EDITORIAL COMMENT

Florian S. Schoenhoff[1]

[1] Chair of the Vascular Domain of EACTS
Associate Editor (Open Aortic) of the EJCTS

Department of Cardiac Surgery, University Hospital Bern, Inselspital, Bern, Switzerland

The Future of Aortic Surgery

The future of aortic surgery is bright. Aortic surgery is the fastest growing field in cardiac surgery. Epidemiological studies have shown that the incidence of aortic aneurysm is constantly increasing (Figure 1, Panel A).[1] Although the ageing of the population is an important factor, reasons for this are not completely understood.

When we surgeons refer to advances in our field, we often refer to certain procedures or surgical techniques. Nevertheless, the driving force behind enabling aortic surgery and making it safer lies not so much within the way we pass the needle through the tissue but rather in preoperative assessment, advances in perioperative management, new devices, genetics and imaging. In an interesting series of articles on "200 years of surgery" in the New England Journal of Medicine,[2] the authors illustrated that the rapid advances in surgery during the end of the 19th and beginning of the 20th century have largely been driven not by surgical technique itself but rather enabling the development of new techniques through the advent of anesthesia, antisepsis and later antibiotics.

While surgery has progressed since the time of ether anesthesia, advances in surgery still depend on advances in perioperative medicine. Classic complications in aortic surgery have been myocardial failure, bleeding and stroke. The first two have almost been eliminated by advances in perioperative management. Modern cardiopulmonary bypass concepts coupled with effective cardioplegia protocols have virtually eliminated post-cardiotomy failure. And, if it occurs, temporary mechanical circulatory support will bridge the time until recovery. More recently, several groups have advocated beating-heart total arch replacement thereby further reducing cardiac ischemic time.[3] While exact hemostasis is still an important part of a successful aortic operation, advances in blood product management have not only contributed to effective hemostasis in many patients but also made it safe to administer these products.

Stroke remains the nemesis of aortic surgeons whether open or endovascular surgery is performed. In fact, stroke rates in open and endovascular total arch repair are surprisingly similar. Advances in temperature management and cerebral perfusion driven by detailed cerebral imaging has lowered the risk for stroke but it remains high with 10% of patients experiencing neurological events during total arch repair.[4] Cerebral protection devices have so far not proven to be effective and the search is ongoing. Developing a tool that significantly reduces stroke rate in aortic surgery is probably the holy grail in our field at this point.

Surgical technique

While many advances in surgical technique have been gradual improvements, the introduction of the frozen elephant technique (FET) has been transformative for the field of aortic surgery (Figure 1, Panel B). Interestingly, for the first decade after its introduction, it remained a device that was used very sparingly. Over the past 10 years, the use of FET has exploded and now routinely enables one-stage repair of thoracic aortic aneurysm, comprehensive treatment of type A aortic dissection and hybrid repair of thoracoabdominal disease. Most surgeons now use some form of debranching thereby reducing circulatory arrest time. Likewise, performing an early proximal anastomosis enables early cardiac reperfusion with many surgeons using the beating-heart technique to completely avoid cardiac ischemia.

After the first FET studies reporting a high rate of stroke and spinal cord ischemia,[5] most centers started to perform surgery at lower temperatures again.[6] While most surgeons now perform total arch repair between 24-26°C, there is a strong trend towards using tailored selective antegrade cerebral perfusion strategies and warmer temperatures. The future will certainly see further modifications of the FET with e.g., branched grafts for the left subclavian artery and other supraaortic branches. FET has greatly reduced the number of Crawford type II thoracoabdominal repairs, especially those with circulatory arrest. Contemporary data has shown that dividing thoracoabdominal repair into several steps reduces the overall risk of the patient.[7] Nowadays, most patients undergo total arch replacement first using FET, followed by TEVAR and then either F/BEVAR or a so called open "III and ½ repair" which seems to have a significant lower risk than a Crawford type II repair.

This trend will most probably continue and I would predict that most patients with complex aortic disease will undergo both, open and endovascular repair over the course of their lifetime.

Aortic centers

In the eye of the public, successful surgery is still very much associated with the surgeon performing the procedure. Nevertheless, there is evidence showing that excellent surgeons were not able to reproduce their results in other hospital settings. Aortic surgery is very much a team sports. In order to provide excellence in care, creation of aortic centers is of paramount importance. Data from Medicare patients undergoing surgery for type A dissection shows that not only are outcomes better when patients are treated in a high-volume aortic center but surprisingly, results were also better when patients were transferred to a high-volume aortic center from a different hospital even in the acute setting.[8] We have to establish functional units that combine experts from different specialties in one team. Promoting subspecialization is therefore a necessity. Integrating counseling, imaging, molecular diagnostics, surgical care and long-term follow-up within a functional unit is the future of aortic medicine.

Endovascular vs. open repair

There is a lot of enthusiasm in the field with regard to advances in total endovascular arch repair. Nevertheless, the number of patients that are eligible is still quite limited. In a retrospective study by the Philadelphia group looking at patients undergoing re-do total arch repair, only 26% would have been eligible for endovascular repair. Common problems preventing endovascular repair are large ascending aortic diameter, short or kinked grafts, arch angulation and dissected supraaortic branches. Furthermore, results of total endo arch repair are quite sobering. In a large systematic review, mortality was 4-5% and stroke 11-12%.[9] This is in line with a multi-center study using a double branch device with 9% in-hospital mortality, 7% disabling and 19% non-disabling stroke.[10]

Aortic surgeons take care of very different patient populations. While a child born with Marfan syndrome today can enjoy an almost normal life expectancy, we have to accept that all-cause mortality in patients presenting with intramural hematoma is 20-25% after 6 years with less than half of it being aortic-related.[11] Therefore, patient characteristics are important. My prognosis is that technical limitations of the devices will gradually subside and we will be moving towards an even more patient centered decision where we discuss not so much feasibility but the impact of surgical trauma vs. durability depending on life expectancy. It is important that we as surgeons focus on treating a certain disease and not on performing a specific procedure. Patients benefit from integrated care in multidisciplinary team.[12] The next frontier in aortic surgery is certainly the endovascular treatment of the ascending aorta and especially the aortic root. While data on endovascular ascending aortic repair for compassionate use in type A dissection shows that it is more than feasible,[13] endovascular repair of the ascending aorta is associated with a high reintervention rate. There are unique challenges to treatment of the proximal aorta, especially pulsatile movement of aorta, proximity to the left ventricle and the coronary ostia as well as curvature of the ascending aorta. The idea to combine a transcatheter valve and a stent graft to repair the aortic root has already been around for some time but management of the coronary arteries remains a challenge.

Aortic surgery will provide surgeons with many challenging situations in the years to come. The widespread use of FET or F/BEVAR devices lead to increasingly difficult situations in cases of vascular graft infection which has become a silent epidemic. More and more patients will present with complex situation after multiple operations and we will face difficult decision with failure of endovascular repair over time implanted in younger patients.

Identifying patients at risk

Acute type A aortic dissection is associated with a 10-25% in-hospital mortality depending on patient characteristics and experience of the center. A large number of patients dies before reaching the hospital or even been diagnosed with this

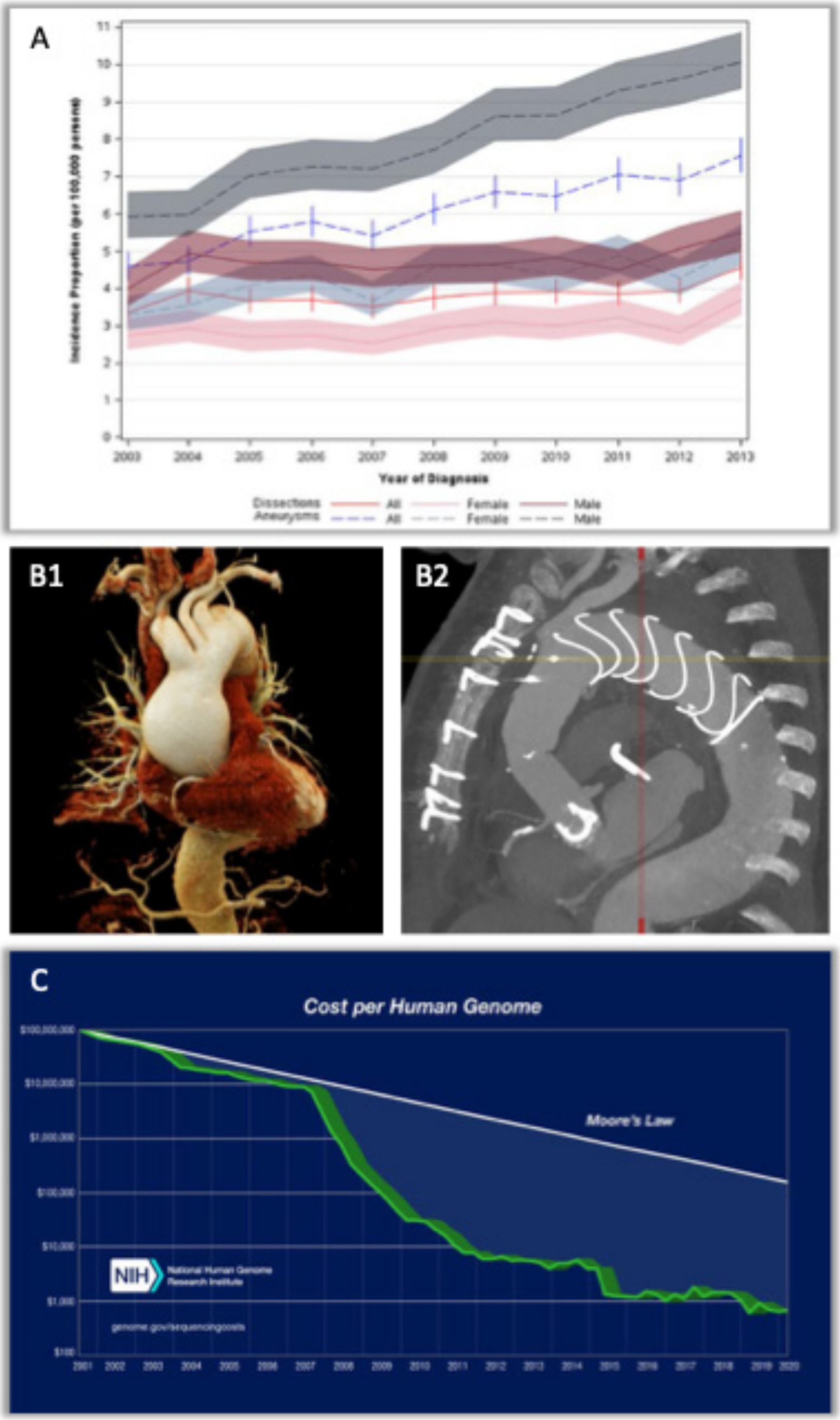

Figure 1

Panel A: Increasing incidence of aortic disease (from McClure RS et al, 20181).
Panel B1 and B2: The frozen elephant trunk, a disruptive technology in aortic surgery.
Panel C: Costs of genetic testing constantly decreasing (from https://www.genome.gov/about-genomics/fact-sheets/DNA-Sequencing-Costs-Data).

disease. This is in stark contrast to elective surgery in which mortality is 0.4% for aortic root replacement in selected series.[14] We have to realize that identifying patients at risk will save more lives than any change in surgical technique. Implementing screening programs for aortic aneurysms is an important but neglected field of aortic surgery. Imaging has become such an important part of medicine that many patients undergoing imaging for different reasons could potentially be identified as having aortic aneurysm. Aortic arch anomalies, cerebral aneurysm, aneurysms of the visceral arteries, asymptomatic localized dissections or even renal cysts are all associated with thoracic aortic aneurysm and should prompt a systematic screening. While the current guidelines provide more and more granular advice regarding the indication for surgery, they still largely rely on aortic diameter. I am convinced that in the future genetic analysis will become an integral part of the decision-making process in the way computed tomography or magnetic resonance imaging (MRI) do now. The cost of sequencing an entire human genome have decreased from 1 billion USD for the first one to 600 USD today (Figure 1, Panel C). While there are still additional costs of analysis to consider, costs of genetic testing will soon be in line with that of a contrast MRI (cMRI). While we will most likely see few new monogenic diseases, other forms of genetic information will certainly become important tools. Researchers evaluating data from >30.0000 people in the UK biobank were able to predict thoracic aortic disease and the need for surgical intervention using polygenic risk scores and automated extraction of aortic diameter by cMRI.[15]

While I certainly agree with Niels Bohr that "predictions are difficult, especially about the future", I am very much looking forward to the future of aortic surgery.

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