ESC European Society of Cardiology

European Heart Journal (2020) **41**, 3693–3701
doi:10.1093/eurheartj/ehaa707

How to shape the future of cardiology and cardiac surgery?

Gilles Dreyfus [1,2]* **and Stephan Windecker** [1,2]

[1]Department of Cardiac Surgery, Institut Mutualiste Montsouris, Université Pierre et Marie Curie, 42, Boulevard Jourdan, 75014 Paris, France; and [2]Department of Cardiology, Inselspital, Bern University Hospital, University of Bern, Freiburgstrasse, 3010 Bern, Switzerland

Received 5 April 2020; revised 23 June 2020; editorial decision 25 July 2020; accepted 17 August 2020; online publish-ahead-of-print 16 October 2020

Cardiovascular (CV) medicine has provided an abundance of diagnostic and therapeutic advances in the fields of prevention, imaging, biomarkers, drugs, devices, and surgical interventions with profound impact on quality of life and life expectancy.[1] Whereas *Cardiology* emerged as initially diagnostic specialty from *Internal Medicine*, *Cardiac Surgery* arose from *General Surgery* while developing specialized surgical procedures for a broad range of congenital and acquired heart disease manifestations.

Interventional cardiology

Interventional cardiology is a well-established subspecialty within any major Cardiology Department and has evolved into a discipline at the boundaries between clinical cardiology and cardiac surgery. Although the list of less-invasive therapeutic interventions in the history of interventional cardiology is long,[2] the discipline has entered into the spotlight and direct competition with cardiac surgery in September 1977 with the advent of percutaneous coronary intervention (PCI).[3] Ever since, the impetus to advance *less-invasive* rather than open surgical correction of cardiac diseases has become more intense driven by the desire to preserve physical integrity and enhance rapid recovery and restoration of quality of life, features that are intuitively attractive to patients, healthcare providers, and payers.

Transcatheter aortic valve implantation (TAVI) is the most recent example of a minimal-invasive alternative to surgical aortic valve replacement (SAVR) demonstrating similar efficacy and safety during short- to mid-term follow-up while providing more rapid restoration of quality of life.[4] The insights gained from numerous randomized clinical trials performed within only one decade in a field devoid of randomized evidence prior to the introduction of transcatheter therapies is remarkable and has impacted guideline recommendations.[5] Noteworthy, the clinical experience and evidence generated in randomized clinical trials comparing PCI with coronary artery bypass grafting (CABG) and TAVI with SAVR evolved from opposite extremes of patient's risk (*Figure 1*). While the first patient to undergo PCI was an otherwise healthy 38-year-old patient with a simple isolated lesion of the proximal left anterior descending artery,[3] the first patient to undergo TAVI was a 57-year-old inoperable patient with severe aortic stenosis and multiple comorbidities.[6] This observation raises the issue how new technologies can best be evaluated in the context of existing therapies under appropriate regulatory oversight.

The advent of TAVI is disruptive not the least by the apparent paradigm shift to no longer consider SAVR as default therapy in patients with severe, symptomatic aortic stenosis raising challenging questions going far beyond the treatment of aortic stenosis addressing complex issues such as the professional interaction of cardiologists and cardiac surgeons, the future of the Heart Team, centres of excellence in cardiovascular medicine, future training, and education as well as patient's choice.[7] However, the extension of TAVI to patients that have been excluded from randomized clinical trials such as those with high risk of coronary obstruction, excessive annular calcification, bicuspid aortic valves, severe native coronary artery disease, or multivalve disease is associated with less favourable outcomes and should not be considered an alternative to SAVR. Similarly, while outcomes for patients undergoing transfemoral TAVI are excellent, the evidence for patients requiring alternative access is less well-established, and TAVI in patients with poor iliofemoral access may lead to peripheral vascular complications or bleeding events. These examples illustrate the importance to carefully weigh the pros and cons of both replacement strategies in the context of the Heart Team.

Although minimal-invasive in nature, the cost of procedures such as TAVI or transcatheter mitral valve repair (TMVR) remains high resulting in socioeconomic and geographic inequalities that prevent

The opinions expressed in this article are not necessarily those of the Editors of the *European Heart Journal* or of the European Society of Cardiology.

* Corresponding author. Tel: +33 603 13 73 74, Email: gillesdreyfus1@gmail.com

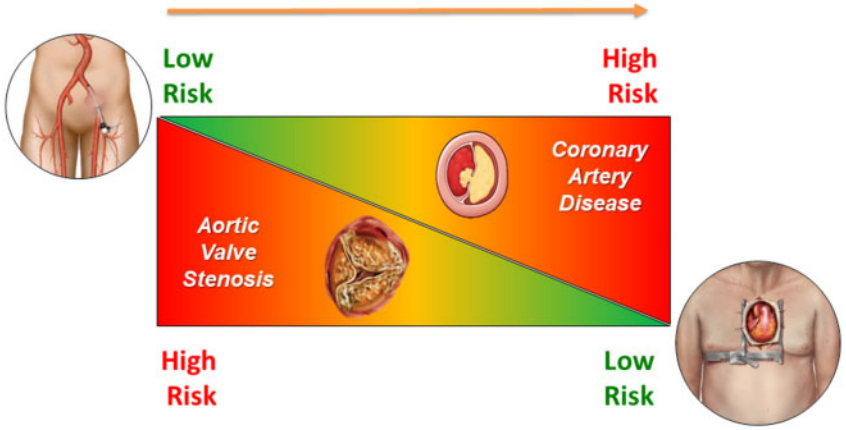


Figure 1 The first percutaneous coronary intervention (PCI) was performed in a low-risk patient (38 years of age, isolated lesion of proximal left anterior descending artery) in September 1977. Since then the procedure for the minimal-invasive revascularization of coronary artery disease was progressively investigated compared with coronary artery bypass surgery (CABG) in increasingly complex lesion and patient populations during the past four decades. The first (antegrade) transcatheter aortic valve implantation (TAVI) was performed in a 57-year-old extreme risk patient with severe symptomatic aortic stenosis and numerous comorbidities in 2002. At variance with percutaneous coronary intervention, the minimal-invasive treatment of severe aortic stenosis was investigated in a series of randomized clinical trials that began at the extreme risk patient spectrum and then was compared with surgical aortic valve replacement (SAVR) first in high risk followed by intermediate risk and most recently low-risk patients.

delivery of care to all patients and need to be addressed.[8] The life cycle of devices is short with the consequence of device cost deappreciation over time. In addition, cost-effectiveness considerations take into consideration the entire hospital stay and may be expanded by longer-term considerations such as rehospitalization. Nevertheless, the high cost of these procedures continues to be a burden for healthcare systems.

Cardiac surgery

Cardiac surgery was for many years the only option to treat coronary artery disease, valvular heart disease, and congenital heart defects. This therapeutic predominance by cardiac surgery for 30 years was increasingly challenged by interventional cardiology procedures, while cardiac surgery was not prepared to such changes. Over time, PCI proved particularly useful among patients with acute coronary syndromes owing to its ability to rapidly restore reperfusion in case of partial or complete epicardial vessel occlusion,[9] whereas CABG was found superior to PCI particularly among patients with complex and advanced three-vessel coronary artery disease.[10] Of note, the peri-procedural risk of CABG appears unaffected by the extent of underlying coronary artery disease and is more dependent on ventricular function, pulmonary hypertension, and comorbidities.[11] Although cardiac surgery remains the therapy of choice in patients with advanced coronary artery disease, there are important differences in quality and outcomes between centres notably in the use of complete arterial revascularization. Although the Arterial Revascularization Trialists (ART) trial did not show conclusive superiority of bilateral vs. single internal mammary artery grafting,[12] this outcome does not justify to abandon the concept of bilateral internal mammary artery grafting or full revascularization. Currently, <20% of CABG procedures are performed with the use of double internal mammary artery grafting in the real world despite excellent outcome data in experienced hands, and the ongoing ROMA trial explores the issue further.[13] Surgeons need to be conscious of the risks of not performing the highest-quality surgery and in the future quality indicators may mitigate this issue.

Similarly, many patients with symptomatic severe aortic stenosis may be treated by TAVI today. Although there is no longer a controversy to prefer TAVI over surgery in patients at increased surgical risk, the debate regarding low-risk patients has just started. Evidence from all randomized trials comparing TAVI and SAVR suggest similar outcomes irrespective of surgical risk. However, data from so-called low-risk trials are currently limited to two industry-sponsored trials (Evolut Low Risk, Partner 3) and one investigator-initiated trial (NOTION I) that also included patients at increased surgical risk. Noteworthy, low risk in these trials does not equate to young age as the mean age was 74 ± 6 years. Moreover, follow-up in this patient population is limited and issues such as the long-term impact of mild paravalvular regurgitation or the increased risk of permanent pacemaker implantation remain to be explored. For young patients without comorbidities, SAVR should remain the reference treatment, whereas for older patients TAVI will be preferable. As the definition of low surgical risk remains fuzzy, emphasis on life expectancy may become clinically more relevant in the future in choosing between TAVI and SAVR than biological age.

Surgical mitral valve repair for primary mitral regurgitation (MR) in high-volume centres is and remains the gold standard even though there are novel transcatheter therapies. Conversely, secondary mitral regurgitation when isolated and applied to highly selected

patients has been shown to benefit from TMVR. The Cardiothoracic Surgical Trials Network trial published by Acker *et al.*[14] exemplifies how a prospective randomized trial, even though published in a prestigious journal, may be conveying a misleading take home message which was that mitral valve replacement was a better choice over mitral valve repair. Therefore, prospective randomized trials have to have clear inclusion criteria, appropriate endpoints, and complete ascertainment during follow-up. In fact in 2018, the COAPT trial dealing with similar patients as the Cardiothoracic Surgical Trials Network population but including highly selected patients showed that transcatheter mitral edge-to-edge repair had a positive impact on heart failure hospitalization and survival.[15] The findings of the COAPT trial should be considered a positive impetus when a patient has combined pathologies requiring surgery and acceptable operative risk, and the surgical community should not abandon mitral annuloplasty in ischaemic functional MR.

Cardiac surgery's future should not be limited to complex cases but include straightforward pathologies provided that surgery delivers the best long-term results with an agreement among cardiac surgeons on a common technique for a given pathology. Cardiologists appear stronger as one technique is adopted by all of them in a standardized fashion. Surgical aortic valve replacement which is the most common and regular valvular procedure is still a source of conflicting data among surgeons even as far as approach is concerned onto whether median sternotomy vs. mini sternotomy vs. anterior thoracotomy is the preferred technique. Many surgical teams publish case series trying to prove their point, but fail to provide scientifically consistent and solid outcome data. Surgeons need to produce long-term series, showing improvement and durability over other therapeutic options.

Heart Team

The Heart Team concept was put forward during the conduct of the randomized SYNTAX trial comparing PCI with use of drug-eluting stents with CABG in patients with three-vessel and left main coronary artery disease.[16] It was subsequently formalized in the 2010 Joint ESC/EACTS guidelines on myocardial revascularization[17] and has been widely endorsed and extended to other fields including valvular heart disease, heart failure, and atrial fibrillation. The interaction between interventional cardiology and CV surgery proved fertile not the least due to the interdisciplinary competition propelling the field forward exemplified by the number of randomized clinical trials comparing interventional and surgical techniques rendering aortic valve interventions and revascularization the best-studied percutaneous or surgical interventions in medicine. Needless to say that cardiology and cardiac surgery need to be equally efficient in order to reach a balanced and valid decision.

The function of the Heart Team depends on the composition, the local setting, and the availability of essential members in view of busy clinical schedules. However, Heart Teams may not be in place or feasible in all institutions and the absence of on-site cardiac surgery units effectively precludes transparent discussion of all cases carrying the risk of indication bias. This also applies for all cases that require an urgent decision which has to be made when surgeons are stuck in the operating room. Moreover, referring cardiologists, internists, or general practitioners may raise expectations on part of the patient that are difficult to be overcome in subsequent institutional Heart Team discussions. This may result in referral bias favouring transcatheter over surgical intervention based on established physician referral pathways rather than medical considerations. This is amplified by the lack of transparent communication of volume, outcomes, and expertise for minimal-invasive and surgical procedures at individual institutions.

The ideal would be to discuss every single case in the presence of the principal stakeholders. However, this is practically not feasible in view of other clinical responsibilities. One way to facilitate the discussion of cases is to draft institutional protocols that can be followed for 'routine' cases, reserving discussion to more complex or controversial cases by the physically present Heart Team. Bias in the discussion can be overcome by placing the patient in the centre of decision-making aiming at the best outcome and quality. The latter may be monitored by appropriate quality indicators that institutions are held responsible for. Heart Teams have also a training and educational role as every participant involved in the decision-making process will provide clinical-pathological insights, imaging findings, and therapeutic options, which in turn will lead to the best therapeutic approach.

Although results from randomized clinical trials inform guideline recommendations, outcomes for both transcatheter, and surgical interventions have been shown to depend on operator- and institutional volume as well as proper risk stratification, parameters that are usually not available in the public domain but importantly impact outcomes in the individual patient.[18] Therefore, concentration of care in large cardiovascular medicine and surgery units may facilitate true Heart Team discussions, enhance trust among referring physicians leaving the ultimate decision in regard to the most effective type of intervention to the site without putting at risk the referring patient flow pathways.

Patient choice

Although patient choice is frequently cited in the Heart Team decision process, the grounds on which a given patient chooses one therapeutic option over another is a complex multifaceted procedure. Transcatheter aortic valve implantation has been shown as safe and effective as SAVR in numerous randomized trials, and most patients will prefer the less-invasive procedure to avoid a scar, perioperative pain, prolonged recovery, and intensive care unit stay. While the data that pertain to both procedures are certainly applicable to elderly patients, no information on long-term outcomes beyond 10 years or even 15 years is currently available in younger patients. This raises the question how objectively patients can be informed, how pertinent patient's choices are, and whether the focus on short- and mid-term results does suffice. In this context, it is essential that patients are able to comprehend the information provided during the Heart Team discussion and that they are presented with the opportunity to interact with both cardiac surgeons and interventional cardiologists. General practitioners and referring physicians assume a central role in the information cascade. They need to be involved in all steps of evaluation and decision-making while avoiding premature and unrealistic expectations on part of the patient.

How can a given patient informed by internet, convinced by referring cardiologists outside of any specialist discussion and information, change his mind even if a Heart Team decision does not reach the same conclusion? There are even more serious issues such as some legal implications if the medical decision is in contrast with the patient's choice or belief, and some serious complications arise. Should the Heart team decision supersede the patient's choice and when should the patient's choice become preponderant?

Education and training

Education and training of cardiac surgical residents may be one of the most important but also worrying issues. It is part of our profession and duty to adequately train junior physicians, whether cardiologists or surgeons. It is the responsibility of professional societies to ensure that training is comprehensive, up-to-date, and sufficient to allow physicians to practice independently. Ideally, interventional cardiologists performing valve interventions should gain direct exposure to valvular pathology during open-heart surgery similar to surgeons do in order to fully appreciate the anatomical complexity. More importantly, it will be increasingly difficult for young surgeons to gain exposure to simple aortic valve procedures in view of the competing displacement by TAVI. While this is a natural development such as the effect of proton-pump inhibitors on gastric ulcer surgery, the more pressing question is how to ensure adequate hands on experience for surgeons to master complex aortic valve surgery if there are no simple cases left to train. While aortic stenosis is most of the time a rather simple disease entity explaining the success of TAVI over SAVR, the problem may become more pronounced especially for redo aortic valve patients, for explantation of TAVR prostheses after degenerative processes or even more complicated for acute bacterial endocarditis. Mitral and tricuspid regurgitation that are far more complex than aortic stenosis require individualized decision-making and a much wider therapeutic spectrum of intervention. Finally, patients with multivalvular disease pose a particular challenge in the ageing population both in terms of correct diagnosis, indication for valve intervention, and therapeutic skills.

One approach may be to define a new process supervised by ESC and EACTS in Europe as well as ACC/AHA and AATS/STS in North America to define novel standards for training and education. Ideally, both cardiologists and cardiac surgeons should enter a common educational track of 1–2 years that provides a core curriculum related to epidemiology, prevention, diagnosis, and medical treatment of major cardiac disease entities validated at the end of the year allowing to check if basic knowledge has been acquired. During this period, cardiac surgeons would be able to become familiar with non-invasive cardiac imaging [ECHO, computed tomography (CT), magnetic resonance imaging (MRI)], acquire basic knowledge in the evidence-based medical treatment of major cardiovascular disease entities and drug adverse effects, and perhaps most importantly, learn about appropriate indications of therapeutic interventions. Conversely, cardiologists would expand their knowledge from non-invasive imaging to observing the real anatomy and appreciate the intricacies of surgical repair in various pathologies. The latter may be particularly important in areas where both specialties—Cardiology and Cardiac Surgery—offer therapeutic interventions such as valvular repair (mitral, tricuspid), aortic valve replacement, revascularization, etc. Moreover, intensive care training should be a common achievement for both specialties as the stabilization of acutely ill cardiovascular patients as well as the post-procedural management importantly contributes to the overall quality and outcome of interventions/surgery. For young cardiac surgeons, there should be a minimum of different types of surgical procedures performed as first surgeon assisted by a more senior surgeon. In the UK, surgeons have a logbook showing they have performed 150 CABG themselves. It is a good example but it should involve at least 50 aortic valve replacements for aortic stenosis and 20 mitral valve replacements all procedures under supervision.

Following the basic formation, future cardiac care specialists will then enter dedicated fellowships to gain therapeutic skills in either interventional or surgical cardiac units. In addition, the societies would set standards in terms of minimal number of simple and complex procedures to be performed by each trainee to become proficient independently. Moreover, it would be determined how much time interventional cardiologists should spend in surgical cardiac units and vice versa how much time cardiac surgeons would spend in interventional cardiac units in order to achieve a set of predefined skills. While a certain overlap in the two tracks would be worthwhile and should be defined, it is neither the goal to train surgeons that perform routinely interventional catheter-based techniques nor interventional cardiologists that perform surgical procedures as the skill set is rather different. Cardiologists will not become cardiac surgeons, and surgeons performing equally well surgery and interventional procedures may exist but such individuals will remain the exception rather than the rule. Finally, societies may merge efforts in education related to congresses and publications in journals that will complete the transition in training and education into a common cardiac care specialist track.

Cardiac disease centres of excellence

Modern cardiovascular disease centres will overcome the classic separation of medical and surgical disciplines by hosting cardiology and cardiac surgery services in common organizational entities to fully exploit the entire range of preventive, diagnostic, and therapeutic options in disease-oriented treatment pathways. The incentive to strive for excellence will result in super-specialization that goes along with innovation and will safeguard the need for highly qualified interventional cardiologists and cardiac surgeons.

Despite all differences, adult cardiac surgery may learn from the experience in congenital heart disease with successful centralization of services. Owing to the high technical complexity of care including diagnosis, intervention, and surgery, centralization of care has resulted in few highly specialized congenital heart disease centres concentrating patients, resources, funding, and professional experiences.

Future cardiac centres of excellence may be organized into specialized units for the most common cardiac disease manifestations including coronary artery disease, heart failure, valvular heart disease, arrhythmias, aortic disease, and congenital heart disease (*Figure 2*). In each unit, specialized experts will provide high-end skills in state-of-the-art diagnosis, imaging, interventional, and surgical treatment.

Coronary Artery Disease	Valvular Heart Disease	Thromboembolic disease	Heart Failure	Arrhythmias and Electrophysiology	Congenital Heart Disease
Imaging	Imaging	Imaging	Imaging	Imaging	Imaging
Medical	Medical	Medical	Medical	Medical	Medical
Intervention	Intervention	Intervention	Intervention	Intervention	Intervention
Surgery	Surgery	Surgery	Surgery	Surgery	Surgery

Figure 2 Possible organization of institutions delivering highly specialized care for cardiac patients according to disease-specific entities (coronary artery disease, valvular heart disease, thrombocardiology heart failure, arrhythmias, congenital heart disease). Each of the disease-specific entities will comprise experts in imaging, medical treatment, interventional, and surgical procedures with clinical and research interest in the respective domain.

Certain pathologies will require exclusive surgical skills performed by dedicated specialists for valve reconstruction, minimal-invasive beating heart coronary surgery, aortic surgery, congenital adult surgery, and specialists for heart transplantation and assist devices. An important prerequisite will be the concentration of cardiovascular care in large tertiary care centres that will provide sufficient volume to ensure excellence in outcomes for high-end CV surgery. The latter will require superregional structures that are supported by healthcare authorities in order to replace competition for patients between smaller units by the common goal to ensure adequate training and education while providing excellence in outcomes.

One might consider a tiered system of delivery with primary cardiac care services (level I) complemented by comprehensive cardiac care centres (level II) (*Figure 3*). This system would allow for continued delivery of basic cardiac care services in the elective and emergency setting in the community setting, while fostering centres of excellence being integrated into supra-regional healthcare delivery networks. Communication between different centres can be further improved by telemedicine, teleproctoring, and videoconferences.

Obviously, not all trainees both in cardiology and in cardiac surgery will remain during their entire career at centres of excellence. Some of them will be employed at primary cardiac care centres performing the main bulk of the work on straightforward coronary disease and valvular heart diseases. Not all cardiologists want to be interventional cardiologists and not all those performing PCI want to be involved valvular heart disease interventions. Likewise, not all cardiac surgeons want to master mitral or aortic valve repairs.

Centres of excellence bear the risk to prematurely embrace novel innovative interventions that may fail the test of time in routine clinical practice. While we acknowledge the associated risks, we nevertheless maintain that it is more appropriate to introduce novel technologies in centres of excellence rather than at primary care cardiac centres as long as appropriate governance will be followed. Along these lines, novel technologies should follow a careful stepwise evaluation with early mechanistic studies followed by large-scale clinical trials and expanded by real-world post-marketing practice evaluation. Of note, protocols on novel devices should be scrutinized by independent clinical experts without financial interest in the technology, ethics committees, and regulators. Moreover, endpoints and data management require supervision with careful attention to prespecified endpoint definition, statistical analysis plans, and supervision of endpoint adjudication by independent clinical event committees and data and safety monitoring boards.

Future centres for cardiovascular care providing both interventional and surgical services will have a common rather than separate budget. This will eliminate current differential sources of revenue that may (dis)advantage one discipline over another. Instead, financial resources will be shared and serve to support both 'bread-and-butter' interventions as well as innovative techniques, and common disease manifestations as well as rare diseases. Moreover, reimbursement of cardiac interventions would be directly linked to outcome research and quality assurance programmes with real-time public reporting of institutional outcomes providing advanced level of transparency for patients, healthcare providers, and payers. In other words, financial resources would be directed to optimize quality and patient outcomes rather than increasing revenue by volume of procedures.

Outcome data and research

Cardiovascular medicine has been at the forefront of efforts in the era of evidence-based medicine and numerous trials have compared interventional and surgical techniques in the field of revascularization and aortic valve intervention.[2] Notwithstanding, Class IA recommendations in European and US professional guideline documents constitute <10–15% of all recommendations pointing to a continuous lack of knowledge and gap in evidence that has not changed during the

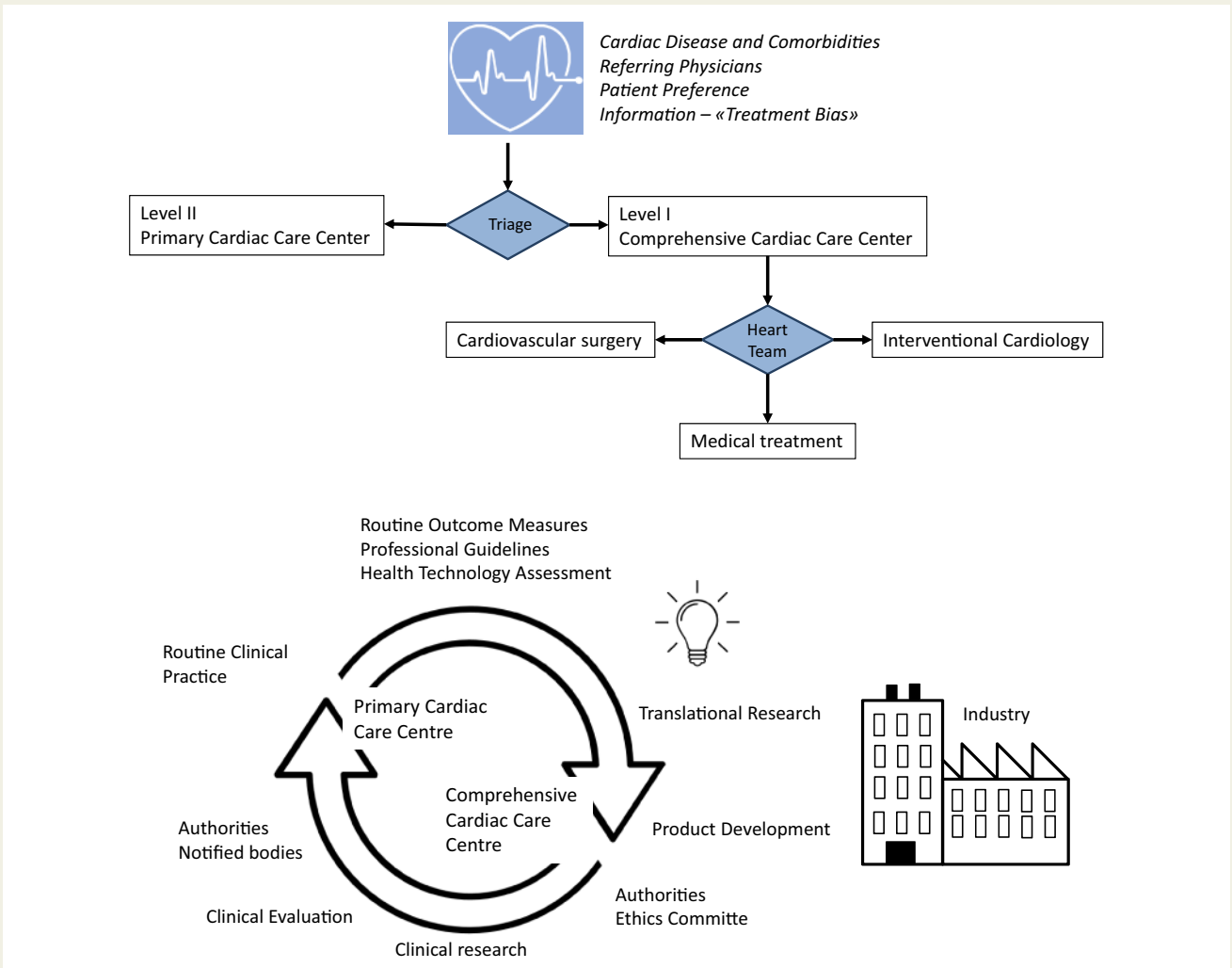


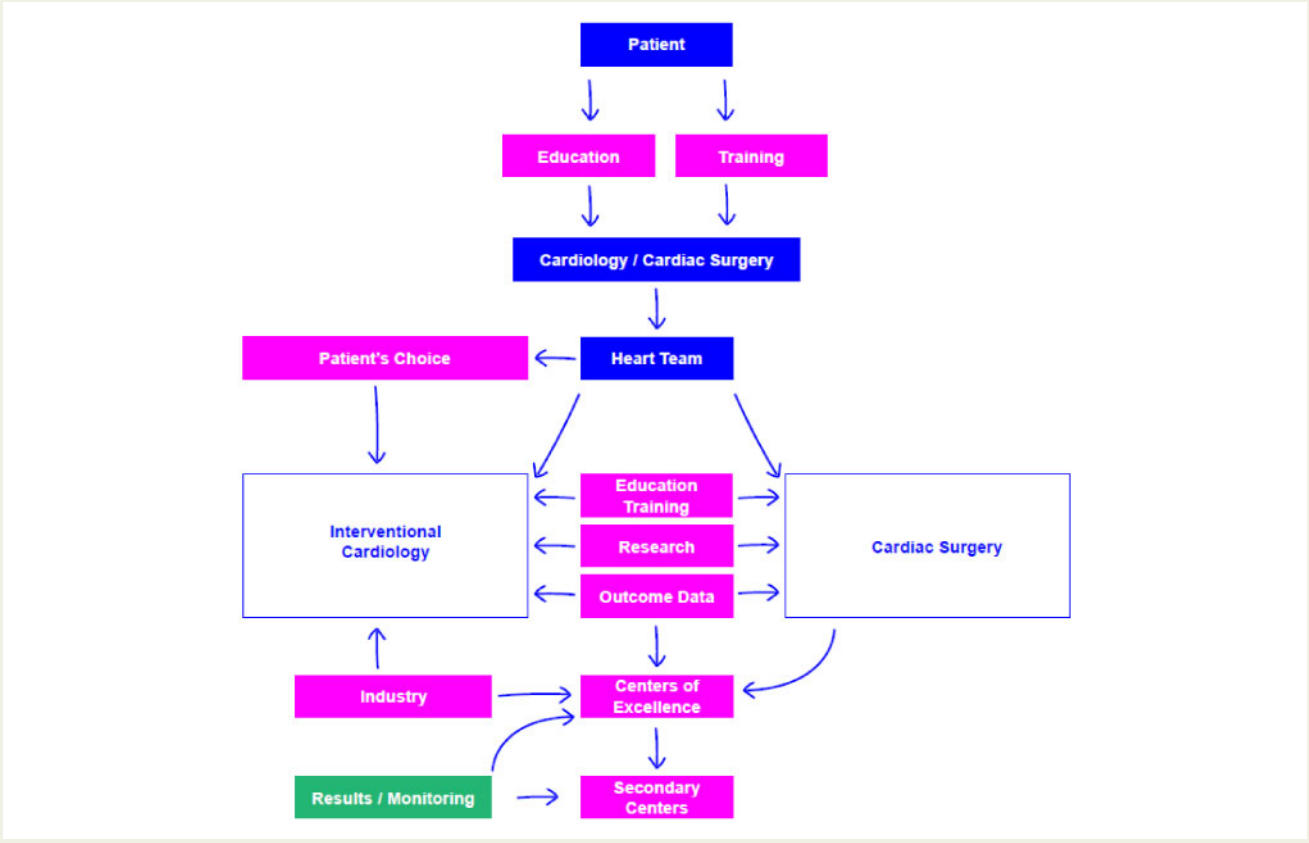
Figure 3 Interdependence of cardiology and cardiac surgery in terms of patient triage, delivery of cardiac care, education, research, and quality control.

past decade.[19] In other words, many clinical scenarios continue to lack conclusive evidence from large-scale randomized trials.

Cardiac surgeons often identify themselves with a particular technique that is mastered and perfectionated over time by ever more sophisticated iterations. However, they frequently fail to submit the technique or intervention to a structured prospective clinical investigation that proves the reproducibility independent of the operator in routine clinical practice. Moreover, a declining trend to conduct randomized clinical trials in cardiac surgery, difficulties to perform blinded studies and slow recruitment into studies are important challenges.[20] It also proves difficult to implement surgical standards that have been proven superior in trials into routine uptake in clinical practice as for example the more frequent use of arterial revascularization. As surgery for CABG does usually not imply the use of devices, the lack of economic incentives may explain at least in part the lack of commercial sponsorship to conduct trials in cardiac surgery. Notwithstanding, investigator-initiated trials independent of industry such as those by the ART or supported by the National Institutes of Health such as the Cardiothoracic Surgical Trials Network have become important initiatives to inform clinical decision-making in cardiac surgery.[12,21]

Surgeons have to accept that if a smaller incision is better, no incision at all is even better. As the extent of invasiveness is concerned, surgeons need to acknowledge that there is only one truly non-invasive method and that is percutaneous access. Surgeons argue among themselves about the size of the incision, where to approach the heart and how to operate endoscopically or robotically. While surgeons try to convince each other on technical issues, cardiologists by means of percutaneous access bypass these discussions with patients being discharged the same day sometimes or 1 day later in the absence of a notable incision and associated pain or discomfort.

As it relates to interventional cardiology, there is a long-standing culture of engagement into randomized clinical trials, systematic longitudinal follow-up, and standardized endpoint definitions. However,



Take home figure Summary of future training, education and research, Heart Team, and patient focus.

many studies are industry-sponsored and have the clear objective to expand or change indications in favour of a given commercial product. The example of bioresorbable scaffolds is an important lesson that only appropriately powered randomized clinical trials with long-term follow-up are able to address relevant safety issues. The issue of bioresorbable scaffolds resulted in an ESC/EAPCI position paper[22] summarizing the evidence and resulted in the allocation of a class III recommendation in recent guidelines.[23] The document also provided guidance on how to improve the evaluation of coronary stents and scaffold in the future pointing to the responsibility that can be shared by academic institutions, professional societies, and regulators.

In order to move forward, cardiac surgeons and cardiologists should intensify the collaboration in independent, investigator-initiated trials to reproduce the findings of industry-supported trials and address unmet clinical needs. As randomized clinical trials frequently deal with highly selected patients population that are not reflective of the 'real world', special efforts to engage into all-comer trials or registries that complement randomized clinical trials need to be pursued more systematically. In addition, longitudinal follow-up in carefully conducted long-term registries may be of particular importance as it relates to issues such as valve durability and should ensure independence from industry. In order to set up a clinical trial and provide longitudinal follow-up, there is a need for such units to have research assistants or physicians. Due to a chronic lack of funding, few units cannot afford it, and working hours constraints require more clinicians than needed. At least all academic Institutions should review this issue in order to be able to participate in clinical research. European academic institutions and national or supranational research foundations do not systematically support the expensive infrastructure and administrative burden of clinical research that requires dedicated staff, adherence to standard operating procedures, quality management, maintenance of electronic databases, and electronic case records. As long as clinical research is not more widely supported and funded independent of industry, the gap in evidence and high-quality evidence-based recommendations will not diminish. Sweden and the Nordic countries have been at the forefront to integrate registry-based randomized clinical trials at reasonable cost into routine daily practice that has resulted in numerous guideline relevant insights.[24]

Interaction with industry

Industry has never been more involved into medical education and clinical studies. On the positive side, technological improvements and innovations are breath-taking and investments are large. Without the technology, innovation, and financial resources of industry, cardiovascular medicine would not have witnessed the extent and speed of medical progress to date in pharmaceutical drug development, device

innovation, and imaging tools. On the negative side, however, most of the resynchronization therapies (RCTs) investigating devices are industry-sponsored guided by FDA advise to obtain commercial approval. Although these studies need to adhere to rigorous regulatory and scientific standards, the commercial interest to obtain positive study results is undeniable and may influence study design in terms of patient selection, comparator, and assumptions.[25] Therefore, it will remain critical that industry-sponsored trials are complemented by investigator-initiated RCTs to reciprocate results, address unmet clinical needs, and reduce the evidence gap in terms of high-quality evidence-based recommendations. Moreover, high-quality independent registries to obtain reliable information on issues such as long-term durability of heart valves are much needed.

The interaction with industry in educational matters has been regulated to curtail undue influence while preserving a useful forum of exchange. Recently, members of the European medical technology industries in Europe revised the Eucomed code with the aim to implement a new conduct that proposes a controlled framework governing industry sponsorship with the aim to withdraw direct sponsorship for all healthcare professionals attending conferences and aiming also to limit indirect sponsorship.[26] It remains to be seen whether professional societies in collaboration with hospitals and national governments will be able to fill the gap to provide broad professional member education in the future. While industry engages into company-sponsored medical education with educational content that enables direct physician sponsoring, these activities do not fulfil standards of academic and scientific independence.

Conclusion

In order to be successful in the future, it will be best for Cardiology and Cardiac Surgery to not only work hand in hand but rather become one single entity in terms of training, education, departmental structure, and professional society (*Take home figure*). Interventional Cardiology has undeniably changed the therapeutic spectrum of options to address a wide spectrum of degenerative cardiac disease notably coronary artery disease and valvular heart disease. However, it is in the interest of Cardiology to have a strong Cardiac Surgery partnership by its side. At every level, hospital, universities, professional and scientific societies, and across countries the training of young physicians should be more closely monitored and enabled to allow everyone to practice safely. There should no longer be the artificial separation by 'technique' between surgeons, interventional and non-invasive physicians but rather a new form of organization respecting the cardiac disease pathways according to underlying pathology-physiology and assembling the cardiac specialists (surgical, interventional, non-invasive) best suited to address all needs within a comprehensive Heart Team to the benefit of patients.

Conflict of interest: S.W. reports research and educational grants to the institution from Abbott, Amgen, BMS, Bayer, Boston Scientific, Biotronik, Cardinal Health, CSL Behring, Daiichi Sankyo, Edwards Lifesciences, Johnson&Johnson, Medtronic, Querbet, Polares, Sanofi, Terumo, and Sinomed. S.W. serves as unpaid member of the steering/excecutive group of trials funded by Abbott, Amgen, BMS, Boston Scientific, Biotronik, Cardiovalve, Edwards Lifesciences, MedAlliance, Medtronic, Polares, Sinomed, V-Wave, and Xeltis, but has not received personal payments by any pharmaceutical company or device manufacturer. He is also member of the steering/executive committee group of several investigated-initiated trials that receive funding by industry without impact on his personal remuneration. G.D. has no conflict of interest.

References

1. Nabel EG, Braunwald E. A tale of coronary artery disease and myocardial infarction. *N Engl J Med* 2012;**366**:54–63.
2. Windecker S. Interventional cardiology's golden age of contributions to evidence-based medicine. *EuroIntervention* 2019;**15**:31–34.
3. Gruntzig A. Transluminal dilatation of coronary-artery stenosis. *Lancet* 1978;**1**:263.
4. Siontis GCM, Overtchouk P, Cahill TJ, Modine T, Prendergast B, Praz F, Pilgrim T, Petrinic T, Nikolakopoulou A, Salanti G, Sondergaard L, Verma S, Juni P, Windecker S. Transcatheter aortic valve implantation vs. surgical aortic valve replacement for treatment of symptomatic severe aortic stenosis: an updated meta-analysis. *Eur Heart J* 2019;**40**:3143–3153.
5. Baumgartner H, Falk V, Bax JJ, De Bonis M, Hamm C, Holm PJ, Iung B, Lancellotti P, Lansac E, Rodriguez Muñoz D, Rosenhek R, Sjögren J, Tornos Mas P, Vahanian A, Walther T, Wendler O, Windecker S, Zamorano JL; ESC Scientific Document Group. 2017 ESC/EACTS Guidelines for the management of valvular heart disease. *Eur Heart J* 2017;**38**:2739–2791.
6. Cribier A, Eltchaninoff H, Bash A, Borenstein N, Tron C, Bauer F, Derumeaux G, Anselme F, Laborde F, Leon MB. Percutaneous transcatheter implantation of an aortic valve prosthesis for calcific aortic stenosis: first human case description. *Circulation* 2002;**106**:3006–3008.
7. Otto CM. Informed shared decisions for patients with aortic stenosis. *N Engl J Med* 2019;**380**:1769–1770.
8. Pilgrim T, Windecker S. Expansion of transcatheter aortic valve implantation: new indications and socio-economic considerations. *Eur Heart J* 2018;**39**:2643–2645.
9. Fox KA, Clayton TC, Damman P, Pocock SJ, de Winter RJ, Tijssen JG, Lagerqvist B, Wallentin L; FIR Collaboration. Long-term outcome of a routine versus selective invasive strategy in patients with non-ST-segment elevation acute coronary syndrome a meta-analysis of individual patient data. *J Am Coll Cardiol* 2010;**55**:2435–2445.
10. Head SJ, Milojevic M, Daemen J, Ahn JM, Boersma E, Christiansen EH, Domanski MJ, Farkouh ME, Flather M, Fuster V, Hlatky MA, Holm NR, Hueb WA, Kamalesh M, Kim YH, Makikallio T, Mohr FW, Papageorgiou G, Park SJ, Rodriguez AE, Sabik JF 3rd, Stables RH, Stone GW, Serruys PW, Kappetein AP. Mortality after coronary artery bypass grafting versus percutaneous coronary intervention with stenting for coronary artery disease: a pooled analysis of individual patient data. *Lancet* 2018;**391**:939–948.
11. Mohr FW, Morice MC, Kappetein AP, Feldman TE, Stahle E, Colombo A, Mack MJ, Holmes DR Jr, Morel MA, Van Dyck N, Houle VM, Dawkins KD, Serruys PW. Coronary artery bypass graft surgery versus percutaneous coronary intervention in patients with three-vessel disease and left main coronary disease: 5-year follow-up of the randomised, clinical SYNTAX trial. *Lancet* 2013;**381**:629–638.
12. Taggart DP, Altman DG, Gray AM, Lees B, Gerry S, Benedetto U, Flather M; ART Investigators. Randomized trial of bilateral versus single internal-thoracic-artery grafts. *N Engl J Med* 2016;**375**:2540–2549.
13. Gaudino M, Alexander JH, Bakaeen FG, Ballman K, Barili F, Calafiore AM, Davierwala P, Goldman S, Kappetein P, Lorusso R, Mylotte D, Pagano D, Ruel M, Schwann T, Suma H, Taggart DP, Tranbaugh RF, Fremes S. Randomized comparison of the clinical outcome of single versus multiple arterial grafts: the ROMA trial-rationale and study protocol. *Eur J Cardiothorac Surg* 2017;**52**:1031–1040.
14. Acker MA, Parides MK, Perrault LP, Moskowitz AJ, Gelijns AC, Voisine P, Smith PK, Hung JW, Blackstone EH, Puskas JD, Argenziano M, Gammie JS, Mack M, Ascheim DD, Bagiella E, Moquete EG, Ferguson TB, Horvath KA, Geller NL, Miller MA, Woo YJ, D'Alessandro DA, Ailawadi G, Dagenais F, Gardner TJ, O'Gara PT, Michler RE, Kron IL; CTSN. Mitral-valve repair versus replacement for severe ischemic mitral regurgitation. *N Engl J Med* 2014;**370**:23–32.
15. Stone GW, Lindenfeld J, Abraham WT, Kar S, Lim DS, Mishell JM, Whisenant B, Grayburn PA, Rinaldi M, Kapadia SR, Rajagopal V, Sarembock IJ, Brieke A, Marx SO, Cohen DJ, Weissman NJ, Mack MJ; COAPT Investigators. Transcatheter mitral-valve repair in patients with heart failure. *N Engl J Med* 2018;**379**:2307–2318.
16. Ong AT, Serruys PW, Mohr FW, Morice MC, Kappetein AP, Holmes DR Jr, Mack MJ, van den Brand M, Morel MA, van Es GA, Kleijne J, Koglin J, Russell ME. The SYNergy between percutaneous coronary intervention with TAXus and

cardiac surgery (SYNTAX) study: design, rationale, and run-in phase. *Am Heart J* 2006;**151**:1194–1204.
17. Wijns W, Kolh P, Danchin N, Di Mario C, Falk V, Folliguet T, Garg S, Huber K, James S, Knuuti JL, Opez-Sendon J, Marco J, Menicanti L, Ostojic M, Piepoli MF, Pirlet C, Pomar JL, Reifart N, Ribichini FL, Schalij MJ, Sergeant P, Serruys PW, Silber S, Sousa Uva M, Taggart D; Task Force on Myocardial Revascularization of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS); European Association for Percutaneous Cardiovascular Interventions (EAPCI). Guidelines on myocardial revascularization. *Eur Heart J* 2010;**31**:2501–2555.
18. Carroll JD, Vemulapalli S, Dai D, Matsouaka R, Blackstone E, Edwards F, Masoudi FA, Mack M, Peterson ED, Holmes D, Rumsfeld JS, Tuzcu EM, Grover F. Procedural experience for transcatheter aortic valve replacement and relation to outcomes: the STS/ACC TVT registry. *J Am Coll Cardiol* 2017;**70**:29–41.
19. Fanaroff AC, Califf RM, Windecker S, Smith SC Jr, Lopes RD. Levels of evidence supporting American College of Cardiology/American Heart Association and European Society of Cardiology Guidelines, 2008-2018. *JAMA* 2019;**321**:1069–1080.
20. Gaudino M, Kappetein AP, Di Franco A, Bagiella E, Bhatt DL, Boening A, Charlson ME, Flather M, Gelijns AC, Grover F, Head SJ, Juni P, Lamy A, Miller M, Moskowitz A, Reents W, Shroyer AL, Taggart DP, Tam DY, Zenati MA, Fremes SE. Randomized trials in cardiac surgery: JACC review topic of the week. *J Am Coll Cardiol* 2020;**75**:1593–1604.
21. Smith PK, Puskas JD, Ascheim DD, Voisine P, Gelijns AC, Moskowitz AJ, Hung JW, Parides MK, Ailawadi G, Perrault LP, Acker MA, Argenziano M, Thourani V, Gammie JS, Miller MA, Page P, Overbey JR, Bagiella E, Dagenais F, Blackstone EH, Kron IL, Goldstein DJ, Rose EA, Moquete EG, Jeffries N, Gardner TJ, O'Gara PT, Alexander JH, Michler RE; Cardiothoracic Surgical Trials Network Investigators. Surgical treatment of moderate ischemic mitral regurgitation. *N Engl J Med* 2014;**371**:2178–2188.
22. Byrne RA, Stefanini GG, Capodanno D, Onuma Y, Baumbach A, Escaned J, Haude M, James S, Joner M, Juni P, Kastrati A, Oktay S, Wijns W, Serruys PW, Windecker S. Report of an ESC-EAPCI Task Force on the evaluation and use of bioresorbable scaffolds for percutaneous coronary intervention: executive summary. *Eur Heart J* 2018;**39**:1591–1601.
23. Neumann F-J, Sousa-Uva M, Ahlsson A, Alfonso F, Banning AP, Benedetto U, Byrne RA, Collet J-P, Falk V, Head SJ, Jüni P, Kastrati A, Koller A, Kristensen SD, Niebauer J, Richter DJ, Seferović PM, Sibbing D, Stefanini GG, Windecker S, Yadav R, Zembala MO; ESC Scientific Document Group. 2018 ESC/EACTS Guidelines on myocardial revascularization. *Eur Heart J* 2019;**40**:87–165.
24. James S, Rao SV, Granger CB. Registry-based randomized clinical trials–a new clinical trial paradigm. *Nat Rev Cardiol* 2015;**12**:312–316.
25. Gaudino M, Hameed I, Rahouma M, Khan FM, Tam DY, Biondi-Zoccai G, Demetres M, Charlson ME, Ruel M, Crea F, Falk V, Girardi LN, Fremes S, Chikwe J. Characteristics of contemporary randomized clinical trials and their association with the trial funding source in invasive cardiovascular interventions. *JAMA Intern Med* 2020;**180**:993.
26. Serruys PW, Wijns W, Windecker S. A vote taking place on 2 December 2015 (EUCOMED) that will definitely influence our profession and continuing medical education. *EuroIntervention* 2015;**11**:847–849.