OPINION ARTICLE

EXPECTATIONS FOR THE FUTURE OF CARDIOVASCULAR SURGERY

Author:
J Rafael Sádaba MD PhD
Cardiac Surgery Service
University Hospital of Navarra
Public University of Navarra
Pamplona, Spain

Correspondence:
J Rafael Sádaba
jr.sadaba.sagredo@navarra.es

Recently, I had the opportunity to watch a video, Surgical Correction of Dissecting Aneurysm of Ascending Aorta (Baylor College of Medicine, 1963), which made me reflect on the evolution of cardiovascular surgery in recent decades and, at the same time, on the future of our specialty.

This video shows an ascending aorta replacement procedure in a patient with an ascending aortic dissection, performed by Dr. M. E. De Bakey in 1963. I also invite you to compare the procedure in the video with what we can do six decades later. Although ancillary aspects of the procedure, such as cardioplegia, oxygenators, and sutures, among others, have evolved, the surgical technique itself, which at that time represented a disruptive innovation in treating this disease, has yet to evolve that much. What has evolved the most is the camera with which the intervention was recorded, a 16mm film camera, which has little to do with the digital cameras used today.

Nevertheless, let us look at those elements of the procedure that have evolved over the last 60 years. Today's sternal saws are a major advance over the Lebsche sternotome used in the video. From my point of view, myocardial protection, with new cardioplegic solutions that make it possible to perform interventions with the heart stopped, is the element that has evolved the most, the one that has had the most significant impact on results, and the one that has opened up the most possibilities for new treatments. Likewise, mechanical circulatory assistance for treating heart failure is another field in which we have seen significant progress. Otherwise, evolution has been limited, and the innovations introduced have merely served to improve or refine existing technologies or techniques.

Since 1963, two innovations that could be considered "disruptive" have emerged in the surgical treatment of cardiovascular disease: aortocoronary bypass and valve replacement and/or repair. Both have impacted the surgical treatment of coronary artery disease and valvular heart disease and made it possible to treat diseases for which, until then, there were no effective remedies. The advent of percutaneous coronary intervention, introduced by Andreas Gruentzig in 1976, was a significant breakthrough in the treatment of coronary artery disease. Since then, the technology has evolved fundamentally in two aspects: the stent construction material and the radial artery vascular approach. However, both the technique and the technology, as well as their

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surgical alternatives, have evolved little in the last two decades. Percutaneous treatment of valvular heart disease (without the need for extracorporeal circulation) represents another disruptive innovation in the treatment of cardiovascular disease. Disruptive innovations, although they may initially offer inferior results to those of traditional technologies, end up eliminating the latter. The similarity between the graph of trends in the number of TAVRs and aortic valve replacements in North America and the well-known graph of disruptive innovation (*Figures 1A and 1B*) is striking.

A technology, a manufacturer, or a specialty that does not reinvent itself ends up being replaced by others that are more innovative.

Let us see the case of Kodak, an undisputed leader in the printed photography market, which, although the initial leader in digital photography, disappeared because it needed to learn how to adapt to new market trends. Can cardiac surgery end up like Kodak? Are we destined to disappear as a specialty, to perish in the face of the avalanche of alternative percutaneous treatments to our surgical procedures?

Let us perform a SWOT analysis of our specialty to determine the position of cardiovascular surgery in the current "market".

Weaknesses: with honorable exceptions, and unlike our predecessors, today, we are not an innovative specialty, nor does a scientific spirit characterizes us. Most of the evidence published in cardiovascular surgery is retrospective and observational, and most of our research is clinical and focused on testing the safety or efficacy of established treatments. On the other hand, our treatments are not as profitable for manufacturers as percutaneous alternatives, and, therefore, manufacturers' R&D investment is primarily devoted to the latter. This means that the technology of percutaneous devices is advancing faster than that of surgical devices. As if this were not enough, manufacturers promote randomized trials that are sometimes designed to favor percutaneous devices (which give them more profit) over surgical devices.

Threats: the increase in the number of percutaneous treatments and the consequent decrease in the number of surgical treatments will result in fewer cases per center and less opportunity for training and development surgical skills, especially for newer surgeons. The cases referred to surgery will be the most complex or result from complications of percutaneous treatments. The combination of decreased opportunities for training and skill development, and the need to deal with higher-risk cases, will lead to increased mortality and complications, affecting the specialty's reputation. The best and brightest students will gravitate toward those specialties that are less demanding and offer innovative treatment alternatives.

Strengths: current surgical treatments are, in most cases, safe and effective and capable of treating diseases that, without these treatments, would be lethal. Some of these highly complex treatments require skills developed over years of experience. Cardiac surgeons acquire extensive knowledge of pathophysiology, natural history, and treatment of these diseases. Cardiovascular surgery has pioneered the development of registries and data analysis. This puts us in an advantageous position, allowing us to learn from our mistakes and improve our medical practice.

Opportunities: surgical experience and knowledge of anatomy and pathophysiology put the surgeon in an excellent position to acquire percutaneous skills. The development of minimally invasive techniques (including robots) improves patient acceptance of surgical treatments. Surgery may be the only therapeutic option in certain situations of complexity or complications of percutaneous treatments. Therapies such as transplantation cannot be approached percutaneously. On the other hand, there is much room for maneuvering to optimize the results of surgical treatments, putting the patient at the center of our activity.

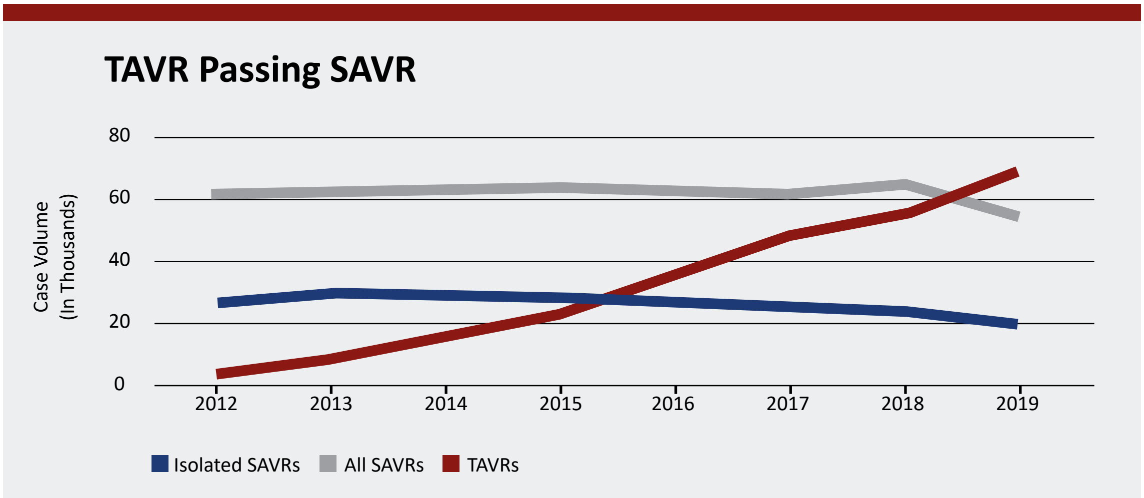
It is not the strongest species that survive, but those that are best adapted to change. How can we adapt to permanent change?

How will technology evolve in the coming decades? Surgery, in general, has advanced more in the last 20 years than in the previous 100 years. As Raymond Kurzweil, expert systems and artificial intelligence technologist, points out, our intuition about the future is linear. However, the reality of information technology is exponential, making a profound difference. If I take 30 steps linearly, I get to 30. If I take 30 steps exponentially, I get to a billion. So it is not easy to understand what the future holds for us as a specialty.

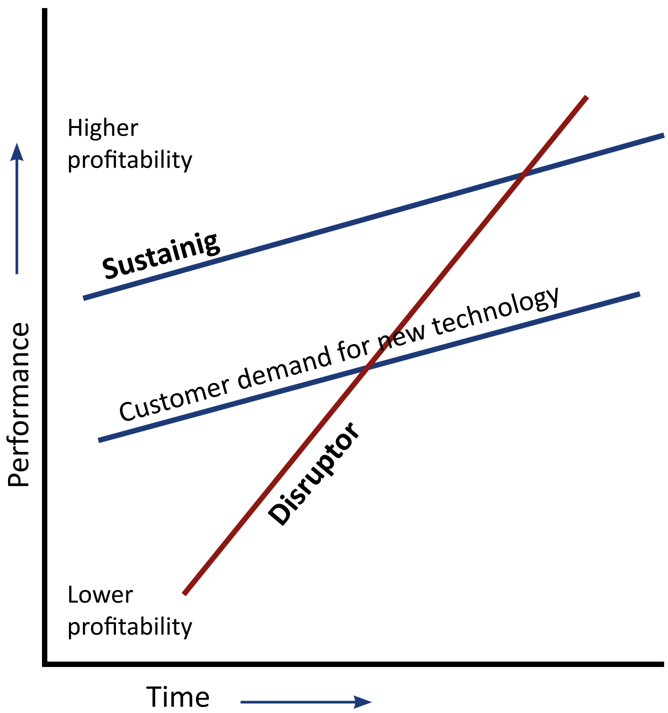
Regardless of the above, the two fields with the most significant potential for development are percutaneous technologies and minimally invasive access, mainly robotics. A third field of development is that of composites for constructing valve prostheses that do not require anticoagulation and, at the same time, do not suffer from structural degeneration or bioengineering developments that allow the construction of biological scaffolds for

FIGURE 1A. Similarity between the graph of trends in the number of TAVRs and aortic valve replacements in North America. **1B.** Graph of disruptive innovation

A



B



From: 1A, https://www.sts.org/publications/sts-news/tavr-surges-past-surgery-us-avr-treatment-volume; **1B**, Gerber, A., Matthee, M. (2019) [9].

valve regeneration. These elements are relevant to the training of future surgeons. Undoubtedly, percutaneous techniques should be included in the curriculum of future training programs, as should specific training in minimally invasive and robotic access techniques. Scientific research should play a more relevant role in the training of future surgeons so that they can play a more critical role in the development of new forms of treatment. Xenotransplantation is an excellent example of the opportunities that are opening up in the future.

In this era of high expectations and “value”-centered medicine, outcomes in surgery take on a new dimension. “Value” in healthcare is measured by those patient-centered outcomes that are achieved, not by the volume of services provided. Perhaps this is where the future development of cardiac surgery should be based. It is worth recalling here the influential article by Michael E Porter [1], which sets out the principles by which "value" in health should be assessed. Outcomes for any medical condition can be organized into a three-level hierarchy in which the top level is usually the most important, and lower-level outcomes involve a progression of outcomes contingent on success at the higher levels. Each level of this hierarchy contains, in turn, two categories, each of which involves one or more distinct dimensions of outcomes.

Level 1 is the state of health achieved by therapeutic intervention. The first category in this level, survival, is undoubtedly the most relevant for most patients.

The second category in level 1 is the degree of health or recovery achieved. For example, in stable angina, this category refers to the absence of angina at maximum stress after myocardial revascularization surgery.

Level 2 outcomes are related to the recovery process. The first category of this level refers to the time required to recover and return to regular activity. This category can be divided into different phases: time to hospital discharge and time to return to work. This is critical for many patients, where percutaneous techniques outweigh surgical techniques.

The second category at level 2 is the futility of the care or treatment process regarding discomfort, need for reoperation, short-term complications, and possible errors and their consequences.

Level 3 refers to the maintenance of health status after treatment. The first category here is recurrences of the original disease or long-term complications, and the second category captures new health problems created as a consequence of treatment.

In the absence of disruptive innovations in surgery, the future of cardiac surgery lies in optimizing outcomes at all 3 levels:

Level 1. Category 1: in-hospital or short-term survival of standard procedures has declined significantly over the past decades and, in most cases, is similar to alternative percutaneous procedures. However, reducing the mortality of other more complex procedures or those that are less common is necessary. This should be a multidisciplinary effort involving both clinical cardiologists and specialists in cardiac imaging, anesthesiologists, and intensive care. Establishing treatment protocols and algorithms to unify the forms of action and reduce variability is an essential part of the process. Category 2: in general, cardiovascular surgery is very effective in the treatment of diseases, and, in most cases, patients reach an adequate level of health. They can lead an everyday life after recovery.

Level 2. Category 1: post-procedure recovery is the area with the most significant potential for improvement in cardiac surgery procedures. Minimally invasive procedures decrease pain and allow earlier ambulation, reducing hospital stay and recovery time. Enhanced Recovery after Surgery (ERAS) programs improve outcomes in cardiac surgery by accelerating post-surgical recovery [2]. The causes of asthenia or weakness after major surgery have not been studied; therefore, there are no interventions or treatments to alleviate it. The casual element may be related to the release of free radicals caused by surgical trauma [3]. The possibility of neutralizing these free radicals could also accelerate the recovery process [4]. Category 2: establishing treatment algorithms and protocols aimed at reducing process variability, improving the training of professionals in surgical safety issues, and recording adverse effects and their analysis are tools that contribute to reducing complications and errors [5,6]. Implementing actions aimed at reducing surgical site infections and those associated with orotracheal intubation are equally important in this section.

Level 3. Category 1: avoiding recurrences and the need for re-interventions is another of the objectives that should be considered. The improvement of valve repair techniques and progress in the knowledge of those factors that dictate the durability of the procedures are fundamental in this field. It is crucial to develop skills in different modes of treatment in order to be able to treat the patient in a personalized way that is targeted to the specific anatomy and pathophysiology. For example, the optimal selection of the types of arterial grafts available contributes to their long-term patency and freedom from recurrences. **Category 2:** the disadvantages derived from the use of valve prostheses, in terms of risk of endocarditis, degeneration, and complications associated with anticoagulation, can also be reduced using valve repair techniques. Developing durable prostheses that do not require anticoagulation treatment is a highly relevant field of research [7].

The sustainability of healthcare systems is everyone's responsibility and is an essential factor in the future of cardiovascular surgery. Historically, the value of medical care has always been defined as the intersection between the highest quality care available at the lowest possible cost. Those treatments that achieve the same results at a lower cost to healthcare systems should be prioritized over those with a higher economic cost. For example, valve repair offers advantages over percutaneous techniques in treating valvular heart disease.

The results of the techniques used in surgery seem to be related to a certain extent to the volume per surgeon and center and, therefore, to subspecialization. The complexity of surgical techniques has evolved significantly over the last 3 decades. Even for the most basic cardiac surgery (such as coronary artery bypass grafting), surgeons dedicated mainly to this technique are advocated to optimize results by applying multiarterial grafts and off-pump surgery [(8)]. Other techniques (such as complex aortic or mitral valve repair), complex aortic surgery, and the use of minimally invasive techniques also require subspecialization to optimize health outcomes and to be able to compete with percutaneous techniques that have so far always been inferior to surgical techniques in terms of medium- and long-term results.

The future of cardiac surgery is bright if we know how to adapt to the development of new technologies and focus on offering a service centered on patient value. Therefore, we must not only train our residents in percutaneous and less aggressive techniques but also instill in them the concepts of value in health: safety of treatments, optimization of perioperative processes for rapid patient recovery, interventions with good lasting results and few complications, and which, in addition, can be performed at a lower economic cost.

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