A Timeline History of Aortic Disease and Therapies, Including Surgery

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Introduction

Aortic disease has long been recognized for its potentially lethal and life-altering effects. Patients have thus presented a therapeutic challenge to physicians for hundreds of years (centuries) as to the treatment options and potential benefits or results. This book presents a large number of aortic disease entities, the patient concerns, the options and the risks for their treatment.

Development of modern aortic disease diagnosis and therapy programs has required not only a great deal of effort but decades of research and therapeutic trials to reach the current level of knowledge and results [1]. The twentieth and twenty-first century advancements and investigations have led to the present level of aortic therapeutics and utilization.

The timeline for delineation of the efforts required to perform modern aortic surgery and the usage of the aorta for non-aortic diagnostic and therapeutic approaches has been slow to develop with many "road blocks" to reach the current level of aortic manipulation, as well as the possible errors in timeline dates and reporting of data or experience. The delineation of various accessory modalities required in the steps over the past centuries (especially the last two) includes such "inventions" as electricity; anesthesia, both general and local; radiology and x-ray techniques; and diagnostic contrast materials demonstrable on radiographic film. All of these considerations and many more, such as cardiopulmonary bypass, and infection control, have been necessary to develop the field of aortic diagnostics and therapeutics. Herein outlined are many of the events which have led to the current ability to diagnose and treat a large number of aortic lesions. Interspersed in the outline, we have added a few of our steps in the chain of aortic "adventures."

This chapter is dedicated to Dr.John Laird for his contribution to education and the treatment of vascular diseases

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Timeline of Aortic Surgery Development

I. *Early Aortic Aneurysm History: 2000 B.C. to 1700s* [2]
   A. The early ancient Egyptian medical text, the *Ebers Papyrus*, one of the earliest known medical writings, describes aneurysms as "tumors of the arteries"—cured only via magic. Peripheral aneurysm treatment should consist of "with a knife and burn it with fire so that it bleeds not too much" and boiling oil treatment [3].
   B. The early Indian text *Sushruta Samhita* noted that aneurysms upon bursting exhibited a rapid flow of hot and red blood and that when situated at any of the vital parts of the body they should be deemed incurable [4].
   C. Ancient Greeks attributed disease to an imbalance of mythological humors—similar to Sushruta [5].
      1. Aristotle's contemporary, Praxagoras, believed epilepsy was due to phlegm accumulation within the aorta.
      2. Hippocrates (460–357 B.C.), a Greek, gave us the "Hippocratic Oath."

R. S. Dieter et al. (eds.), *Diseases of the Aorta*, https://doi.org/10.1007/978-3-030-11322-3_1

(a) No mention of aneurysms but, ligation of arteries, would stop bleeding
(b) Father of Medicine
3. A.D. 97—Archigenes used ligation in limb amputation.

D. Roman Empire
1. Galen (130–200 A.D.) described aneurysms "as the pulse and beating the arteries make and that the tumor vanishes when the artery is pressed down" [6].
(a) Probably treated aneurysms with bloodletting (venesection) [7].
(b) Noted risks of venesection (VS) is aneurysm development near the incision [8].
(c) Also mentioned VS avoidance near large arteries due to increased risk of fatal aneurysms.
(d) Crucial in the development of anatomy and modern surgery.
2. Praxagoras—influential physician of the "dogmatic" school of medicine [8].
3. Antyllus, "Father of Aneurysm Surgery"—his surgery methods were followed for over a millennium (1000 years) despite unfavorable survival rates [8].
(a) Antyllus method was the first attempt at abdominal aortic aneurysm repair: "ligation of artery above and below the aneurysm followed by incision and emptying the sac"
4. Actius, 200 years later—vague aneurysm classification and postulated improvements in the Antyllus method [9]

E. Medical era (next 8–15 centuries)—little advancement

F. Era of inquiry
1. Astronomy, mathematics, and navigation (with Columbus discovering America in 1492)
2. Lancisi, in 1490, delineated true/false aneurysms, vessel calcification and recognized. Syphilis relationship—prescribed rest, sparse diet, bleeding and herbal palliation [10].
3. Vesalius, in his text in 1543, mapped the definitive course of aneurysm disease [10].
4. René Laennec invented the stethoscope.
5. Dietary treatment/fluid restriction/bed rest advocated for centuries into 1800s [11].

G. Harvey's definition of circulation rather than "to and fro." Statues of early notable physicians, including Harvey, are exhibited in the International Museum of Surgical Science "Hall of Fame" by the International College of Surgeons, Chicago, Illinois, USA

H. Hallowell, in 1762, repaired a brachial artery

I. John Hunter ligated the proximal superficial femoral artery to treat a pulsating popliteal aneurysm in 1785—a new beginning [12]

J. Animal experimentation programs developed

II. *1800s*

A. Better recognition by physicians of aortic disease entities.

B. Anesthetics developed—one wonders "what did they use in the past"—high-quality alcohol or strong men.

C. Electricity "harnessed" and electric lights followed Thomas Edison's work.

D. Increased animal lab usage and facilities.

E. 1817: Cooper (Hunter's student) ligated the aorta proximal to an iliac aneurysm after having ligated a dog aorta in 1809 [13].

F. 1869: Charles Moore successfully inserted 78 feet of thin wire into an ascending aortic aneurysm—unfortunately the patient died of sepsis 5 days later [14].

G. William Halsted at Johns Hopkins designed a progressive metal band aortic occlusion technique—most patients died. Later, Elkin located 25 attempts with five survivals using this treatment [15, 16].

H. In the late 1800s—Medical school education was improving

I. Medical inventions followed the enhancement of the profession
1. Development of hypodermic needles and syringes.
2. Blood clotting of the aneurysms with gelatin therapy—similar techniques were available since early Egypt—received support as did various metallic items and pins [17].
3. Steel watch band insertion.
4. Electricity was added to the wire treatments by others (such as Corrali, an Italian physician, in 1881) as the techniques became more widespread and persisted into the 1970s (Charles Rob) [18].

J. In 1885, Buck summarized "Aneurism Treatment to Date" in his text [18] to include:
1. Rest, blood in good chemical condition, be recumbent, slow to sit, walk slowly after months of treatment, no ire or increased emotions, no valsalva, and bloodletting which could lead to anemia
2. Decreased food intake (8 ounces solid 6 ounces liquid), laxatives/saline purgatives
3. Medications:
(a) Iodide of potassium: to thicken the aneurysm wall and possibly thicken the blood, potash (I_2 of Potassium). If the patient is unable to tolerate KI then sodium iodide (NaI_2) is to be used.
(b) To thicken the blood/slow circulation
1. Ergotine subcutaneous for constriction of the aorta or oral ergot
2. Digitalis

(c) Acetate of lead or tannic acid until deep blue lines developed on the gums
(d) Chloride of Barium
4. Surgery
(a) Ligate vascular branches
(b) Ligate aorta above aneurysm or below
(c) Introduce foreign body to induce clots (fine wine, watch springs, horsehair—unfortunately, they all also caused infection)
(d) Constriction or compression apparatus or by hand/Esmarch elastic bandage
5. Coagulation
(a) Galvanic puncture using battery electricity with one or two needles connected to a positive pole and a negative plate on the abdomen for 20–30 minutes to induce clot formation—repeat 2–3 days or even every 2–3 hours
(b) Coagulating injectables:
1. Medicines
2. Solid items
6. Treatment of pain
(a) Hypodermic morphia
(b) Create small "blisters" over tender part and ice on the chest
(c) Sedatives, narcotics, hydrocyanic H+, ETOH to full dose
(d) Bend knees up
7. Protection
(a) Metal or cloth protector, over aneurysm
(b) Astringents and ergot to decrease bleeding
(c) Quiet [18]

K. 7 October 1896: JB Murphy developed a vascular anastomosis technique and performed the first human vascular anastomosis at Mercy Hospital in Chicago [19]. This was 1 month after the first stab wound of the heart was sutured.

III. *Early 1900s of the 20th Century: Cardiovascular*

A. Early heart procedures
1. 1893: Dr. Daniel Hale Williams explored a right ventricle stab wound; no sutures placed, as bleeding had stopped. Provident Hospital, Chicago [20].
2. 9 September 1896: First successful suture of a stab heart wound performed by Dr. Ludwig Rehn—violating an age-old dictum back to Hippocrates that the heart was off limits to the surgeon [21, 22].

B. 1902: Dr. Hill, with two kerosene lamps and chloroform, successfully treated a 13 year- old at home with a stab wound to the heart on an Alabama kitchen table. The patient died 40 years later, in 1942, of a second stab wound [23].

C. 1910: Alexis Carrel performed a graft from the descending thoracic aorta to the coronary artery after Trendelenburg proposed pulmonary embolectomy with aortic and pulmonary artery cross-clamping in 1908 [24].

D. 1912: Alexis Carrel received the Nobel Prize for vascular suture techniques while working with Charles Guthrie and using aseptic techniques.

E. 1915: Heparin was discovered by a medical student (Jay McLean)—a key to future cardiovascular progress [25].

F. 1923: First successful mitral valvulotomy was performed by Elliott Cutler and Samuel Levine—ahead of the times—after Sir Lauder Brunton proposed elective correction mitral valve stenosis by surgical manipulation in 1902.

G. 1928: Fleming discovers penicillin.

H. 1929: Forssmann performed the first heart and vascular catheterization (on himself) and thus received the Nobel Prize [26].

I. 1938: Lelong reported on pleuroscopic diagnosis of a thoracic aneurysm.

J. Aortic aneurysm external wrapping treatment promulgated, e.g., Albert Einstein's aneurysm was wrapped by R. Nissen in 1948 [27]. (Early in our practice, we used Dacron aneurysm wraps successfully for treatment of both high risk thoracic and abdominal aneurysms.)

K. 1952: Dubost promulgated arterial homografts for utilization on the aorta [28].

L. Antibiotic and asepsis programs became key considerations in vascular surgery success.

M. Gross and Oudot repaired non-aneurysmal aortic lesions in the 1940s and 1950s [29, 30]

N. Many other patch or tube grafts of various materials followed, including the cryopreserved, the cloth, and the Dacron graft sewn by DeBakey on his sewing machine, which when placed within the aneurysm reduced the incidence of aortoenteric fistula development [31].

O. Etiology of aortic aneurysms became primarily arteriosclerotic, while syphilitic aneurysm occurrence was disappearing.

IV. *1940s to Date—Cardiac Surgery—An Integral Part of Vascular Surgery Developmental History*

A. 1952: Hufnagel placed into the descending thoracic aorta a caged ball valve to treat valvular heart disease [32].

B. Congenital cardiovascular surgery
1. In 1913, Tuffier dilated a stenotic aortic valve by aortic wall invagination and the book "Surgery of the Blood Vessels and the Heart" was published regarding experimental cardiovascular surgery [33].
2. 1937: Ductus interruption [34]

3. 1944: Crafoord, in Stockholm, resected an aortic coarctation [35].
4. 1945: Gross repaired a vascular ring of the trachea [36].
5. 1948: Gross performed aortopulmonary (A-P) window closure [37].
6. Cooley: aortopulmonary window repair with cardiopulmonary bypass (CPB) [38].

C. The single organ perfusion pump by DeBakey in 1934, was followed by the tissue perfusion apparatus of Lindbergh [39], of which there is one in the International Museum of Surgical Science (IMSS) in Chicago, of which Raymond Dieter, Jr., M.D. is President.

D. Dodrill performed the first human left-sided heart bypass in 1952 using a General Motors' Mechanical pump [40].

E. In the 1930s and 1940s, before and after WWII, John Gibbon did extensive research using a heart lung machine (CPB), contributing extensively to the field [41]. At a meeting in Europe in the early 1970s, Dr. William E. Neville, Dr. Raymond A. Dieter, Jr., and Dr. Gibbon discussed extensively his decision to progress to the human use of CPB in 1954, despite the less than optimal results in the animal lab, stating he had to make a decision. It was a monumental decision for the benefit of the world's physicians and our patients.

F. 1940s: WWII: Dwight Harkin removed 134 cardiac and mediastinal foreign bodies.

G. Cross-circulation was explored by Lillehei for repair of a VSD.

H. 1946: The Vineberg myocardial ischemic procedure was being developed—"an aortomyocardial shunt"— which we later utilized at the Hines V.A. Hospital, Maywood, Illinois in the late 1960s.

I. 1950s: Dr. Kirklin at the Mayo Clinic utilized CPB for cardiac surgery.

J. Simultaneously, hypothermia, myocardial protection, and cardiac arrest (K+) were under investigation by many investigators, including Clowes and Neville, who were exploring various CPB factors for successful whole body perfusion [42].

K. Transposition of the great vessels was corrected by Senning [43].

L. 1962: Sones and Shirey popularized transaortic coronary catheter angiography [44].

M. 1963: Intra-aortic balloon counterpulsation development was progressing.

N. 23 November 1964: A direct aortocoronary vein bypass was performed (Garrett, Dennis, DeBakey [45]).

O. Oz, Komeya, Neville and Clowes, M.D., continued research using hypothermia and blood volume hemodilution [46].

P. Dieter et al. reported on profound hemodilution, hypothermia, and metabolic aspects of CPB with Ringer's Lactate in 1966 and again in 1970 [47, 48].

Q. 3 December 1967: The first human to human heart transplantation was performed utilizing an aortic segment by Christian Barnard in Capetown, South Africa [49].

R. 1968: Favalaro popularized the saphenous vein aortocoronary bypass at the Cleveland Clinic [50].

S. During this period of time, failing cardiac circulation was treated with the diaphragm wrapped canine heart experiment by Kantrovitz (Cardiomyoplasty) and the Carpentier human aorta wrap with latissimus muscle for aortic counterpulsation [51, 52].

V. *Twentieth and Twenty-First Century: Aortic Surgery Post WWII to Date—Development and Its Progress Entwined with Our Experience*

A. Matas—endoaneurysmectomy and rubber tube stent placement preanticoagulation having previously ligated the aorta proximal to an abdominal aortic aneurysm [53].

B. WWII—traumatic cardiovascular injury (primarily suture) repair was a great impetus to vascular surgery.

C. 1948: Descending thoracic aneurysmectomy with primary aortic reanastomosis (Shumaker) was rapidly followed by Swan, Gross, and the DuBost treatment of aneurysms using aortic homografts [54, 55].

D. 1953: Bahnson reported on six saccular abdominal aortic aneurysms resected, while DeBakey and Cooley resected a 20 cm descending thoracic aortic aneurysm using a homograft replacement [56, 57]. In 1958, Dr. Robert McCray placed an abdominal aortic homograft with the lumbar artery stumps placed anteriorly (Illinois Thoracic Surgery Society 14 April, 1988 minutes describes).

E. During the Korean War—vascular homograft and autogenous vein repair reduced limb amputation rates from 49% to 11% [58].

F. Availability of multiple synthetic grafts followed—including the Dacron (DeBakey) (originally constructed and sewn by him reportedly on a sewing machine), Gore-Tex, and Vinyon-N cloth tubes, and research on permanent shunts by Neville and Clowes to replace aortic segments in 1955 [59, 60]. Others were stimulated to experiment building vascular grafts and medical items in their garages or laboratories.

G. Vascular wards and diagnostic angiograms including the translumbar aortograms (TLA) for renal and iliac disease with 17 gauge 7 1/2 inch needles—of which

we performed hundreds and presented the findings of many to the Hines V.A. vascular conferences, then evolved. Tomograms were later followed by computerized tomographic scans (CTs) aiding greatly in the diagnosis of thoracic and abdominal aneurysms, avoiding right transthoracic aortic aneurysm biopsy, and differentiating such from neoplasms.

H. Aortic therapy—surgical or medical—was promulgated in the 1960s at the Hines V.A. Hospital. The vascular service had grown, under multiple attending physicians (J Canning, R McCray, L. Ganshirt, J Graziano, D. Hutchings), with aneurysm; Leriche Syndrome (occluded aorta) bypass and endarterectomy (aortic, iliac, femoral, carotid) procedures were performed when the author (Raymond A. Dieter, Jr., M.D.) joined the program in 1963.

I. Homograft or Dacron replacement of all segments of the thoracic aorta utilizing cardiopulmonary bypass, including arch replacement and its branches, was initiated by Drs. DeBakey, Cooley, Crawford (who were always available for telephone consultation) and others as an option to replace the "clamp and sew" techniques [61].

J. Metabolic aspects of profound hemodilution, hypothermia, and cardiopulmonary bypass was widely researched and utilized by many, including ourselves, for cardiac, vascular, aortic, tumor resections or trauma repair [62, 63].

K. 1960s–1970s: Open "vascular dilation" procedures were developed and frequently utilized, especially in conjunction with other vascular procedures, by ourselves and others. Currently, this procedure is termed "angioplasty" and performed percutaneously utilizing balloon catheters, which we began performing after Dotter presented the concept. Also, balloon catheters became available—under the direction of Tom Fogarty—for multiple purposes.

L. In 1967–1968, we began to use the Vineberg direct aortocoronary grafts and subclavian coronary grafts for coronary occlusive disease (Dr. William E. Neville, Dr. Roque Pifarre, Dr. Raymond A. Dieter, Jr., Dr. Bernie Leinenger and others at the Hines V.A. and Loyola University Hospitals).

M. Beginning in the late 1960s, Raymond Dieter, Jr., personally performed repair of hundreds of ruptured aortas or "leaking" aneurysms in community hospitals (on occasion performing 3 or 4 aortic repairs in a 24-hour period in 3 or 4 different hospitals), along with his associates Drs. Robert McCray, Glen Asselmeier, George Kuzycz, Farouk Hamouda, Robert Wilson, and Robert Maganini.

N. By 1968–1969, CPB was utilized by ourselves for shock syndromes, such as after a perforated peptic ulcer with sepsis and profound shock, for resection of renal tumors invading the inferior vena cava and right heart, thoracic aortic disease, huge thoracic tumor resectional surgery, aortic trauma (especially GSW—gunshot wounds) and other noncardiac diagnoses [64, 65].

O. Then, 17 January 1969: we performed the third human heart transplantation in our area—108th in the World—at the Hines V.A. Hospital having performed similar animal (dog, calf, sheep) procedures in the research laboratory and meeting with Christian Barnard. The surgical team included the following surgeons: William Neville, Roque Pifarre, Robert Lynch, Kushroo Patel, Raymond A. Dieter, Jr., and William Cox [66].

P. 1974: Our private group then initiated a Community Hospital diagnostic coronary angiographic (Dr. Neil Agruss), aortocoronary bypass, and valvular heart disease surgical program with no house staff at Central DuPage Hospital (DuPage County, Illinois) after the first coronary angiogram was performed in a patient with a ruptured thoracic aneurysm in preparation for surgery by Raymond A. Dieter, M.D. prior to the availability of CPB. Other early community hospital procedures, such as coarctation of the aorta correction, aortorenal, or aortomesenteric grafts, were already performed along with the closed valvular procedure by Drs. Robert McCray and Salvatore Nigro in the 1960s at Elmhurst Hospital— a community hospital.

Q. 1983: We reported on simultaneous traumatic thoracic aortic rupture repair in the community hospital and renal salvage after the renal artery was torn from the aorta by utilizing a saphenous vein aortorenal bypass and multiple other injuries, including all long bone fractures except one, the ruptured liver, spleen, bladder, diaphragm, etc. [67].

R. Multigenerational genetic or familial vascular/aortic disease with rupture during pregnancy was reported by us [68]. This was the same year (1983) that we reported a tracheal - carinal resection with primary reconstruction for a mucoepidermoid tumor in pregnancy [69].

S. In 1970, we performed our first and poorly accepted thoracoscopy by the medical community. Each year for 20 years, we performed more and more thoracoscopic procedures. In 1990, we developed a series of thoracoscopic (now accepted by MDs) live, 3-day, hands-on animal seminars for cardiothoracic and aortovascular surgeons, which led to the publication of "Thoracoscopy for Surgeons" by Igaku-Shoin (now Williams and Wilkins) [75]. In our Thoracoscopy textbook, we discussed performance of coronary artery surgery with graft intussusception or telescoping of the bypass graft into the coro-

nary vessel as early as the 1960's at the Hines V.A. Research Center. The technique was simple and we did not hesitate to utilize a simple single tacking stitch to avoid possible graft withdrawal.

T. The transfemoral endovascular procedures and grafting (EVAR) were initiated and promulgated worldwide for the aorta, the aortic branch diseases, and the aortic fistulae after Juan Parodi, in 1990, accomplished the first human aortic aneurysm transvascular endograft following the early Cleveland Clinic 1980s EVAR research [70].

U. Similarly, in the 1990s, special diagnostic and therapeutic procedure rooms utilizing transarterial and transvenous catheter angiograms were promulgated, including those devoted primarily to the aorta or transaortic procedures. A huge swing in aortic surgery, from the open to the endograft technique, followed into the 2000s with development of multiple new techniques and prosthetics. Ultrasound techniques progressed and enhanced vascular graft, aneurysm, and potential complication evaluation.

V. We then reported the second endograft placement for an aortoenteric fistula with shock and hemorrhage following multiple nondiagnostic hospital admissions elsewhere [71].

W. Aortic departments, specialists, and clinics have developed, coinciding with the therapy and vascular development programs, as presented by Stephenson in the Cohn and Edmunds text and by Barr in the History of Aortic Aneurysms [1, 2, 72].

X. Various authors of this current text and the enclosed chapters became interested in vascular disease, and promulgated aortic disease therapy, including Raymond A. Dieter, Jr. (1961), Raymond A. Dieter, III (1992), Robert S. Dieter (2003) and Aravinda Nanjundappa (2004) (the latter two under the tutelage of Dr. John Laird at the Washington Hospital Center/Georgetown University). This interest has led to the production of six reference medical textbooks pertaining to the thoracic and vascular fields and the care of 1000s of patients.

Y. More recently, genetic research involving patients with aortic aneurysms continues to develop the concept of molecular and gene therapy to prevent or reduce aortic aneurysms.

Z. Transaortic paraaortic tumor biopsy has been discussed, but few such procedures are accomplished.

Conclusion and Future Directions

The preceding outline and time table has progressed from the early syphilitic aneurysms of 2000 years ago to the current dedicated aortic facilities and staff. More recently, since the late 1990s, endovascular (EVAR) and transaortic valve replacement (TAVR) programs have developed and flourished around the world in both the university and the community setting for the benefit of the patient. This has coincided with the development of insurance, government sponsored healthcare, and Medicaid financial coverage. Vascular and cardiovascular training programs to provide experience for the physician and the staff have been promulgated.

Communication with qualified personnel is now potentially instantaneous and the electronic transmittal of photographs provides the opportunity for urgent worldwide assistive advice or instruction. Similarly, new concepts or device developments are disseminated in a span of months or weeks. Simultaneously, and as a part of this development, was the opportunity for industry and business intervention. With the opportunity to not only recover expenses but to also realize a significant profit in the provision of new technologies, vascular physicians have seen a huge resource input by industry for the successful long term treatment of these critical aortic diseases in our patients.

The book "100,000 Hearts: A Surgeon's Memoir," by Denton Cooley lists 46 personal contributions, 53 surgical inventions and products, and 1400 publications related to Dr. Cooley along with his C-V [73]. The "Giants" in the aortic and cardiovascular field, including Denton Cooley as mentioned above (who provided the foreward for this text) and Michael DeBakey, were followed by individuals such as Edward B. Dietrich (1935–2017), who developed a keen interest in the minimally invasive approach to cardiovascular disease [74]. Various endografts and techniques were developed to meet the anatomic variances for the abdominal or thoracic aorta and its branches. Guidelines for placement of descending thoracic endografts or structure of the perirenal aortic graft neck were devised. Committees formed and widespread input as well as individual entrepreneur concepts were incorporated in this rapidly changing specialty. Patients and their families quickly accepted the new line of minimally invasive aortic treatments.

Diagnosis, presymptomatic, and possible preclinical treatment has been encouraged. Multiple innovative stents, endografts, and insertion techniques (percutaneous or iliofemoral incision) are under close scrutiny as exemplified by the large number of major industrial exhibitors at national or international meetings.

Speakers and researchers submit their cardiovascular concepts, ideas, and results on national platforms for the adult and the tiny infant. The complications of various techniques (open or endo) as well as the long term results continue to be debated and challenged statistically through a large number of comparative patient studies. When should one intervene and whether the open or endo procedure is ideal are continually discussed. What are the risks, especially radiation dose to the patient, physician, or staff and how to reduce such are

of equal concern. Endoleaks or infected fistula, ruptured aneurysms, arch vessels, abdominal branches, follow-up procedures, embolic stroke, and pediatric vascular emergencies will continue to be treated. Where will the future lead us? Who will devise and provide the new era therapies? As early as the mid-1960s, we experimented with sutureless distal anastomosis or intussusception of a distal end of a graft for aortocoronary bypass procedures [75]. This was abandoned for sutured anastomosis but has been utilized more recently for venous outflow in end-stage renal disease by others [76].

It is exciting and challenging to consider the future of aortic disease and its treatment in the era of minimally invasive disease therapy. Balloons, covered grafts, custom fenestrated grafts, genetic modifications, and parallel grafts are only the beginning as demonstrated by Stephenson and Ruggiero in their text of heart surgery classics [72]. These all show a continued improvement from Stone's discussion of syphilitic cardiovascular disease [77]. The dedicated healthcare team—nurses, technicians, manufacturers, physicians, and many more—will continue developing this rapid and changing environment for the benefit of our patients. Dr. Carabello, Professor of Medicine, Chief of Cardiology at East Carolina University stated, in the June 2017 Chest Physician (page 19), "We've spent $2 billion looking for a percutaneous mitral valve replacement and wonders if this makes sense." Huge resources and analytic minds will be applied to the challenges for future disease minimization with the hope for success for such concepts as gene therapy and molecular surgery to reduce or prevent the occurrence of an aortic aneurysm. Will gene editing of DNA become an aortic reality for aortic disease prevention? The future is already here for some diseases with the utilization of the transfemoral intra-aortic blood pump (Procyrion Aortix™) for chronic heart failure patients and lithoplasty for calcified vessels (Disrupt PAD III). These are exciting times.

Acknowledgment Thank you to Lynn Murawski, organizer and typist, for this extensive timeline.

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