Game-changers in the making of contemporary vascular surgery

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In June 1902, a 29-year-old French surgeon published an original technique of vascular anastomosis that was never conceived before in the field of surgery, together with his work on organ transplantation. His interest in the field of vascular anastomosis led him to be the youngest physician to be awarded a Nobel Prize [1].

This French surgeon was Dr. Alexis Carrel. He was highly disappointed with the inability of the surgeons of his faculty to save the French President Sadi Carnot's life after a fatal stabbing which caused the portal vein to be severed. This spurred Dr. Carrel to design a novel procedure to perform the anastomosis: eversion of the edges of the endothelial surfaces with smooth jawed forceps to avoid endothelial injury that could precipitate thrombus formation [1]. His techniques laid the groundwork for other surgical techniques such as organ transplantation to develop; and his technique was used in Vienna to perform the first successful autotransplantation of a kidney in a dog in 1902.

In the 1940s-1950s, little was known on the definitive treatment for an abdominal aortic aneurysms (AAA) and cellophane was being experimented with as a material to reinforce vessels by inducing fibrosis [3]. It was used to wrap around the aorta like a constrictive wrapper, and the immune response that is triggered against the "foreign body" leads to fibrosis that narrows the aorta where it is affected. This technique was used to reinforce Albert Einstein's aortic aneurysm by an eminent surgeon, Dr Rudolph Nissen in 1948. When it finally ruptured 7 years later, doctors could not stop the internal bleeding [2].

Dr Michael DeBakey's contribution to vascular surgery

After Einstein's death, in the mid-1950s, prosthetic graft replacement for aortic aneurysms had become a reality, thanks to the creative efforts of Dr. Voorhes, Dr. Edwards and Dr. DeBakey. Their innovative ideas led to the change in paradigm of management of vascular disease in their time. The Dacron® graft replacement was the brainchild of Michael DeBakey and his wife. Before that, there was no effective treatment of abdominal aortic aneurysms that could prevent lethal rupture in patients. Dacron® was used only because the departmental store ran out of nylon material and he was offered that [4]. He bought the Dacron®, and used his wife's home sewing machine to create Dacron® tubes. After years of laboratory work and surgical experimentation with dogs, he was convinced to try it on patients. Aneurysm repair using Dacron® tubes is still widely used today.

He also developed the technique of endarterectomy of occluded superficial femoral arteries from Dr Joao Cid dos Santos in 1953 and used it to relieve atherosclerotic occlusion of carotid arteries [12]. Now, carotid endarterectomy is a surgical procedure widely used to reduce the risk of stroke from stenosed arteries, commonly in the common carotid or internal carotid artery. [13]

How did the other techniques of minimally invasive surgery come into the picture?

Dr Charles Dotter, a radiologist from the University of Oregon was the first to describe and perform an endovascular

intervention. In a 1963 address at the Czechoslovakia Radiologic Congress, he envisioned that "the angiographic catheter can be more than a tool for passive means for diagnostic observation; used with imagination it can become an important surgical instrument." [5]. His idea was to treat vascular disease from within the blood vessel, a procedure known as percutaneous angioplasty, which does not require a huge exposure of the artery and can accelerate post-surgical recovery time.

Dr Dotter described the procedure of transluminal angioplasty in 1964, coined "dottering the lesion" [4] for arterial stenosis and occlusions using graduated Teflon dilators passed endoluminally under fluoroscopic guidance.

However, the greatest contribution to vascular surgery was probably from Dr Juan Parodi, who bridged the divide between general surgery and vascular surgery by combining the technology of Dacron® graft with the innovation of endovascular therapy, thereby changing the paradigm of the management of vascular disease. He performed the first successful endovascular aortic repair (EVAR) of an abdominal aortic aneurysm in 1990, subsequently used not only for aortic aneurysms but dissections, transections and other aortic pathology [4].
After the invention of the Dacron® graft, open replacement of the aorta was the gold standard for treatment to repair an abdominal aortic aneurysm. The minimally invasive procedure of endovascular aneurysm repair (EVAR) had been rejected initially in the field of vascular surgery, because it had been way ahead of its time.

Contemporary vascular surgical techniques paving the way for vascular neurosurgery

At the same time, advancements in vascular surgery began to influence the field of neurosurgery, paving the way for endovascular treatment of brain aneurysms. The treatment of vascular disease led to the conception and development of endovascular balloons, which would be inflated with a solidifying substance and then detached, thereby occluding the blood supply of the aneurysm but preserving the parent artery. However, this presented different problems such as delayed rupturing or recanalization (blood clots forming in the vessel and causing chronic obstruction) and was surpassed by the use of coils in the late 1980s. The early coils were rigid and inflexible, and proved to be inadequate as an alternative to the use of balloons. Then in 1991, Guglielmi et al developed platinum coils that were electrolytically detachable which could adopt the shape of the aneurysm and not have the same deforming pressure on fragile vessel walls. Recurrence of the lesion with bare platinum coils were a problem but 10 years later, these coils were further developed to release bioactive substances to promote better "healing" of vessel walls [10].

How would Einstein's situation be changed by the advancement of modern techniques?

It was said that his repaired aneurysm was "the size of a grapefruit" which would have measured at least 10cm. A 2001 review of life expectancy of patients whose aneurysm measured > 7cm and refused surgery showed that the median survival was only 9 months [6]. Hence, his prognosis would not have been much different, although we now have guidelines that require doctors to refer any patient with an abdominal aneurysm larger than 5.5cm for surgery repair [7]. When performed electively, the operative mortality rate is about 5% while the mortality rate is about 50% if the aneurysm has ruptured [8]. Operating on aneurysms <5cm does not seem to improve the long term survival of

patients.
The combination of vascular grafts with the innovation of endovascular therapy has completely transformed our understanding and management of arterial disease. Multiple randomized trials confirms the benefit of endovascular repair in relation to post-operative mortality rates, allowing EVAR to become a commonly accepted treatment option in the modern day [9]. Improvement in modern imaging technologies have also contributed significantly to the management of these patients, where CT / MRI angiography has replaced arteriography to allow rapid and accurate visualization of the abdominal aorta, and evaluation of disease severity, greatly improving patient survival rates.

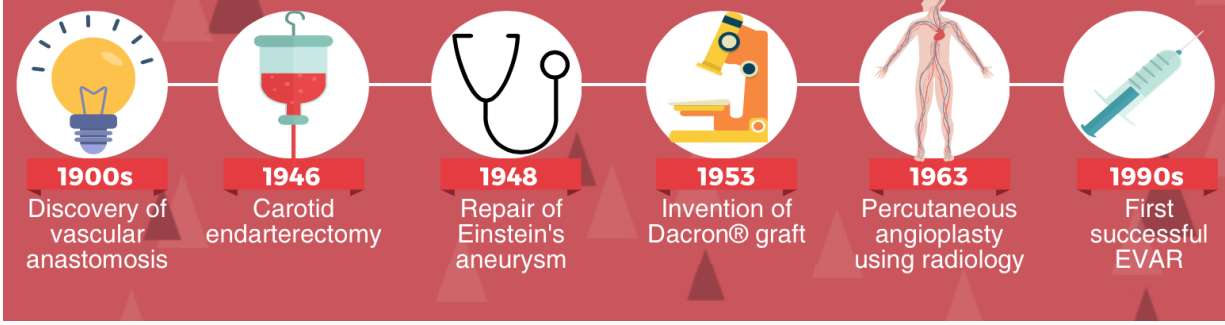
The landscape of modern vascular surgery since its recognition as a unique specialty in the 1960s is rapidly changing with creative innovation and novel technologies, disrupting the established order and creating a new order. The success of vascular surgery is not without the efforts of these surgeons and innovators, who had the vision and foresight to challenge existing paradigms and ways of thinking, establishing its independence as a unique specialty.

What is the future for contemporary vascular surgery?

Moving forward, it is paramount for vascular surgery to stay ahead and keep an open mind to new technology and innovations, as evidenced by its history. The use of imaging techniques was pivotal to the success of vascular surgery in order to allow measurement of physiological blood flow objectively and noninvasively. Newer techniques such as rotational digital angiography now allow 3-dimensional assessment of the aneurysm [10], vastly improving surgical outcomes.

Three-dimensional (3D) printing is also a highly advantageous strategy in the field of surgery as it allows planning of the procedure by mapping out precise anatomy, making prosthesis and implants that are tailored to each patient. Although trials and studies are still underway to ensure that we can make the best use of the given technology with the lowest cost and greatest efficacy, it may well be the answer to the already bright future of contemporary vascular surgery [11].

Game changers in the making of contemporary vascular surgery



1964 **Intracranial catheterisation**

1974 **Balloon angioplasty**

1988 **Platinum and bioactive coils**

Different modalities of vascular disease management

- **Carotid endarterectomy**
  - Carotid stenosis
  - Peripheral arterial disease
- **Endovascular aneurysm repair (EVAR)**
  - Abdominal aortic aneurysm
  - Aortic dissection
- **Vascular neurosurgery**
  - Intracranial aneurysms
  - Arteriovenous malformation
- **Future treatment options**
  - Rotational digital angiography
  - Three-dimensional printing

References

1.Langer, R. and Kahan, B. (2002). Alexis Carrel's legacy: visionary of vascular surgery andorgan transplantation. Transplantation Proceedings, 34(4), pp.1061-1066.

2.Columbiasurgery.org. (2017). History of Medicine: The Ingenious Surgery that Saved the World's Smartest Man | Columbia University Department of Surgery. [online] Available at: http://columbiasurgery.org/news/2015/08/27/history-medicine-ingenious-surgery-saved-world-s-smartest-man-1 [Accessed 18 Jan. 2017].

3.Lesney, M. (2012). Einstein's Aneurysm: Of Cellophane and Rudolph Nissen. [online] Vascular Specialist. Available at: http://www.mdedge.com/vascularspecialistonline/article/83664/einsteins-aneurysm-cellophane-and-rudolph-nissen [Accessed 19 Jan. 2017].

4.Weaver, F. (2014). Disruptive technology and the making of contemporary vascular surgery. Journal of Vascular Surgery, 60(5), pp.1376-1382.

5.Dotter CT. {1965) Cardiac catheterization and angiographic technics of the future. Background and current status of clinical catheter angiography. Cesk Radiol 19(4), pp.217-36.

6.Conway, K., Byrne, J., Townsend, M. and Lane, I. (2001). Prognosis of patients turned down for conventional abdominal aortic aneurysm repair in the endovascular and sonographic era: Szilagyi revisited?. Journal of Vascular Surgery, 33(4), pp.752-757.

7.Nice.org.uk. (2017). Endovascular stent–grafts for the treatment of abdominal aortic aneurysms | 2-Clinical-need-and-practice | Guidance and guidelines | NICE. [online] Available at: https://www.nice.org.uk/guidance/ta167/chapter/2-clinical-need-and-practice [Accessed 21 Jan. 2017].

8.Lowenfels, A. (2002). Famous Patients, Famous Operations, Part 3. [online] Medscape. Available at: http://www.medscape.com/viewarticle/436253 [Accessed 19 Jan. 2017].

9.Endovascular versus Open Repair of Abdominal Aortic Aneurysm. (2010). Journal of Vascular Surgery, 52(1), p.252.

10.Guglielmi, G. (2009). The beginning and the evolution of the endovascular treatment of intracranial aneurysms: from the first catheterization of brain arteries to the new stents. Journal of Neurointervention Surgery. 1, pp. 53-55

11. Li, C., Cheung, T., Fan, V., Sin, K., Wong, C. and Leung, G. (2017). Applications of Three-Dimensional Printing in Surgery. Surgical Innovation, 24(1), pp.82-88.

12.Eastcott, H., Pickering, G. and Rob, C. (1954). Reconstruction of internal carotid artery in a patient with intermittent attacks of hemiplegia. The Lancet, 264(6846), pp.994-996.

13.Nhs.uk. (2017). Carotid endarterectomy - NHS Choices. [online] Available at: http://www.nhs.uk/Conditions/Carotidendarterectomy/Pages/introduction.aspx [Accessed 1 Mar. 2017].