification, and avoids a surgical incision, thereby averting rib-spreading and chest distortion. However, TECAB procedures have been limited to few centers worldwide, primarily due to a long learning curve, high costs, complex instrumentation, and lengthy procedural times. TECAB has been associated with a 0.8% operative mortality rate, with a low rate of perioperative complications such as, perioperative stroke (1.5%) and myocardial infarction (2.3%) (20). Additionally, the ITA graft patency is comparable to conventional CABG and is 98.8%, 95.8%, and 93.6% at <1 month, <5 years and >5 years follow-up, respectively (21).

Hybrid coronary revascularization (HCR)

HCR combines the best of both the revascularization techniques, involving MIDCAB and PCI to non-LAD vessels. The sequence of revascularization that is most commonly used is MIDCAB followed by PCI. However, in urgent/emergent situations PCI has to be performed prior to surgery. Occasionally, both procedures are performed simultaneously. It is most beneficial in patients who have a prohibitive risk for conventional CABG or are at a high risk for sternal wound complications. Patients amenable for multivessel PCI receive the long-term survival benefit of the LITA-LAD graft. Nevertheless, this revascularization strategy is limited to only a few centers, as surgeons are not yet convinced of the long-term outcomes due to the paucity of evidence in literature. Very few randomized clinical trials have been performed that demonstrate non-inferiority of HCR to conventional CABG (22). Therefore, HCR is not well represented in the ACC/AHA guidelines on myocardial revascularization (23).

Conclusions and future perspectives

Although stent technology and techniques of PCI have markedly improved over the last 3 decades, conventional CABG continues to be the therapy of choice for treatment of severe multivessel coronary artery disease, particularly in diabetic patients (24). Nonetheless, the demand for PCI and less invasive surgical procedures has increased tremendously over the last 20 years, as it is attractive to patients. Unfortunately, the uptake of minimally invasive CABG is very slow as compared to the increase in PCI procedures. This may be due to the lack of strong evidence to support the use of minimally invasive CABG procedures, the steep learning curve and the very low margin of error associated with these procedures. Hence, there are very few structured training programs in minimally invasive CABG.

It is imperative to conceptualize and conduct adequately powered randomized studies to at least establish non-inferiority, if not superiority of minimally invasive over conventional CABG. Currently, the MIST trial, which is a comparison between sternotomy and MICS-CABG for multivessel coronary artery disease, is ongoing (25). Additionally, it is upon the surgeons, who are experts in MICS-CABG, to continue to develop techniques and instrumentation in order to simplify the procedure and shorten the learning curve. It will attract a larger number of surgeons to minimally invasive CABG. The cardiac surgical society should recommend every center to have at least one surgeon in the unit who is competent in minimally invasive CABG. Centers of excellence should establish a structured training program in minimally invasive CABG. Besides, such institutions should also offer peer-to-peer training for surgeons interested in pursuing a career in minimally invasive CABG. Surgeons performing robotic CABG should liaison with industry to develop robots and equipment that would reduce the cost of surgery.

Every institution should adopt the heart team approach involving cardiac surgeons, general and interventional cardiologists in decision-making regarding the appropriate revascularization strategy for every patient, particularly HCR. This would not only optimize the care, but would also increase the confidence of patients in the health care team.

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