

A critical overview of the changes in cardiac surgery since its beginning in the 1950s

Rapidly changing world of cardiac surgery

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Summary

Cardiac surgery developed rapidly in the seventies and eighties of the last century, followed by a period of stabilisation and finally a numerical decline in 21st century. Coronary bypass surgery has been largely supplanted by percutaneous interventions, arrhythmia surgery has been replaced by percutaneous ablation and implantable defibrillators, correction of simpler congenital anomalies is also accomplished by catheter techniques, and we are now observing the emergence of transcatheter aortic valve replacement, which is rapidly overtaking surgical valve repair. On the horizon are mitral and tricuspid repairs; even some short-term circulatory assistance devices are being employed by transcatheter approach. This development has important consequences for cardiosurgical training: minimally invasive procedures are becoming standard of care, catheter training in a heart laboratory ("wire skills") is becoming essential, education in interpretation of advanced imaging techniques: magnetic resonance imaging, angio- and multislice computed tomography, and 2D and 3D echo must be introduced, and surgeons must be also trained in endoscopic and robotic surgery for advanced minimally invasive interventions.

Key words: cardiac surgery; TAVI; percutaneous interventions; surgical education



In surgery, as in many other medical disciplines, it is from time to time intellectually rewarding to look back and assess the changes in the profession at a larger time-scale. According to famous American philosopher of Spanish origin, George Santayana, "those who cannot remember the past are condemned to repeat it". Having myself witnessed and participated in the rapid development, later stagnation and present major transformation of cardiac surgery, I feel that the time has come for a critical overview of the changes that have occurred in this field since its beginning in the late fifties and early sixties of the last century. Cardiac surgery originated as correction of congenital anomalies in the forties and early fifties, first with closure of patent ductus arteriosus and resection of coarctation, later with palliative operations in tetralogy of Fallot and transposition of great arteries, and continuing with correction of atrial and ventricular septal defect and other anomalies. With the development of

reliable pump oxygenators began the correction of various heart valve diseases, which grew into the large field of valve replacement and repair. But a real explosive growth of cardiac surgery came with the establishment of aorto-coronary bypass grafting, known as CABG, in the seventies, as clearly seen in the annual number of open heart procedures in Zurich through the eighties of the last century (fig. 1). With the development of cardioplegia, the risk associated with CABG in Zurich, as in many other large-volume centres, fell to less than 1% in this period.

The first major development in cardiology, which thoroughly changes the practice of cardiac surgery, was the development of percutaneous dilatation of coronary artery stenosis, known first as PTCA (percutaneous coronary angioplasty) and later as PCI (percutaneous coronary intervention) in Zurich in 1977/78 by Andreas Gruentzig. In spite of initial high complication rates [1], this revolutionary invention spread through cardiology like wildfire, creating a new specialist – the cardiac interventionist – and rapidly reducing the number of candidates for CABG. This is best shown by the statistics of the Swiss Society for Cardiac and Thoracic Vascular surgery and Swiss Society of Cardiology [2], which show that in recent years only about one fifth of patients with coronary artery disease are referred to surgery and the remaining four fifths undergo PCI

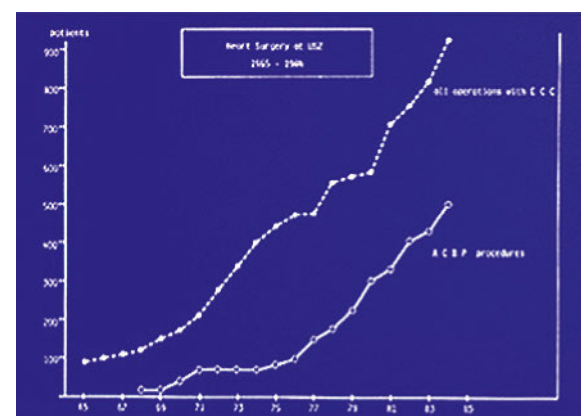


Figure 1: Growth of heart surgery procedures at the University Hospital Zurich in the 1970s and 1980s. Obviously, the increase in number of procedures was mostly due to rapid proliferation of coronary bypass grafting.

Based on a lecture presented at the 2016 Joint Meeting of Swiss Society of Cardiology and Swiss Society for Cardiac and Thoracic Vascular Surgery in Lausanne.

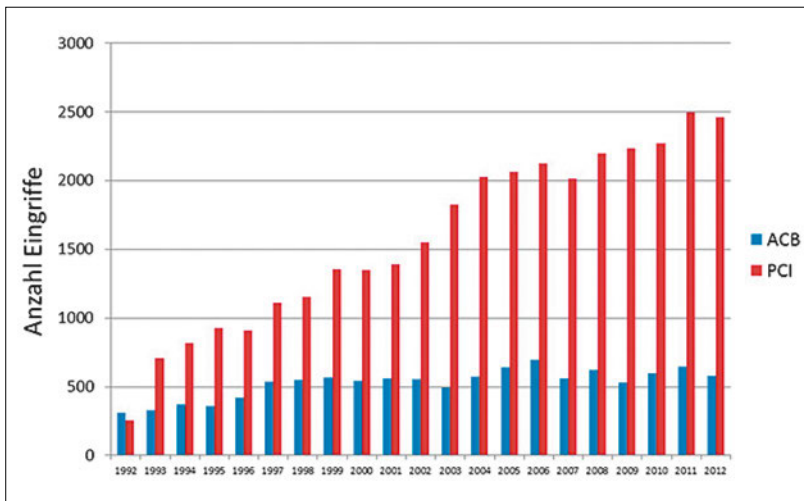


Figure 2: Percutaneous coronary interventions (PCI) and coronary artery bypass grafting (shown as ACB) in Switzerland, 1992–2012, according to statistics of Swiss Society for Cardiac and Thoracic Vascular surgery and Swiss Society of Cardiology (Courtesy Prof. Carrel, Berne).

(fig. 2). In recent years, surgeons have observed that PCI was often used rather indiscriminately, and was indeed overused in some centres, which eventually led to legal proceedings and to punishment of the responsible cardiologists. PCI overuse was termed “cculos-tentotic reflex and iatrogenosis fulminans” [3] in a recent article in *Circulation*. Nevertheless, in 2004, one of the leading European cardiologists, Patrick Serruys, openly stated that “It is not a question if invasive cardiologist will replace the coronary surgeon, but only when.” In recent years it became obvious that only a small minority of patients with coronary artery disease will go to surgery, in spite of undeniable long-term advantages of arterial grafting, with its excellent long-term patency and certain protective effect on native coronary circulation, which prevents progression of distal disease in the native circulation [4]. New guidelines about coronary revascularisation, developed by the European Society of Cardiology and the European Association for Cardio-Thoracic Surgery surprisingly favoured CABG in a majority of coronary situations, given the better long-term outcome after CABG and similar risk with both procedures, but it does not seem that these guidelines are being followed by invasive cardiologists, as shown by frequency of PCI and CABG in the UK (fig. 3), and PCI remains the primary treatment of coronary artery disease in Western World [5].

In the last decade we have observed another revolutionary development in invasive cardiology, called “transcatheter aortic valve implantation”, TAVI for short. Starting rather unspectacularly in the 1990s,

with only moderate success in percutaneous dilatation of aortic stenosis, it exploded, with the assistance of the biomedical industry, into a huge field, with numerous models of catheter-introduced aortic prosthesis, with various methods of fixation. TAVI addressed a major problem in the western world, aging of the population, with concomitant development of degenerative aortic stenosis in septuagenarians and octogenarians, a group of patients at higher surgical risk owing to their age and accompanying comorbidity. Spectacular, quick implantation with short, light anaesthesia, and fast postinterventional recovery, resulted in a rapid increase in the number of TAVI procedures, which in 2014 represented 57% of all aortic procedures in Germany [6]. Strangely enough, the number of surgical aortic valve replacements remained constant in the same period, showing that TAVI presently addresses a segment of the population that was, until now, denied treatment of their aortic valve disease. According to a recent analysis [7], mild, moderate or severe aortic stenosis is encountered in 12.4% of population and severe stenosis in 3.38%, indicating that invasive cardiology and surgery will have to devote considerable activity to this increasing population segment. According to EUROSTAT, the populations of the European Union is expected to include 24.8 million octogenarians by 2020.

Numerous problems arise from TAVI. Some asymptomatic cerebral and coronary embolisation seems to take place during the procedure, and the durability of this new type of prosthesis is still unknown, although they seem to function well up to 5 years after implantation. Treatment of coexisting coronary disease, which is very common in this advanced-age group, is still debated: do nothing, pre-dilate or post-dilate (difficult with a prosthesis in place)? TAVI endocarditis, a highly

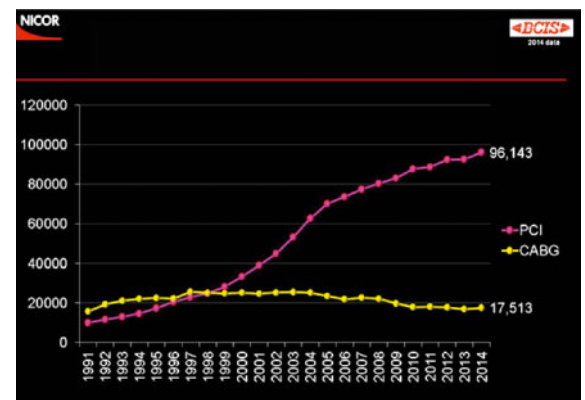


Figure 3: Annual incidence of PCI and CABG in UK, according to the British Cardiac Intervention Society. <https://www.bcis.org.uk/education/bcis-audit-presentation-audit-returns-2014/>

lethal disease and almost unamenable to surgery, seems currently to be rather rare. But it is obvious that the biomedical industry is betting on the success of TAVI, with huge investments in this sector: they are projecting implantation of up to 289 000 units by 2025, with a projected global TAVI market of 5 billion US\$ [8]. And TAVI still receives major attention in scientific publications, as shown by rising number of articles indexed in Medline that address this subject (fig. 4).

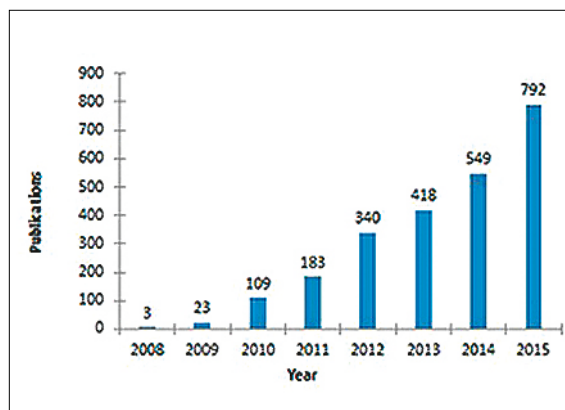


Figure 4: Annual incidence of scientific publications on transcatheter aortic valve implantation (TAVI), from Medline.

Innovations in percutaneous procedures have also reached the mitral valve. By use of a well-established surgical method, the Alfieri stitch, placed with a transseptal catheter under echocardiographic control, reduction of mitral incompetence can be achieved, especially in the surgically difficult group with ischaemic mitral regurgitation, although results are presently still very inferior to surgical annuloplasty. Transcatheter mitral annuloplasty is already being tried clinically, and the same technique is also being applied to incompetent tricuspid valves. Transcatheter mitral valve replacement has had its first clinical trials, and transcatheter pulmonary valve replacement for pulmonary incompetence occurring late after surgical correction of Fallot's tetralogy is already a clinical reality and is accepted as a standard procedure in properly selected cases.

New developments, especially when they challenge the prevailing routine, are subjected to increasing public scrutiny, and it is becoming difficult to develop a new surgical procedure, which in the beginning will be unavoidably saddled with an added risk. A classic example is the arterial correction of transposition of the great arteries (TGA). The original, atrial correction of TGA, designed and developed by Ake Senning [9], was achieving excellent results in the 1970s, without operative mortality [10]. When Adib Jatene first developed

his alternative method of TGA correction, called arterial switch, his initial results showed a mortality of 71% (!), which improved later to 16.6% [11]. Such an effort would be impossible today, with continuous, widespread public scrutiny of surgical results: the surgeon would have been ostracised and indeed punished for his pioneering work. And today Jatene's method is the only technique used in newborns with TGA, which needs correction in the first days of life, and it can be performed with minimal risk in experienced centres.

Another challenging cardiosurgical field was surgery of arrhythmias, beginning first with curative operations in Wolff-Parkinson-White syndrome, which was followed by electro-physiologically guided resection of arrhythmogenic zones in ischaemic cardiomyopathy, and finally by surgical treatment of atrial fibrillation, pioneered by James Cox, with an operation which even today bears his name – the Cox procedure [12]. But all these procedures, which received wide exposure in Zurich and were used in many operations with good success rates, are today almost totally superseded by catheter-based interventions, albeit with a lower long-term success rate in atrial fibrillation, which are favoured by patients for their minimally-invasive nature, with short anaesthesia and one-day hospitalisation. Surgery for atrial fibrillation is nowadays only performed as an adjunct procedure during CABG or mitral and aortic valve operations. Ablation of atrial fibrillation and closure of the atrial appendage are today possible with minimally invasive, thoracoscopic procedures; nevertheless their numbers remain low.

Use of circulatory assist devices has long been a neglected area of cardiac surgery, with few institutions specialising in the use of total artificial hearts and modest long-term survival. The main problems remain thrombosis and infection of the device, embolisation, and large, often loud, extracorporeal devices. The intra-aortic balloon pump and, later, extracorporeal membrane oxygenation remain the principal, universally used assist devices. In the last decade, a number of very small, highly efficient pumping systems have been developed, with continuous flow pumps being in the foreground. Intermacs statistics [13] from the USA, reporting effectiveness of assist devices in 163 centres and in 20 659 subjects enrolled, show the attractiveness of left ventricular assist devices (LVADs), with total artificial hearts and isolated right heart assist being very rarely used (fig. 5). This also led to a change in attitude towards these devices: whereas they were previously used only for bridging the patient to transplantation, nowadays a substantial proportion of patients have LVADs as “destination therapy”, for keeping the patient alive and moderately

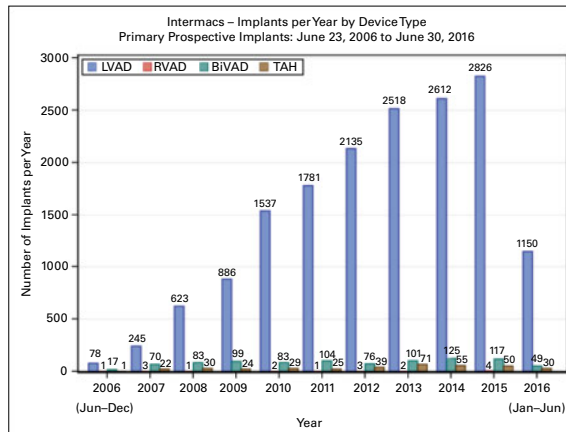


Figure 5: Intermacs annual statistics about the use of heart assist devices in the USA, 2006–2016. LVAD is principal mode of assist; BiVAD and TAH are very rarely used. Bi = biventricular assist device; LVAD = left ventricular assist device; RVAD = right ventricular assist device; TAH = total artificial heart. From: Kirklin, James K. (2016, September). Intermacs Quarterly Statistical Report 2016 Q2: Page 24. Retrieved from <http://www.intermacs.org>.

mobile and healthy without resorting to heart transplantation, because of either the patient’s age or polymorbidity (fig. 6). This destination therapy LVAD is achieving surprising survival rates of more than 50% after 3 years.

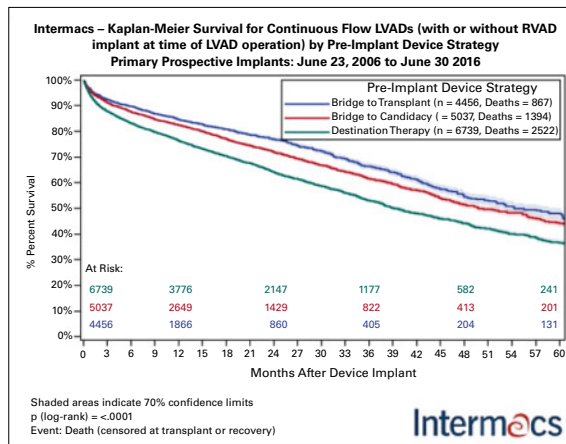


Figure 6: Survival after assist device implantation: best results are achieved by “Bridge to transplant” strategy, but even “destination therapy”, with assist device as functional heart replacement, is achieving survival of more than 50% @ 3 years after implantation. From: Kirklin, James K. (2016, September). Intermacs Quarterly Statistical Report 2016 Q2: Page 24. Retrieved from <http://www.intermacs.org>.

It is obvious that cardiac surgery is presently undergoing major changes, with loss of some areas, but promising developments in other fields. Clear changes include:

- A substantial proportion of CABG replaced by PCI
- Aortic valve replacement superseded by TAVI
- Mitral repair and replacement by catheter techniques
- Catheter closure of atrial septal defects, patent ductus arteriosus and even some ventricular septal defects
- Coarctation: balloon dilatation and covered stents
- Mitral and pulmonary stenosis: catheter dilatation
- Arrhythmia surgery: catheter procedures and automatic implantable cardioverter-defibrillators
- Pulmonary valve replacement: catheter technique
- Aortic aneurysms: endovascular aortic repair (EVAR) and thoracic EVAR

With changes in the nature of cardiosurgical activity, it is equally obvious that substantial changes must be made in the education of future cardiac surgeons: they must be trained in catheter technology to be able to perform trans-vascular procedures, they must undergo training in image processing to be able to interpret two- and three-dimensional echo, computed tomography and magnetic resonance imaging, and they should become familiar with thoracoscopic techniques for minimally invasive heart operations.

It is equally obvious that cardiac surgery is being split into specialised fields of coronary and paediatric heart surgery, surgery of the aorta, interventions for complex valve repair and arrhythmia surgery; the field of transplantation and assist devices is already established as a specialised discipline. Substantial investment in research, with surgeons working closely with invasive cardiologists, offers the greatest promise for future advancement in our field.

Disclosure statement

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References

The full list of references is included in the online version of the article at www.cardiovascmed.ch.

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