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Film and Filament: Early Techniques in the Surgical Treatment of Aortic Aneurysms

Craig A. Miller

Dublin, Ohio, USA. Email: *drcraigamiller@gmail.com*

Abstract

Advances in surgical technique and technology in the 1950s rendered cardiovascular pathologies that had seemed impervious to surgical intervention amenable to safe and successful operative strategies. Among these disease entities was aortic aneurysm, a diagnosis of dread and death prior to that decade. Before this revolution in vascular surgery, well-meaning but desperate clinicians who dealt with aortic aneurysms devised methods of treatment that were ineffective, often dangerous, and, to modern eyes, sometimes baffling. This article will discuss these futile approaches, which included wrapping the aneurysm in cellophane film (as was done in the case of Albert Einstein) and the introduction of metal wire into the aneurysm sac to induce thrombosis, sometimes with the fruitless and hazardous addition of connecting the wire to a live electrical battery. The retreat of these failed techniques in the face of evolving modern surgical approaches will be discussed as well.

Keywords

Aortic aneurysm, Aneurysm, Surgery, Ligation, Cellophane, Wire, Galvano-puncture

Introduction

For most of human history aortic aneurysm has been a diagnosis of dread and despair.[1] Attempts at surgical correction were almost universally unsuccessful and the typical outcome, with or without intervention, was death. It was only in the 1950s that intrepid

[1] The spelling of 'aneurism' was used almost exclusively in English language publications until the mid-to-late nineteenth century, when the change to 'aneurysm' began, reflecting a scholarly push toward the etymological origins of the term. In this paper the spelling utilised by the original authors will be retained.

surgical pioneers such as Charles Dubost (1914-91) in Paris, Russell Brock (1903-80) in London, and Michael DeBakey (1908-2008) in Houston, buoyed by recent advances in surgical technology and technique, began to report cases of successful repair of aortic aneurysms.[2] Before that, well-meaning but hapless practitioners struggled to care for their affected patients, sometimes conjuring interventions that appear, to modern eyes, bizarre.

Aneurysms are dilatations of blood vessels to 1.5 times the normal diameter or greater. This expansion occurs in response to weakening in the vessel wall. Although many risk factors have been identified in the development of aneurysms – including smoking, hypertension, and genetic predisposition – the fundamental underlying aetiology remains elusive. Those aneurysms of greatest clinical significance arise in the arterial system. Intracerebral versions are associated with haemorrhage and cerebrovascular accidents, while those in the peripheral circulation are more frequently prone to thrombosis and embolisation, with ischaemic sequelae. Aortic aneurysms arise throughout the vessel but are most frequently encountered in the abdominal portion. Left untreated, they may continue to expand, resulting in eventual rupture with attendant haemorrhage, the most feared and dire clinical scenario and one which often results in death. Despite the development of successful surgical techniques, aortic aneurysms remain a significant public health concern, with over 5,000 reported deaths in the United Kingdom annually. The term pseudoaneurysm, or 'false aneurysm', refers to a disruption of the vessel wall which can lead to contained extravasation, mimicking the clinical presentation of aneurysm.[3]

Antiquity

Aneurysms and the threats they pose were recognised in ancient times, with the earliest surviving reference widely attributed to the Ebers Papyrus, an Egyptian medical text from the sixteenth century BCE. The author of the relevant section described a bold approach to treatment:

> When you identify an *a'at* growth [aneurysm] of the vessels on any body part of a man, [and] you find it throbbing and firm when handled under your fingers, and where it separates from his flesh, without being large … then you say for this: 'This is an *a'at* growth of the vessels, a disease that I will treat.' It is the vessels that cause it. It has developed as a result of an injury to a vessel. Because of this you then prepare a knife-treatment for it. The knife is to be heated in a fire. The growth should not bleed too much.[4]

The optimism of the final statement may not have borne out in the application.

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[2] Miller CA. *A time for all things: the life of Michael E. DeBakey*. Oxford: Oxford University Press; 2019.

[3] Rutherford RB. *Vascular surgery, Vol. 1*. Fifth Edition. Philadelphia PA: W.B. Saunders Co; 2000. p.373-382.

[4] Papyrus Ebers. Universitätsbibliothek Leipzig. https://papyrusebers.de (accessed 12 Mar 2025). Eb 872 (108, 3 – 108, 9).

In the second century CE, Galen (129-c216) applied the Ancient Greek term for widening ('aneurysma') to denote the pathology in question, although some sources give credit to Rufus of Ephesus (110-180). Galen's succinct and accurate description indicates familiarity with pseudoaneurysms, which might be expected given his occupation as physician to gladiators:

> Aneurysma is the name given to the condition where an artery is dilated. It occurs after trauma to the artery, whenever the skin above it has formed into a scar and the wound to the artery remains unhealed, not completely cicatrised and unprotected by flesh … if the aneurysm is damaged, blood spurts out and is very difficult to control.'[5]

Ligation of peripheral artery aneurysms

The first reasoned approach to the surgical treatment of aneurysms came from Antyllus (dates unknown), a Greek physician practicing in Rome in the second century CE. Though his original writings are lost, fragments of Antyllus' work have come down to us from the compilations of the fourth-century physician and encyclopaedist Oribasius (320-403), among other sources. Antyllus advocated ligating the affected artery proximal and distal to its aneurysmal segment, then opening the sac to evacuate the contents. In this way the threat of rupture was eliminated. Evidently, hard experience had taught him to pack the sac but leave the vessel intact: 'Ligating the artery on both sides, as just described, and then excising the dilated portion in the middle, is a dangerous operation; often, in fact, the force and tension of the arterial blood pressure dislodge the ligatures'.[6]

In the sixth-century work *De vasorum dilatation*, the Byzantine physician and scholar Aëtius of Amida (502-575) discussed aneurysms and their surgical treatment, describing his approach to such lesions of the brachial artery:

> An aneurysm located in the bend of the elbow is treated thus. First, we carefully trace the artery leading to it, from armpit to elbow, along the inside of the upper arm. Then we make an incision on the inside of the arm, three or four finger-breadths below the armpit, where the artery is felt most easily. We gradually expose the blood vessel and, when it can be lifted free with a hook, we tie it off with two firm ligatures and divide it between them. We fill the wound with incense and lint dressing, then apply a bandage. Next, we open the aneurysm itself and no longer need fear bleeding. We remove the blood clots present and seek the artery which brought the blood. Once found, it is lifted free with the

[5] Lytton DG, Resuhr LM. Galen, on abnormal swellings. *Journal of the History of Medicine and Allied Sciences*. 1978; 33: 545-546.

[6] '*Lier, comme il vient d'être dit, l'artère des deux côtés, puis extirper la partie dilatée qui se trouve au milieu, est une opération dangereuse; souvent, en effet, la violence et la tension du pneuma artériel repoussent les ligatures'*. Oribase. Collection Médicale. Livre XLV. 24. De l'anévrisme - tiré d'Antyllus. In: *Oeuvres d'Oribase, Vol. 4.* Bussemaker UC, Daremberg C (trans). Paris: Imprimerie Impériale; 1862. p.54. Author's translation.

> hook and tied as before. By again filling the wound with incense, we stimulate good suppuration.[7]

In ensuing eras others, such as Albucasis (al-Zahrawi, 936-1013) of Cordoba in the tenth century, left similar accounts. These records indicate that early surgeons never strayed far from the recommendations of Antyllus. Such operations were restricted to the extremities. Indeed, the very identification of aneurysms in that greatest of arteries, the aorta, did not occur until the sixteenth century. This 1557 discovery is credited to the pioneering anatomist Andreas Vesalius (1514-64), whose friend, the equally-celebrated surgeon Ambroise Paré (1510-90), went on to describe a case of ruptured aneurysm of the thoracic aorta. The characteristically humble Paré observed with resignation that, 'Aneurysms occurring in the inward parts are incurable'.[8]

John Hunter's (1728-93) famously successful 1785 operation, essentially a modification of the ligation technique of Antyllus (although Hunter did not mention his ancient predecessor and may not have known of his work) was performed on a popliteal artery aneurysm of the leg. Hunter's improvement involved ligating the superficial femoral artery, the inflow vessel to the aneurysm, at some distance from the lesion (in the space now known as 'Hunter's canal'), reflecting his recognition from prior experience that nearer the aneurysm this artery, although normal in appearance, might be, in fact, degenerate and likely to disintegrate from the ligature, with disastrous consequences.[9]

Sir Astley Cooper (1768-1841), a disciple of Hunter and, like him, a master surgeon and educator with innumerable contributions to medical science, extended the technique of aneurysm ligation to the carotid and femoral arteries, still within the peripheral circulation. In his most famous case, however, Cooper broadened the surgical horizon much wider. In 1817 he attended the case of a man admitted to Guy's Hospital with a rapidly expanding external iliac artery aneurysm. Recognising that a fatal rupture was imminent, Cooper took the extraordinary step in this pre-anaesthetic, pre-Listerian era of ligating the patient's distal abdominal aorta through a small transperitoneal incision. The patient succumbed 40 hours later, but Cooper had demonstrated that, Paré's earlier admonition notwithstanding, such an operation was technically possible.[10]

Cooper had both admirers and detractors in the surgical community regarding this case. When surgeons in the admiring category were faced with similar scenarios they emulated Cooper's approach, though always with the same, grave result. After Cooper's operation, ligation of the abdominal aorta, typically for aortic aneurysm, was followed

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[7] Aëtius of Amida. *Contractae ex Veteribus Medicinae Tetrabiblos*. Cornarius J, translator. Basel: Froben; 1542. p.312.

[8] Paré A. *The Workes of that Famous Chirurgion Ambrose Parey*. Translated by Thomas Johnson. London: Th. Cotes and R. Young; 1634. Book XI, p.429. The French physician Antoine Saporta (1507-1573) wrote a Latin manuscript describing a thoracic aortic aneurysm in 1554 but this was not published until 1624.

[9] Hunter J. *A Treatise on the Blood, Inflammation, and Gun-Shot Wounds*. London: John Richardson; 1794. p.246-252.

[10] Cooper A. Case of a successful ligature of the abdominal aorta. *Medico-Chirurgical Transactions*. 1817; 9: 223-233.

by death in every reported case for the next century. The cause was, of course, interruption in the blood supply of the body below the point of ligation.[11]

Rational efforts were made to defeat this seemingly insurmountable obstacle by means of a known physiological compensatory phenomenon, collateralisation. Before 1800, Hunter and others had observed the re-routing of blood supply pathways around occluded arteries, preventing distal ischemia. The mechanism of the effect was poorly understood (as it remains today) but its reality, especially in cases of gradual occlusion, was undeniable. Accordingly, some clinicians attempted to harness collateralisation in the setting of aortic ligation by obliterating the lumen in a stepwise fashion over a matter of days or weeks. This only became practical after anaesthesia and aseptic principles allowed safe surgical entrée to the abdominal cavity in the late nineteenth century. In time, sophisticated devices were introduced to gradually constrict the aorta above the aneurysm. Such luminaries as William Stewart Halsted (1852-1922) of Johns Hopkins, who favoured a metal band, applied the technique in the early twentieth century.[12]

Medical, excisional and compression therapies in peripheral and aortic aneurysms

In the years after Cooper's well publicised 1817 case, even as the drive to extend a surgical approach to aneurysms of the aorta came under consideration, an understandable impetus to develop alternatives to the ligation method, age-old but clearly suboptimal, began to coalesce. Amputation, advocated by Percival Potts (1714-1788) and others in the previous century, could be curative in aneurysms of the limbs, although perioperative mortality and long-term disability were undeniable obstacles.[13] Medical therapies also emerged, typically with the sensible goal of lowering the heart rate and blood pressure. Oral potassium chloride was foremost of these, but, despite some positive reports, they were of limited benefit.

Since the true goal of interventional aneurysm therapy to this point was thrombosis of the lesion, which was the outcome of successful ligation and occasionally observed to occur spontaneously, many physicians attempted external compression in hopes of diminishing blood flow sufficiently to achieve this. Such highly regarded figures as Paul Broca (1824-80) argued for this approach, and it remained in vogue throughout the nineteenth century.[14] Catastrophic experience with direct pressure on aneurysms, which often led to embolisation of mural thrombus or iatrogenic rupture, convinced physicians to apply the pressure to the relatively normal inflow and/or outflow arteries. Manual pressure, elastic bandages and mechanical devices were all utilised, sometimes with success, especially in peripheral aneurysms. The injection of substances such as gelatin into the aneurysm sac was also attempted in an effort to induce thrombosis.[15]

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[11] Cooper BB. *The Life of Sir Astley Cooper, Bart, Vol. 2.* London: Harrison & Co; 1843. p.199-207.
[12] Halsted WS. Partial, progressive and complete occlusion of the aorta and other large arteries in the dog by means of the metal band. *Journal of Experimental Medicine*. 1909; 11(2): 373-391.
[13] Potts P. *Remarks on the necessity and propriety of the operation of amputation in certain cases.* London: J Johnson; 1808.
[14] Broca P. *Des Anévrysmes et de leur Traitement*. Paris: Labé; 1856.
[15] Matas R. Aneurism. In: Keen W (ed). *Surgery, its principles and practice, Vol. 5*. Philadelphia: W B Saunders; 1906. p.249-250.

Needle insertion in peripheral and aortic aneurysms

In 1826 Sir Everard Home (1756-1832), who happened to be Hunter's brother-in-law, reported in the *Philosophical Transactions of the Royal Society* a case in which his initial treatment of an aneurysm of the external iliac artery, namely ligation distal to the lesion, a technically simpler but physiologically flawed variation introduced by the French surgeon Pierre Brasdor (1721-99),[16] failed to have the desired effect. Home then briefly placed a percutaneous needle into the aneurysm 'connected with a heated bar of steel.' Over the next several weeks the aneurysm grew and became more painful, probably due to the combination of its primary outflow having been tied off, infection from the introduction of bacteria via the unsterilised needle, and a component of pseudoaneurysm induced by the puncture. Undeterred, Home repeated the procedure two more times on the unfortunate patient. Ultimately, he achieved apparent thrombosis of the aneurysm, but the outcome was far from ideal: 'The tumour was solid to the touch, and there was no return of pulsation in it. The leg, however, soon afterwards became oedematous, mortification ensued, and the patient died …'. Despite this dismal outcome, Home concluded his report with the remarkable comment that the case 'proved that coagulation of the blood in an aneurismal sac, by the means pointed out in this paper, is not only practicable, but that it may be resorted to without the production of any important local or constitutional symptoms'.[17]

A few years after Home's report articles appeared in both the Paris and London *Medical Gazette* journals describing experiments by the noted French surgeon ALM Velpeau (1778-1862) in which needles were inserted into the arteries of dogs to induce thrombosis, with the hope of clinical adaptation in humans: 'It is suggested as possible that even aneurisms of the external iliac, or of the aorta, might thus be cured'.[18]

Shortly after this, the Welsh surgeon Benjamin Phillips (1805-61) published an 1832 pamphlet in London descriptively titled *A series of experiments performed for the purpose of showing that arteries may be obliterated without ligature, compression or the knife*. Herein he reported studies in which, like Velpeau, he inserted needles into the femoral and carotid arteries of dogs, successfully inducing intraluminal clot formation.[19]

If the methods of Velpeau and Phillips were ever extended to actual patient care in their time the record has not come down to us, but later in the century Sir William MacEwen (1848-1924) of Glasgow reported placing needles into aneurysms of the aorta, subclavian artery and femoral artery in a similar fashion.[20] Modifying the technique by leaving the needles *in situ* for 24 hours, but periodically redirecting the

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[16] Brasdor P. Mémoire sur les anévrysmes, et sur la ligature des artères. *Mémoires de l'Académie Royale de Chirurgie.* 1775; 5: 261–280.

[17] Home E. On the coagulation by heat of the fluid blood in an aneurismal tumour. *Philosophical Transactions of the Royal Society*. 1826, Part III, 189.

[18] Velpeau M. Memoir on the acupuncture of arteries in the treatment of aneurism. *London Medical Gazette*. 1830-31; 7: 499.

[19] Phillips B. *A series of experiments performed for the purpose of showing that arteries may be obliterated without ligature, compression, or the knife*. London: Hurst, Rees, Orme, Brown, and Green; 1832.

[20] Macewen W. An address on aneurysm: its cure by inducing the formation of white thrombi within the sac. *British Medical Journal*. 1890; 2(1560): 1164-68.

needle to different areas of the aneurysm sac, MacEwen's goal was to achieve thrombosis by scratching the endothelium of the aneurysm in many places. In Keen's surgery textbook of 1906, Rudolph Matas (1860-1957) remarked that this method had been abandoned 'on account of its uncertainty, the difficulty of limiting the effect of the puncture to the internal surfaces, and the fact that the aneurism is already lined with laminated clot'.[21]

Galvano-puncture in peripheral and aortic aneurysms

In the same 1832 pamphlet noted above, Benjamin Phillips described a variation on the needle insertion method for the induction of arterial thrombosis: the application of a galvanic current to the ends of two needles inserted into the vessel. The observation that electrical current could cause intravascular clot formation had been noted as early as 1824 by Charles Scudamore (1779–1849) in his monograph, *An Essay on the Blood*.[22] Phillips duplicated these results and 'became strongly impressed with the belief that arteries might be obliterated by galvanic action'. Considering applications in the clinical realm, he remarked:

> I cannot conceal from myself the conviction, that, wherever we find an aneurysmal sac, we may with impunity introduce into it attenuated needles, for the purpose of conducting a stream of galvanism, and thereby produce the coagulum of its fluid contents … If further experience shall confirm the correctness of these observations, I can scarcely conceive the existence of any case of aneurism which may not be successfully treated by the methods which I have now made known.[23]

Despite these sanguine hopes, galvano-puncture did not gain either immediate or widespread acceptance. Cautiously optimistic reports from the French surgeons Charles Pravaz (1791-1853) and Joseph-Pierre Petrequin (1809-76), among others, did not appear until the next decade.[24] Perhaps the most enthusiastic purveyor of the technique in ensuing years was Luigi Ciniselli (1803-78) of Cremona. He wrote on the topic from 1847 to the 1870s, including a monograph called *On Electropuncture in the Treatment of Aneurysms: Studies and Observations*, published in 1856. In this work, Ciniselli reported 50 cases of galvano-puncture in the treatment of aneurysms, with no less than 50% cures and a mere 14% mortality (the mortality from ligation was 33%). Notably, only five of the reported cases were in aortic aneurysms.[25]

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[21] Matas. Aneurism, 1906 (Note 15). p.251.

[22] Scudamore C. *An essay on the blood: comprehending the chief circumstances which influence its coagulation; the nature of the buffy coat; with a concise medical view of the state of the blood in disease; and an account of the powers of a saturated solution of alum, as a styptic remedy in hemorrhage.* London: Longman, Hurst, Rees, Orme, Brown, and Green; 1824.

[23] Phillips. *A series of experiments,* 1832 (Note 19). p.63.

[24] Petrequin JPE. Nouvelle méthode pour guérir certains anévrysmes sans opérations à l'aide de la galvano-puncture. *Comptes Rendus de l'Académie des Sciences* 1845; 21: 992-996.

[25] Ciniselli L. *Sulla elettro-puntura nella cura degli aneurismi : studj et osservazioni.* Cremona, Tipografia Vescovile Feraboli; 1856.

These early investigators were aware of the deleterious effects the procedures could engender. Inflammation of the aneurysm was reported as both a complication of the procedure and desired effect *en route* to thrombosis. More troublesome was inadvertent cauterisation of the skin or aneurysm wall, which could lead to abscess, sloughing and haemorrhage. There was no question that the therapy could be highly unpleasant for the patient, particularly from charring of the skin caused by the electrical current. In 1866 the Scottish surgeon John Duncan (1839-99) observed 'the most intense pain is often experienced during the operation, so great, indeed, as to cause convulsions and alarming syncope …'.[26]

The following year Duncan reported a case in which he used the galvano-puncture method on a 52-year-old man at the Barnhill Hospital in Glasgow. The patient presented with an enlarging pulsatile mass extending two inches from his chest wall, to the right of the sternum. Duncan made the diagnosis of thoracic aortic aneurysm with 'the tendency to death by external hemorrhage' and 'determined to attempt its delay by means of electricity'. He applied current through two needles placed percutaneously into the aneurysm (Figure 1).

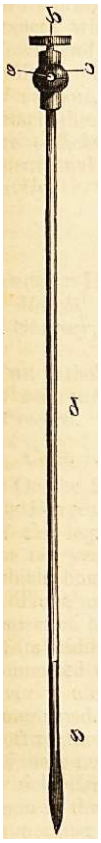

Figure 1. A woodcut of John Duncan's puncture needle which was presented in actual size in his 1866 publication (Note 26). The segment labelled *a* is the non-insulated steel portion, about one and 1/8 inches in length; *b* is the insulated portion, of about three and ¼ inches in length. The wire from the battery was inserted into the hole, *e*, in the brass head, *c*, and secured with the screw top, *d*.

[26] Duncan J. On the galvano-puncture of aneurisms. *Edinburgh Medical Journal.* 1866; 11: 928.

The needles were insulated with glass and gutta percha to prevent skin burns, although the glass broke and the rubber melted. Despite the procedure, the aneurysm continued to grow afterwards and a month later Duncan repeated his efforts on the still-hospitalised patient. The postoperative course was duplicated – this time accompanied by skin necrosis and abscess formation – and, a few weeks later, the aneurysm eroded through to the surface. The haemorrhage that ensued was 'so copious that, after soaking through the bed, it formed a pool on the floor. From this the patient died'. A sobered Duncan remarked that 'Galvanism in aortic aneurism is to be regarded … as a means of prolonging life in exceptional circumstances'.[27]

Enthusiasm for direct electrification of aneurysms to initiate thrombosis faded shortly afterward, but in the next decade a variation on the theme arose that would endure to the modern era.

Filament packing in aortic aneurysms

In 1864 surgeon Charles Moore (1821-70) of the Middlesex Hospital reported a new technique for aortic aneurysm treatment: packing the aneurysm sac with a foreign body from the outside, to induce thrombosis. The patient in question was a 27-year-old man who presented with signs and symptoms of a large thoracic aortic aneurysm, similar to the case that would be reported by Duncan three years later. Moore realised that this case would also end in fatal haemorrhage if left untreated. He recalled examples from Holmes's *System of Surgery,*[28] in which foreign bodies were found in the arteries of anatomical specimens, surrounded by fibrin clot. Reasoning that he could incite such an effect in this aneurysm, Moore opted to pack the sac with the most thrombogenic (but, he considered, least irritating) material that came to his mind: coils of iron filament. He inserted the impressive length of 26 yards of this wire through a cannula placed percutaneously into the aneurysm. The patient died five days later. Careful clinical descriptions and the autopsy findings make it clear that death was from bacterial sepsis, a diagnosis of which the author could not have been aware, undoubtedly caused by the non-sterile wire in this pre-Listerian period. Once again, the physician involved felt that, despite the outcome, the technique had demonstrated what might today be termed 'proof of concept': at autopsy the aneurysm sac was found to be nearly thrombosed. Moore was astute enough, though, to recognise that there was room for improvement in the method: he speculated about other wire materials and the ideal amount to be introduced. He also identified possible technical pitfalls with considerable insight, observing that this new approach should be applied only in cases of saccular aneurysm (bulging out of

[27] Duncan J, Fraser TR. On the treatment of aneurism by electrolysis with an account of an investigation into the action of galvanism on blood and on albuminous fluids. *Edinburgh Medical Journal*. 1867; 13: 105.

[28] Holmes T (ed). *A System of Surgery, Theoretical and Practical, Vol. 3*. London: Longman, Green, Longman, and Roberts; 1860. p.194–198.

the side of the aorta), not fusiform (spindle-shaped) and recognising the risk of both perforation and embolisation.[29]

In the decades that followed, physicians documented their experiences with the filament packing method. Some replicated Moore's use of iron wire, while others experimented with alternatives such as silver, copper, or steel wire, watch springs, and even horsehair. In the early twentieth century, George H Colt (1878-1957) in Aberdeen devised an ingenious apparatus for the filament packing procedure consisting of 'a trocar and cannula, a ramrod, a tube, and a wisp'.[30] The wisp, which was intended to minimise embolic events, was an umbrella of fine steel wire which could be compacted to fit into the cannula, expanding when inserted into the aneurysm sac in the manner of some modern endovascular devices. The Colt apparatus also eased the procedure of inserting great lengths of wire. With the advent of asepsis, general anaesthesia and the expansion of surgery into the peritoneal cavity, surgeons could more safely and precisely place packing materials into the exposed aorta (Figure 2).[31]

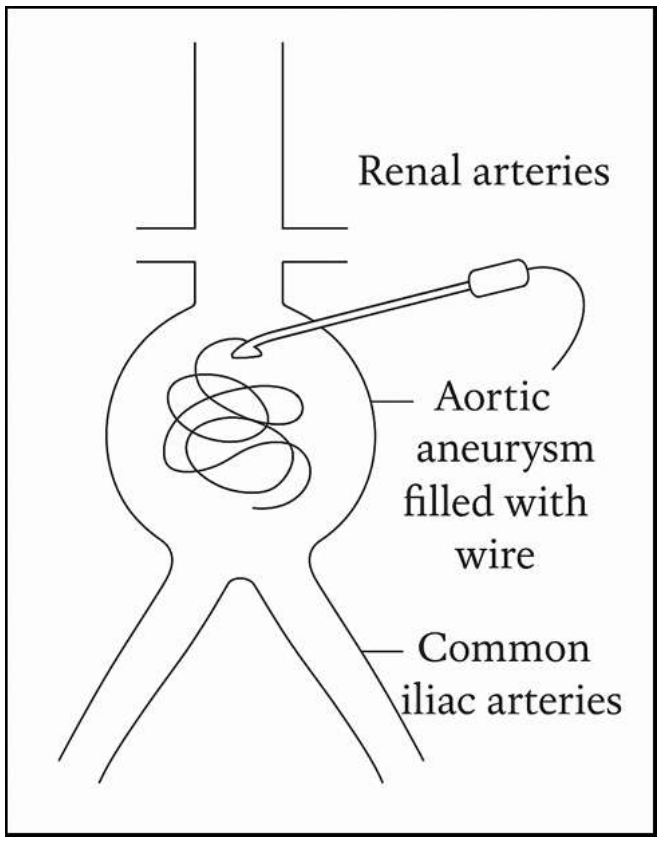

Figure 2. The technique of filament packing. Author's illustration. © Craig A Miller.

[29] Moore CH, Murchison CM. On a new method of procuring the consolidation of fibrin in certain incurable aneurisms with the report of a case in which an aneurism of the ascending aorta was treated by the insertion of wire. *Medico-Chirurgical Transactions*. 1864; 47: 129-149.
[30] Colt GH. The treatment of aneurisms by wire insertion. *Practitioner.* 1925; 115: 221–227.
[31] de Takats G, Marshall MR. Surgical treatment of arteriosclerotic aneurysms of the abdominal aorta. *AMA Archives of Surgery*. 1952; 64(3): 307-319.

None of these advancements led to especially encouraging results. Yet, lacking a better alternative—and given the fatal trajectory of untreated aortic aneurysms—the filament packing method persisted (Figure 3).

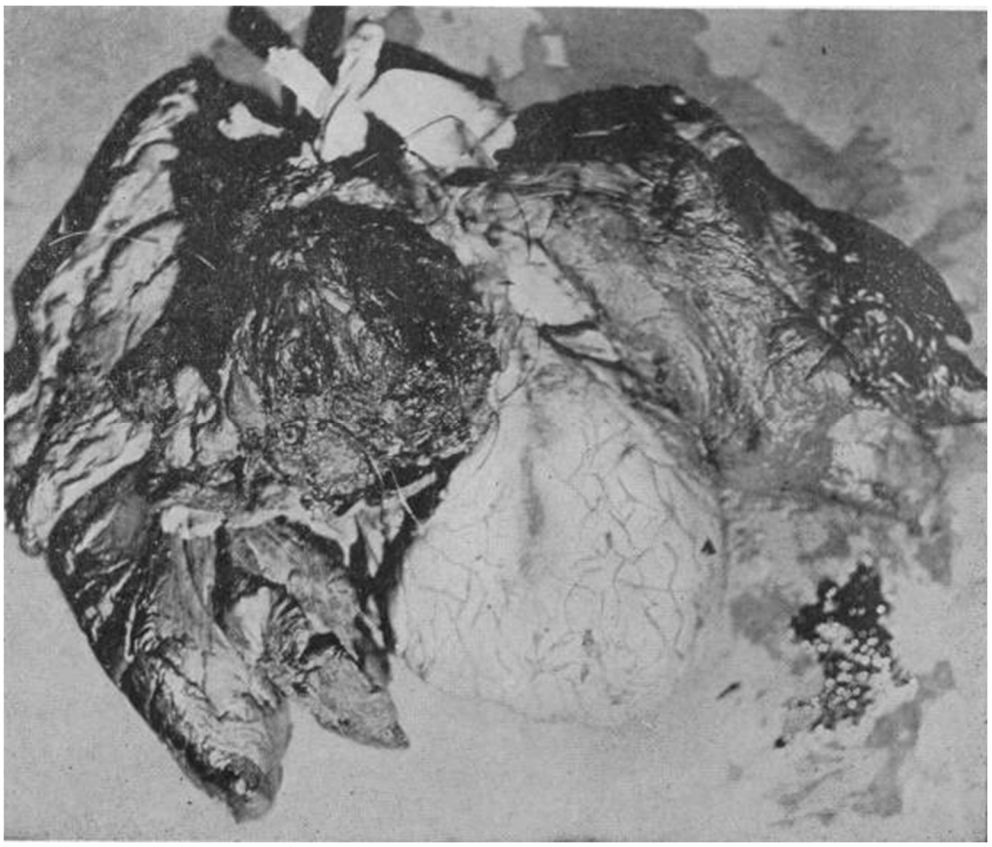

Figure 3. Autopsy photograph of blood clot formation around wire coiled in an opened aneurysmal sac. From: Finney JMT. The wiring of otherwise inoperable aneurysms. *Annals of Surgery*. 1912; 55(5): 661–681.

Interestingly, in the modern era of vascular intervention, the technique of intentionally inducing occlusion of vessels with packed wire coils has returned: for example, in the treatment of some visceral and intracerebral aneurysms, generally via endovascular catheterisation.

Combined wire insertion and electrolysis in aortic aneurysms

Given their theoretical appeal but disappointing practical results, it was probably inevitable that the techniques of filament packing and galvano-puncture would eventually be combined. The author of this innovation was Alfonso Corradi (1833-92) of the University of Pavia, who published his early work with the technique in 1879. Corradi inserted 40 cm of wire into an aneurysm, then connected the positive pole of a battery to the protruding end and the negative pole to an area on the patient close to the

lesion.[32] Once again, success was elusive, but this did not stop others from following suit (Figure 4).

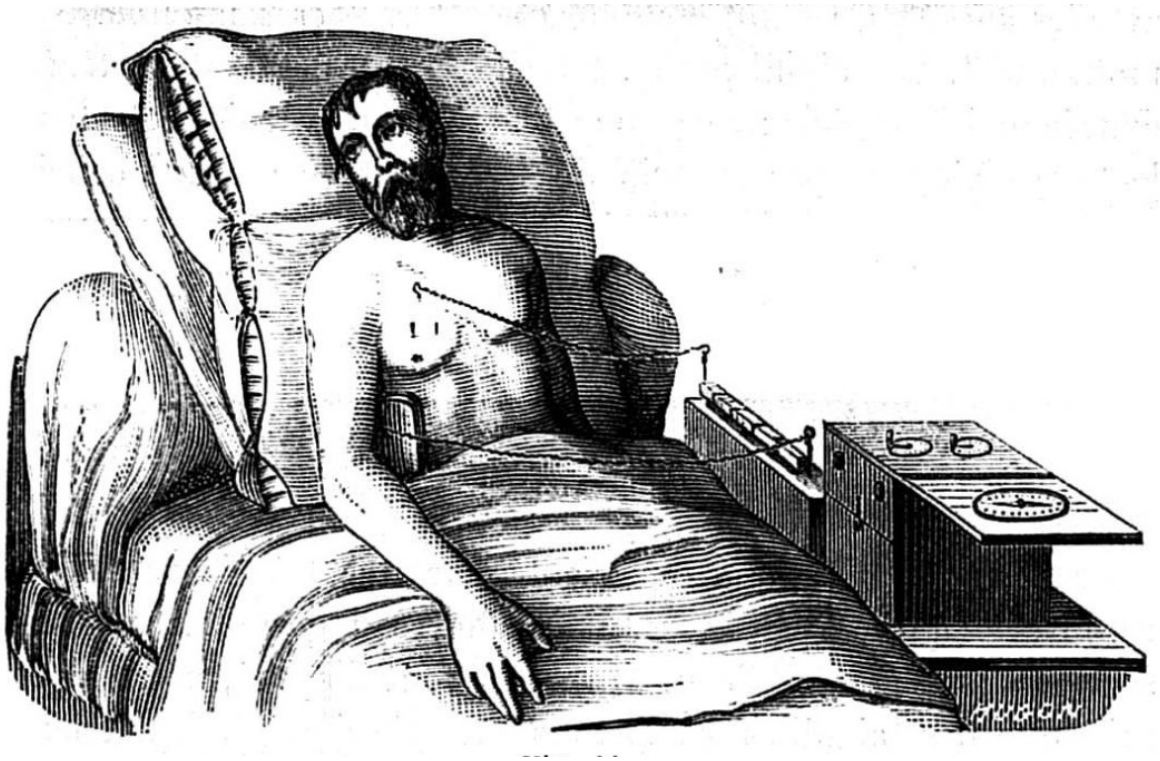

Figure 4. Image of a patient being treated for aortic arch aneurysm by galvano-puncture. From: Dujardin-Beaumetz G. Note sur un cas d'anévrysme de la crosse de l'aorte traité par l'électro-puncture. *Bulletin général de thérapeutique médicale et chirurgicale*. 1877; 93(1): 1-14. p.12. Source: Université Paris Cité. Open licence. https://numerabilis.u-pariscite.fr/

In 1900 Guy Hunner (1868-1957) of Johns Hopkins University summarised the reported world experience in what became known as the Moore-Carrodi technique up to that time: 23 cases of aortic aneurysm had been treated in this way, seventeen in the thorax and six in the abdomen. Only four were reported cured, a questionable conclusion based on the relief of pain. Hunner also collected the cases treated by Moore's wire method alone; of the fourteen he could identify, just two were reported cures.[33]

With the turn of the century, surgeons modified the Moore-Corradi technique with the packing apparatus of Colt and direct surgical exposure of the aorta, although results remained unimpressive. In 1912 Henry A Christian (1876-1951) of Harvard University reported on 40 cases of thoracic aortic aneurysm treated by wiring, with a 25% fatal

[32] Corradi G. Dell'aneurisma curato coll'introduzione di corpi estranei nella cavità del sacco. *Annali Universali di Medicina*. 1879; 251: 225–240.

[33] Hunner GL. Aneurism of the aorta treated by the insertion of a permanent wire and galvanism (Moore-Corradi method) with a report of five cases. *Bulletin of the Johns Hopkins Hospital*. 1900; 11: 263–279.

rupture rate within seven months of operation.[34] In 1921 Sir D'Arcy Power (1855-1941) noted 21 cases, with a 33% two-month mortality from rupture.[35]

In 1938 Arthur Blakemore (1897-1970) of Columbia Presbyterian Hospital reported his experience with the electrified wire technique, a sample of the state of this arcane art some 60 years from its description. Emphasising the role of blood velocity reduction by the wire and the need for consistent, high temperature (they aimed for 80 degrees Celsius), Blakemore's team reported considerable success (defined by them as relief of pain and absence of aneurysm growth) which was, unfortunately, not seen by others.[36] The erstwhile New York City surgeon-scientist was still performing cases using the modified Moore-Corradi procedure into the mid-1950s. By that time, however, surgeons and investigators, including Blakemore himself, were moving in a new and fruitful direction.[37]

Wrapping of peripheral and aortic aneurysms

A radically different approach to the challenging problem of aortic aneurysms arose for a short time in the 1940s. Experimental observations had demonstrated that certain chemical irritants could cause the development of progressive fibrosis in human tissue. Among these were the ingredients of the packing material cellophane, which was found to generate dramatic fibrotic responses in perirenal and pulmonary tissues. Research-minded surgeons also showed that the film could induce occlusion of the aorta in dogs.[38] It was an obvious extension to consider whether such a response in the vicinity of an aortic aneurysm could either occlude the vessel or encase it in dense fibrous tissue, providing external support to the weakened vessel wall and preventing rupture. In 1943 Paul Harrison (1883-1962) and Jacob Chandy (1910-2007) reported from Bahrain the cellophane wrapping of a subclavian artery aneurysm with successful occlusion of the vessel. Although the process took nineteen months to reach completion, the authors considered this an advantage, since collateralisation evidently took place and ischaemic complications were avoided. Within a few years the technique was applied to aortic aneurysms (Figure 5).[39]

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[34] Christian HA. The treatment of thoracic aneurysms by the introduction of wire. *Boston Medical and Surgical Journal*. 1912; 166: 845-849.

[35] Power D. The palliative treatment of aneurysms by 'wiring' with Colt's apparatus. *British Journal of Surgery*. 1921; 9(35): 346-352.

[36] Blakemore AH, King BG. Electrothermic coagulation of aortic aneurysms. *Journal of the American Medical Association* 1938; 111(20): 1821-27.

[37] In the 1920s in Boston the biophysicist Thomas Bovie and noted neurosurgeon Harvey Cushing began clinical use of an electrocautery device both to cut and cauterise tissue. This harnessing of the electrocoagulation effect has become ubiquitous in the surgical setting.

[38] Pearse HE. Experimental studies on the gradual occlusion of large arteries. *Annals of Surgery.* 1940; 112(5): 923–937.

[39] Harrison PW, Chandy J. A subclavian aneurysm cured by cellophane fibrosis. *Annals of Surgery*. 1943; 118(3): 478-481.

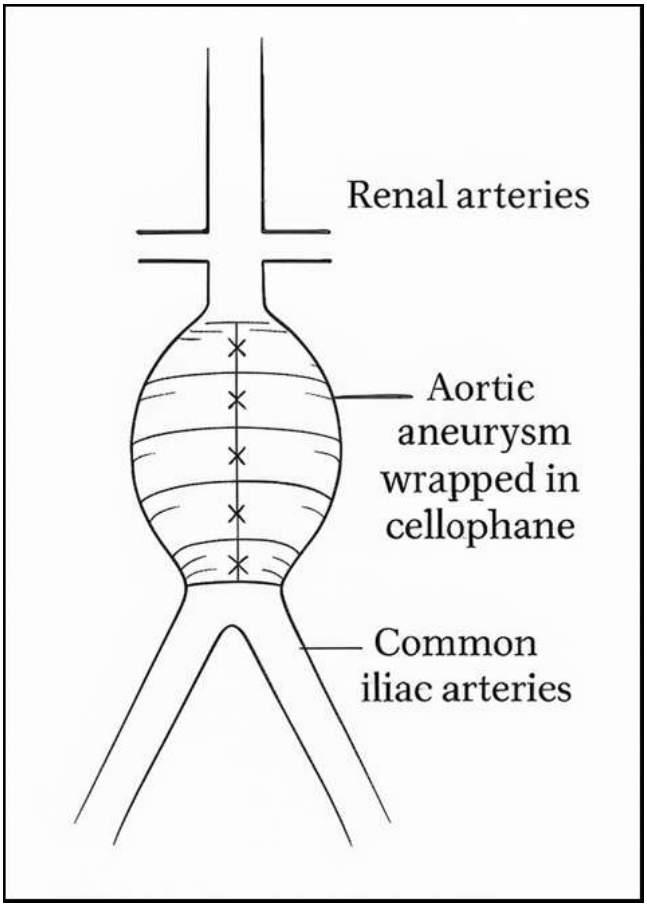

Figure 5. The technique of cellophane wrapping in a case of abdominal aortic aneurysm. Author's illustration. © Craig A Miller.

The first of these reports, from J Karl Poppe (1911-2012) and H Renault de Oliveira (dates unknown) in 1946, demonstrated satisfactory results (relief of pain) in thoracic aneurysms.[40] However, careful follow up in succeeding years, sometimes in hybrid procedures such as wrapping combined with partial ligation, did not bear out the early optimism of the technique.

The most famous instance of the utilisation of cellophane wrapping in the case of an aortic aneurysm occurred in December 1948 at the Jewish Hospital in Brooklyn. At that time the great physicist Albert Einstein (1879-1955), who had suffered from recurrent, severe abdominal pain, underwent exploratory laparotomy (a standard practice in the era preceding sophisticated imaging techniques) performed by the noted surgeon Rudolph Nissen (1896-1981). Einstein was found to be harbouring a large, non-ruptured aortic aneurysm and, aware of the recent reports, Nissen, who had suspected this diagnosis from his physical examination, wrapped the anterior two-thirds of the aneurysm in cellophane film. Unfortunately, the famous scientist suffered rupture of this aneurysm in April 1955. The role of the cellophane wrap in possibly delaying this event is debatable but, by the mid-1950s, far more effective operative alternatives were

[40] Popp JK, de Oliveira HR. Treatment of syphilitic aneurysms by cellophane wrapping. *Journal of Thoracic Surgery*. 1946; 15: 186-195.

available (see below). One of the pioneers in the field, Michael DeBakey, was contacted about operating on Einstein, whose rupture was not immediately fatal. Although DeBakey agreed to proceed, Einstein demurred with the graceful observation: 'I want to go when I want. It is tasteless to prolong life artificially. I have done my share; it is time to go. I will do it elegantly'.[41]

In the 21st century a variation on the wrapping technique, the Personalised External Aortic Root Support (PEARS) procedure, would be introduced.[42]

Summarising the state of abdominal aortic aneurysm surgery in 1951, Geza de Takats (1892-1985) of the University of Illinois noted presciently: 'While the results are far from satisfactory, enough data have been assembled to warrant a further attempt, possibly with a more direct surgical approach to the sac'.[43]

The advent of modern techniques

The first major step toward the modern surgical treatment of aneurysms came in 1889, when Rudolph Matas (1860-1957), at the Charity Hospital in New Orleans, took an entirely novel approach in the case of traumatic brachial artery pseudoaneurysm. Confused by his inability to achieve success with proximal and distal ligation – the aneurysm in question remained a pulsatile, tense mass – Matas took the dramatic, risky step of opening the sac. In the wash of arterial blood that flooded the operative field Matas was able to identify collateral vessels feeding the lumen. He sutured shut the orifices of these arteries, a technique he called endoaneurysmorrhaphy, which both cured the aneurysm and preserved the collateral circulation to prevent distal ischaemia. The patient recovered uneventfully. Although it would be decades before Matas's ingenuity could be applied to the aorta, this was the first definitive step forward in the surgical treatment of aneurysms since Antyllus.[44]

Aortic aneurysms of the early twentieth century fell into two main categories: syphilitic and atherosclerotic, and the differences were not just in aetiology. Syphilitic (luetic) aneurysms were more common, they arose in younger patients, were almost invariably in the thoracic aorta, and tended to be saccular. Atherosclerotic aneurysms, by contrast, typically appeared in older patients, were most often found in the abdomen, and generally were fusiform.

Surgeons of the time considered the leathery walls of syphilitic aneurysms to be easier and safer to sew than the fragile, crumbling vessels of atherosclerotic lesions. Thus, once the challenge of opening the thorax to surgical exposure had been met, saccular syphilitic aneurysms could sometimes be excised from the side of the aorta with the vessel partially clamped, then the defect sutured closed (Figure 6). This approach was current by mid-century, but its application was limited. With the advent of antibiotics, atherosclerotic aneurysms became the more common variety and in these the partial clamp/excisional approach could not be used.

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[41] Miller. *A time for all things*, 2019 (Note 2). p.266-268.

[42] Pepper J, et al. The Personalized External Aortic Root Support (PEARS) procedure: mid-term results from the first 100 patients. *Heart.* 2015; 101(5): 380–387.

[43] de Takats, Marshall. Surgical treatment of arteriosclerotic aneurysms, 1952 (Note 31).

[44] Matas, R. Traumatic aneurysm of the left brachial artery. *Medical News.* 1888; 53: 462-466.

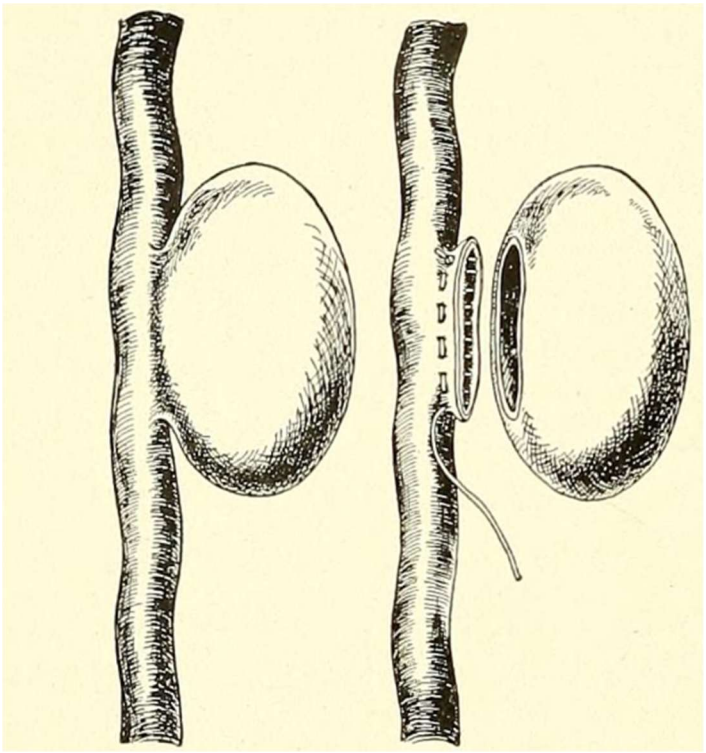

Figure 6. The technique of lateral aneurysmorrhaphy in a saccular aneurysm, especially applicable in luetic cases. From: Matas. Aneurism, 1906 (Note 15). p.286.

A key jump forward came from the wards and laboratories of Boston Children's Hospital, where Robert Gross (1905-88) and his team laid the groundwork for successful repair of the congenital narrowing of the thoracic aorta, known as coarctation, in the early 1940s. In the first such operations the narrowed aortic segment was excised and the ends apposed primarily, but in some cases this was not possible due to the length of the diseased region. To address these cases Gross conceived the idea of interposing lengths of cadaveric aorta into the defect.[45] In 1950 Jacques Oudot (1913-53) in Paris successfully employed the same technique to replace a segment of aorta occluded by atherosclerosis and the stage was set.[46]

In March of 1951 Charles Dubost, also in Paris, successfully resected an aortic aneurysm in a 50-year-old man, replacing it with the aorta of a twenty-year-old automobile accident victim. The patient lived another eight years before succumbing to a myocardial infarction. Dubost's case report appeared in the March 1952 issue of *Archives of Surgery*.[47] Later that year, Brock, Ormand Julian (1913-87) in Chicago, and DeBakey performed similar operations. DeBakey's report of his first case, at a meeting of the Southern Surgical Association in Florida in December, 1951, came in the

[45] Shumacker HB. *The Society for Vascular Surgery: A History: 1945-1983*. Manchester MA: The Society; c1984. p.70.
[46] Oudot J. La greffe vasculaire dans les thromboses du carrefour aortique. *Presse Médicale*. 1951; 59: 234-236.
[47] Dubost C, Allary M, Oeconomos N. Resection of an aneurysm of the abdominal aorta. *Archives of Surgery.* 1952; 64: 405-408.

discussion following a presentation by Blakemore of his most recent results with the Moore-Corradi technique.[48]

Unfortunately, such aortic 'homografts' were found to disintegrate over time, necessitating the development of synthetic arterial substitutes. (Homograft replacement was the operation Michael DeBakey planned for Albert Einstein if he had been given the opportunity.). A dramatic, worldwide search for the proper material for this exacting purpose ensued, which devolved on Dacron and a few other plastic fabrics. After these prosthetic aortic grafts came into widespread use in the late 1950s, the age-old reputation of aortic aneurysms as incurable death sentences was finally eliminated for good. There were technical modifications to the procedure, such as Oscar Creech's (1916-67) application of Matas's endoaneurysmorrhaphy method, but open repair of aortic aneurysms by graft replacement remained the standard of care until the endovascular revolution of the 21st century.[49]

In the majority of instances today, aortic aneurysms are repaired with 'stent-grafts' composed of tubular, fabric-coated metal frames which can be deployed through peripheral arteries using catheters. Despite the prevalence of the new minimally invasive techniques, open graft replacement for aortic aneurysms is still utilised in certain circumstances.[50]

Summary

Though their methods may seem outlandish, misguided, or even harsh to modern observers, the physicians of the past who tackled the formidable challenge of aortic aneurysms deserve our admiration for their pioneering efforts. Despite blind alleys and seemingly endless clinical disappointments, these individuals persevered in their efforts, and their professional descendants eventually conquered the most fearsome of diagnoses. In some cases, most notably the treatment by wire coiling of some visceral and intracerebral aneurysms and the PEARS procedure, in which the aortic root is encircled in a custom-tailored mesh, the filament packing and film wrapping techniques pioneered by these earlier surgeons have returned to common use in the modern era, albeit in different guises.[51]

Aortic aneurysms remain a significant public health issue due to their high mortality in rupture, with up to 80% fatality rates, causing approximately 5,000 deaths annually in the United Kingdom, mainly among men over 65. Since they are often asymptomatic

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[48] Blakemore AH. Progressive constrictive occlusion of the aorta with wiring and electrothermic coagulation for the treatment of arteriosclerotic aneurysms of the abdominal aorta. *Transactions of the Southern Surgical Association*. 1952; 64: 202-219.

[49] Miller. *A time for all things*, 2019 (Note 2). p.298.

[50] Wanhainen A, Van Herzeele I, Goncalves FB, Montoya SB, Berard X, Boyle JR. *et al*. European Society for Vascular Surgery (ESVS) 2024 Clinical Practice Guidelines on the Management of Abdominal Aorto-Iliac Artery Aneurysms. *European Journal of Vascular and Endovascular Surgery.* 2024; 67(2): 192-331.

[51] Guglielmi G, Viñuela F, Dion J, Duckwiler G. Electrothrombosis of saccular aneurysms via endovascular approach. Part 2: Preliminary clinical experience. *Journal of Neurosurgery.* 1991; 75(1): 8–14.

prior to rupture, screening efforts are vital. The NHS Abdominal Aortic Aneurysm Screening Programme offers men aged 65 and older screening ultrasound (women can apply but are not automatically offered due to their lower incidence of the disease). Data from 2019–20 showed 291,904 men tested, with 1,542 aneurysms identified. A total of 875 patients with large aneurysms (≥5.5 cm) were referred for surgery, achieving a 94.5% elective repair rate.[52]

[52] Public Health England. *NHS Abdominal Aortic Aneurysm (AAA) Screening Programme: AAA standards report 2019 to 2020.* Published 25 February 2021. Gov.uk. https://www.gov.uk/government/statistics/abdominal-aortic-aneurysm-screening-standards-report-2019-to-2020/aaa-standards-report-2019-to-2020#referral (accessed 17 Nov 2025).

Biographical details

Craig A Miller MD FSVS FACS is Attending Vascular Surgeon, United States Veterans Administration and Scholar-in-Residence, Medical Heritage Center, The Ohio State University College of Medicine, and Michael E. DeBakey Fellow in the History of Medicine, National Library of Medicine.

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