

REVIEW ARTICLE

Innovations in cardiovascular care: Historical perspective, contemporary practice, recent trends and future directions

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Abstract

Cardiovascular diseases continue to be a major cause of mortality and morbidity in the world population. First open heart procedure was performed by Gibbon in 1953, since then many advancements have been introduced to the field of cardiac surgery. Minimally invasive techniques were introduced, which include minimally invasive coronary artery bypass grafting (CABG), off-pump technique, minimally invasive valve surgery or transcatheter techniques to implant stentless or sutureless valves. The hybrid strategy to address coronary disease combines catheterisation procedures with standard surgical techniques. Cardiac imaging has also progressed to provide three-dimensional images of the heart, enabling surgeons to plan procedures with greater accuracy. Left ventricular assist devices can be used in patients suffering from cardiogenic shock or awaiting heart transplantation. Total artificial heart can be used for biventricular mechanical support. As technology becomes increasingly used for patient management, the future surgeon needs to be trained in minimally invasive surgical techniques.

Keywords: Cardiovascular diseases, Cardiac surgery, Minimally invasive surgery, Cardiac catheterization.

Introduction

Cardiovascular disorders continue to be the leading cause of mortality and disability across all age groups throughout the world. The World Health Organisation (WHO) expects this burden of disease to increase in the coming years in the developing world. Prevention and medical treatment continue to be mainstay of treatment and disease prevention and limitation. With advancements in technology, newer options for treatment have become available. This review aims to summarise these options.

History of Modern Cardiothoracic Surgery

In 1953, Gibbon successfully performed an open-heart

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procedure using a heart lung machine, which worked on the principle of extracorporeal oxygenation; this pioneered the modern-day techniques used in cardiothoracic surgery. The 1960s saw the advent of usage of internal mammary artery and saphenous venous grafts on a heart with ischemic arrest, to bypass the atherosclerotic coronary vessels.

Minimally Invasive Cardiac Surgery

With the birth of minimally invasive cardiothoracic surgery (MICS), the term minimally invasive coronary artery bypass grafting (MICABG) was introduced. This includes modifications in the visualisation techniques, myocardial stabilisation, "off-pump" and port-access CABG (PACAB), techniques of harvesting internal mammary artery, radial artery and saphenous veins, alternatives to vascular anastomosis, and device-supported myocardial revascularisation. This includes access to the heart through smaller incisions for valvular and congenital heart deformities. Off-pump technique is made possible by use of stabilisation devices, which allow localised stabilisation to facilitate anastomosis.¹ With the advent of MICS, the patient satisfaction increased as pain was reduced, cosmesis became better, and recovery was faster. MICS can be performed through a J or an L shaped partial sternotomy or through the third or the fourth intercostal space on the right side. Robotic Da Vinci system also came to be used for MICS for performing totally endoscopic coronary artery bypass grafting (TECAB) and to perform valve repairs. The 1990s saw the initiation of minimally invasive mitral valve surgery (MIMVS) and minimally invasive direct coronary artery bypass (MIDCAB) also known as the off-pump coronary artery bypass grafting (OPCABG), the latter is performed through anterolateral thoracotomies with no usage of cardio-pulmonary bypass (CBP). Other examples of MICS include minimally invasive aortic valve (MIAVR) and minimally invasive atrial fibrillation ablation. Transcatheter valve replacement or repair has also been in use for the replacement or repair of mitral (with a mitralclip) or aortic valve though percutaneous intervention, also known as transcatheter aortic valve implantation

(TAVI). Transcatheter mitral valve repair or replacement is also being performed.² Suture less or rapid deployment aortic valves are also becoming popular for implantation through minimally invasive techniques.³ Stentless bioprosthetic valves were also introduced in the 1990s to optimise hemodynamics, reduce stress along the valve, to increase its durability. They are primarily used to replace the aortic valve.⁴ Thoracic and abdominal aortic aneurysms may also be repaired using endovascular stent grafts through a minimally invasive technique. This is known as thoracic endovascular aneurysm repair (TEVAR).⁵ Angioplasties and stenting of carotid, renal, visceral and peripheral arteries can also be achieved.

Hybrid Cardiac Operating Room

The hybrid strategy to address coronary artery disease (CAD) combines catheterisation procedures with standard operating surgical techniques. Anastomosis of left internal mammary artery (LIMA) is performed with the left anterior descending artery (LAD) with minimally invasive or open technique. Percutaneous coronary intervention (PCI) procedure is then used to catheterise non-LAD occluded vessels.⁶ Other procedures include PCI in combination with minimally invasive valve surgery such as MIAVR, hybrid atrial fibrillation ablation with epicardial and epicardial approach and for repair of complex thoracic aortic aneurysms. Hybrid operating room (OR) has high-quality imaging available, which includes a multiplane angiography machine, the ability to change the OR table for open surgery, transesophageal

echo, OR lighting, laminar air flow and anaesthesia and heart lung machine (Figure-1).⁶

Advances in Cardiac Imaging: 3-D Modeling and Printing

Cardiac imaging has become an integral facet in diagnosing and managing cardiac diseases. Images from echocardiography, computed tomography (CT) and magnetic resonance imaging (MRI) can now be integrated to provide a 3-D image of the heart, or 3-D computational image. This will aid the cardiothoracic surgeons greatly in preoperative planning, decision-making and management of their patients. The 3-D printing is an increasingly popular clinical tool and this technology can bioprint customised valves and grafts for cardiac surgical procedures. It can also be used for building patient-specific realistic models for surgical planning, education and training of young surgeons. Three-dimensional transesophageal echocardiography is also in use, which provides better estimations of left ventricular function. This allows for better preoperative planning and evaluation of postsurgical repair.⁷

Stem Cells for Treatment of Heart Failure: Cardiosphere-Derived Cells

Contrary to previous belief, the human heart has the ability to repair itself. Recent trials also bring resident cardiosphere derived cells (CDCs) into the limelight as a possible management for heart failure, as they exert a cardioprotective effect on the heart. Use of autologous cells from the body solves the problem of rejection. A phase I clinical trials using endogenous stem cell population isolated directly from the heart has shown a significant improvement in cardiac function and patient outcome over a 1- to 2-year trial period in patients of heart failure. Cardiosphere-Derived autologous stem Cells to reverse ventricular dysfunction (CADUCEUS) trial established that injection of CDCs into the infarct artery following a myocardial infarction (MI) showed noteworthy increase in viable heart tissue, reduction of scar, increase in regional contractility and systolic wall thickening, but the left ventricular end diastolic

Hybrid Operating Room (OR)

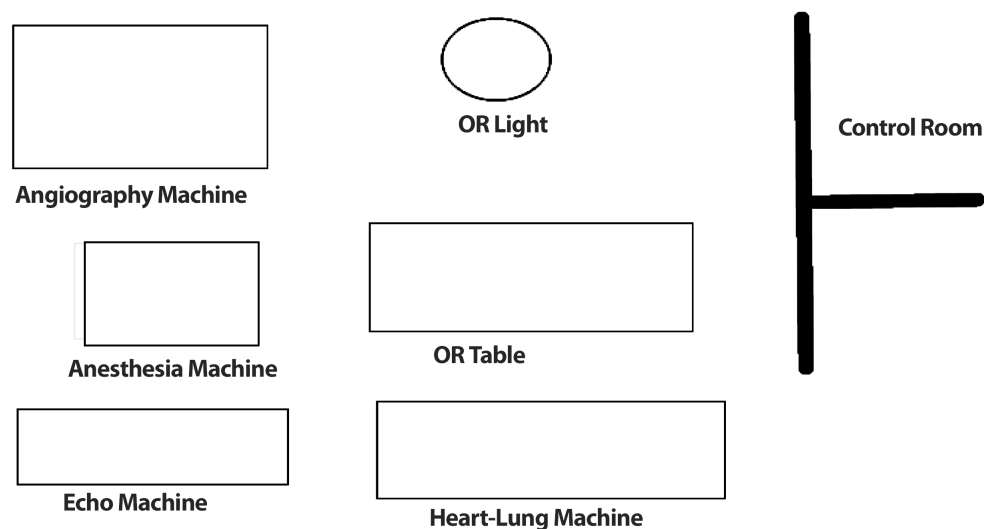


Figure-1: Hybrid OR.

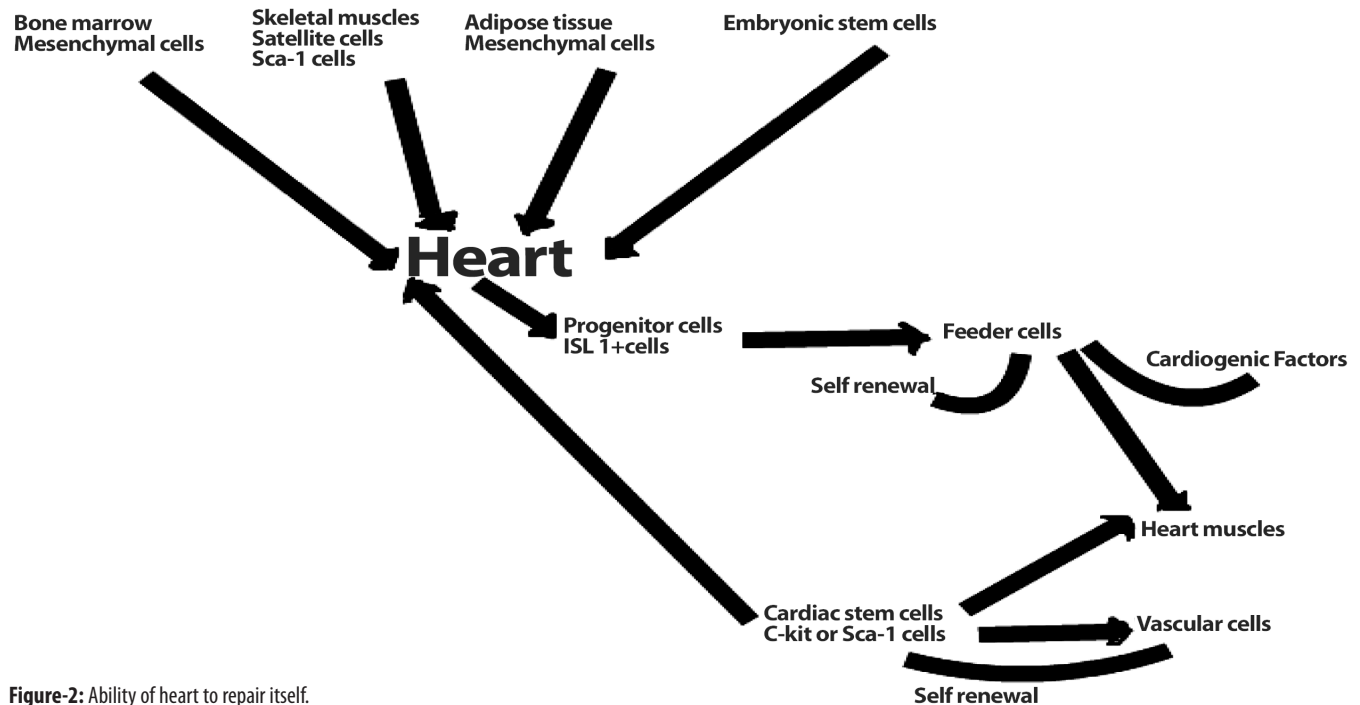


Figure-2: Ability of heart to repair itself.

volume, end systolic volume and ejection fraction (LVEF) did not differ significantly from the control group in 6 months. While the SCIPIO trial tested the use of c-kit cells from the CDCs in patients with heart failure of ischemic aetiology, and found significant increase in LVEF after infusion of c-kit cells following the surgery through percutaneous intervention.⁸ More trials are underway to tap into the endogenous ability of the heart to heal itself as patients with heart failure continue to grow (Figure-2).

Bridging the Gap to Transplantation: Left Ventricular Assist Devices and Extracorporeal Membrane Oxygenation

Left ventricular assist devices (LVAD) have greatly increased the survival rates of patients suffering from cardiogenic shock awaiting heart transplantation. Extracorporeal membrane oxygenation (ECMO) is also a viable option for patients with respiratory failure and in cardiogenic shock to provide emergency circulatory support. ECMO followed by LVAD provide a sustained bridge to ultimate heart transplantation. LVAD cater to population of patients that remain refractory to maximal medical therapy for heart failure. Although this device significantly lowers the morbidity and mortality associated with heart failure, but sepsis continues to be a major threat after device implantation as well as haemolysis, need for anticoagulation and limited battery life. Impella is a

type of ventricular assist device (VAD) which is used in patients with severe heart failure and in cardiogenic shock.⁹ Implantation of a total artificial heart (TAH) can also be used in patients in need of a biventricular mechanical support as a bridge to transplant or as a destination therapy.¹⁰

Implications for Education and Training of Future Surgeons

As technology and automation become increasingly used for patient management, the future surgeon needs to be trained in minimally invasive surgical options. We foresee a greater emphasis in the future on dry and wet labs and simulation models to impart training and evaluation of surgical techniques to the surgeons of the future.

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