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The main epochs and timeline of cardiac and great vessel surgery

a*) 1797-1896: incubation period with animal experiments and human casuistics:* **1798:**
Use of 7°C cold sea water bath for the curing of fever, convulsions and insanity (J. Currie) [1]
1797: M. Baillie described the transposition of the great vessels (TGA) of the heart
1801?: First pericardiostomy (drainage after an incision) for pericardial effusion described by Francisco Romero [2]
1810: Pericardial drainage for tamponade of a stab wound (D. Larrey). The patient survived for less than a month, but another drainage carried out by Larrey in 1824 led to a better outcome
1812/13: C. J. La Gallois outlined the possibility of maintaning life with the help of an artificial pump replacing the heart [3]
1849: Isolated renal perfusion with defibrinated blood (C. E. Loebell) [4]
1869: First attempts for the artificial oxygenation of blood (C. Ludwig, A. Schmidt) [5]
1872: First experiments with the valvotomy of the aortic valve (O. Becker, E. Klebs) [6]
1873: Removal of a foreign body from the heart by G. W. Callender
1882: W. von Schröder designed an oxygenator for perfusion of isolated organs [7]
Visionary concept of an artificial heart in the novelette *The Vivisector Vivisected* by Ronald Ross [8]
1885: First artificial heart-lung machine, a film oxygenator („Respirations-Apparat für isolierte Organe“) constructed by M. v. Frey and M. Gruber [9]
1886-97: Successful side-to-side (P. Postempski) [10] and end-to-end suture of an artery with invagination technique in man (J. B. Murphy, E. Payr) [11]
1888: Endoaneurysmorrhaphy instead of the dangereous ligature of aneurysms (R. Matas) [12]
1890-1915: Prototypes of venous bubble oxygenators designed by C. Jacobi [13]
1893: First successful suture of the pericardium during an operation (H. C. Dalton [14], D. H. Williams [15])

[1] cit. by D. E. Harken, H. Black et al.: Surg. Forum 1953; 4:4, [2] A. Aris: Ann. Thorac. Surg. 1997; 64:870, [3] C. J. La Gallois: Expérience sur le principe de la vie. Paris, 1812, [4] Diss. Marburgi Cattorum, typ Elwerti, 1849, [5] C. Ludwig, A. Schmidt: Arb. Physiol. Anst. Leipzig 1869; 3:1, [6] O. Becker: Arch. Ophthalm. 1872; 18:206, E. Klebs: Prager Med. Wschr. 1876; 1:29, [7] W. von Schröder: Arch. Exp. Pathol. Pharmacol. Leipzig 1881-1882; 14-15:377, [8] R. Ross: Memoirs. London, John Murray, 1923, [9] M. von Frey, M. Gruber: Arch. Physiol. 1885; 9:519, [10] P. Postemski: Arch. Ed. atti d. Soc. Ital. Chir. 1886; 3:391, [11] B. Murphy: M. Rec. Ann. 1897; 51:73, E. Payr: Arch. klin. Chir. 1900; 62:67, [12] R. Matas: NY Med. News 1888; 53:412 [13] C. Jacobi: Arch. Path. Pharm. 1890; 26:388, [14] H. C. Dalton: Ann. Surg. 1895; 21:147, [15] D. H. Williams: Medical Record 1897; 51:439

b*) 1896-1937: preparatory phase of heart surgery and great vessels: closed interventions:*
1896: First successful suture of a punctured heart wound (L. Rehn)
1897: Proposal of the sternum-splitting incision for access to the chest (H. Milton, Cairo)
1898: Brentano, D. W. Samways and B. C. Cantab propose the dilatation of the stenotic mitral valve[2]
E. Delorme proposes the release of the armoured heart with pericardiectomy
1899: Cervical sympathectomy proposed for relief of pain in angina pectoris (C. A. François-Franck)
1902: Technique of the end-to-end anastomosis of great vessels (A. Carrel) [3]
Ligature of an aneurysm of aorta (T. Tuffier) [4]
1903: Indications for operative relief of pericarditis constrictiva (cardiolysis; L. Brauer) [5]

1906: Transplantation of frozen conserved vessels (A. Carrel) [6]
1903-10: Pulsatile blood flow leads to a greater degreee of hemolysis (Hoffmann, Hooker)
1903-15: Bubble oxygenator (T. G. Brodie, D. R. Hooker) [7]
1907: Unsuccessful embolectomy from the main pulmonary artery (F. Trendelenburg) [8]
John Munro conceives the possibility of ligation of the patent (open) ductus arteriosus Botalli through a median sternotomy [9]
1907: F. Sauerbruch's suggestion of compression of the superior and inferior vena cava to control cardiac hemorrhage
1908: H. Cushing's animal experiments on reconstruction of valvular lesions [10]
1910: First successful pericardiectomy (M. P. Hallopeau)
1912: First successful porto-caval anastomosis with the aid of an Ecks' fistula (P. Rosenstein) [11]
1913: Partial pericardiectomy is sufficient for the release from constrictive pericarditis (F. Sauerbruch) [12]
First unsuccessful (E. Doyen) and successful stretching (M. Th. Tuffier) of an aortic stenosis with digital invagination of ascending aorta
1915: Rotating disk film oxygenator (D. R. Hooker, A. N. Richards and C. K. Drinker) [13]
1916: Removal of the cervical sympathetic chain and the first dorsal ganglia bilaterally for denervation of the heart in angina pectoris (T. Jonnesco)
1923-29: First successful „valvulotomy“ for mitral stenosis (closed-finger „fracture procedure“ ; E. C. Cutler, S. A. Levine, B. O. A. Pribram)[14]
1923: Successful repair of a traumatic transection of the thoracic aorta (Dshanelidze)
1924: Successful embolectomy from the main pulmonary artery (L. Kirschner)[15]
1925: First successful transauricular digital sprinkling of the mitral valve (H. Souttar)[16]
1926/27: Invention of the valveless roller pump for perfusion of isolated organs (B. Issekutz) [17]
1928: Restoration of contractility in isolated muscles by perfusing their arteries with oxygenated blood (J. Kay)
Refined type of rotating disk film oxygenator (L. E. Bayliss et al.) [18]
1929: Heart catheterism with the help of **a** ureter catheter designed for resuscitation instead of the transthoracic heart punction (W. Forssmann)[19]
1930: Artificial heart for cat experiments (Gibbs)
1931: Successful resection of an aneurysm of the right ventricle (F. Sauerbruch) [20]
1932: Albert S. Hyman invents an artificial pacemaker to resuscitate patients [21]
1933-37: W. B. Kouwenhoven and O. R. Langworthy, C. J. Wiggers discover in animal experiments that countershock can restore a fibrillating heart to normal rhythm [22]
1937: First successful application of Wigger's countershock for terminating intraoperative ventricular fibrillation (C. S. Beck) [23]
1926-34: Construction of a steady flow roller pump for transfusion (Clemens, Beck, M. E. DeBakey) [24]
1935/36: Abrasion of epicard in order to augment the blood flow through hyperemia and revascularization of myocardium by a pectoralis muscle graft (C. S. Beck) or with an cardio-omentopexy (L. O'Shaughnessy) [25]
1934-37: Extracorporeal blood circulation unit with oxygenator for complete heart-lung bypass for 30-40 minutes in animals (J. H. Gibbon) [26]
1937: First (unsuccessful) attempt to close a patent ductus arteriosus (J. W. Strieder) [27]

[1]: L. Rehn: Arch. klin. Chir. 1897; 55:315, [2] D. W. Samways: Lancet 1898; 1:927, [3]A. Carrel: Ann. Surg. 1910; 52:83, Ann. Surg. 1914; 60:1, [4] T. Tuffier: Bull. Soc. Chir. 1902; 28:326, [5] L. Brauer: Arch. klin. Chir. 1903; 71:258), [6] A. Carrel: Compt. Rend Soc. Biol. 1906; 61:572, [7] T. G. Brodie: J. Physiol. 1903; 29:255 and D. R. Hooker: Am. J. Physiol. 1915; 38:200 (Hooker's device was a forerunner of the modern disk oxygenators.) [8] F. Trendelenburg: Zentralbl. Chir. 1907; 44:1402, [9] J. C. Munro: Ann. Surg. 1907; 46:335, [10] H. Cushing, J. R. B. Branch: J. Med. Res. 1908; 17:471, [11] P. Rosenstein: Arch. klin. Chir. 1912; 98:1082, [12] F. Sauerbruch: Die Chirurgie der Brustorgane. Vol. 2 (Berlin, 1925), [13] R. Hooker: Am. J. Physiol. 1915; 38:200, A. N. Richards, C. K. Drinker: J. Pharmacol. Exp. Ther. 1915; 7:467, [14] C. E. Cutler, S. A. Levine: Boston Med. Surg. J. 1923; C. E. Cutler, C. S. Beck: Arch. Surg. 1929; 18:403, B. O. A. Pribram: Berlin, Tagung der deutschen Gesellschaft f. Chirurgie, 1929; 188:1023, [15] M. Kirschner: Arch. klin. Chir. 1924; Bd.133, [16] H. S. Souttar: Br. Med. J. 1925; 2:603, [17] B. Issekutz: Biochem. Zschr. 1927, [18] L. E.

Bayliss, A. R. Fee, E. Ogden: J. Physiol. 1928: 66:443, [19] W. Forssmann: Klin. Wschr. 1929; 8:2085 (It is noteworthy that only 6 months after Forssmann's publication one measured the cardiac output using a right heart catheter in Prague!), [20] F. Sauerbruch: Arch. Klin. 1931; 167:686, [21] A. S. Hyman: Arch. Intern. Med. 1932; 50:283, [22] W. B. Kouwenhoven: Ann. Intern. Med. 1969; 71:449, C. J. Wiggers: Am. J. Physiol. 1936; 116:161, [23] C. S. Beck, F. R. Mautz: Ann. Surg. 1937; 54:273, C. S. Beck: Am. J. Surg. 1941; 54:273 [24] M. DeBakey: New Orleans Med. Sci. 1934; 87:386 (However, the construction principle of a valveless roller pump was made earlier by Noël in 1874.) [25]C. S. Beck: Ann. Surg. 1935; 102:801, L. O'Shaughnessy: Br. J. Surg. 1936; 23:665, [26] see: J. H. Gibbon: Am. J. Surg. 1978; 135:608, [27]A. Graybiel, J. W. Strieder, N. H. Boyer: Am. Heart J. 1938; 15:621

c) From 1938: pioneer phase of the cardiac and great vessel surgery: closed (blind) heart interventions and open cardiac operations under direct vision without or by means of (deep) hypothermia or crossed circulation:

1938: First successful ligature of an uninfected Botallo's duct (R. E. Gross, J. P. Hubbard) [1]
Cardio-omentopexy for coronary ischemia (L. O'Shaughnessy)
1938: Cardiopneumopexy after removal of the overlaying pericardium for increasing the coronary blood flow (A. Lezius). This procedure was revived in 1958 by Smith in Seattle
1939: First successful ligature of an infected Botallo's duct (O. Tubbs). Further 9 cases were reported in 1944 (and 6 of these remained cured by chemotherapy)
1941: Right-heart catheterization became a routine procedure (A. Cournand, H. A. Ranges) [2]
1944: Successful resection of the aortic coarctation by cross-clamping the aorta and direct suture in 2 patients (C. Crafoord, K. G. V. Nylin) [3]
1945: Experimental resection of a short segment of the aorta with re-anastomosing (R. Gross, Ch. Hufnagel) [4]
1944: Artificial Botallo's duct for amelioration of hypoxemia and cyanosis and in order to increase the pulmonary artery pressure gradient in pulmonary stenosis by means of an anastomosis between left subclavian and pulmonary artery (Blalock-Taussig anastomosis) [5]
1946: Potts operation: a direct side-to-side anastomosis between the descending aorta and the pulmonary artery in small infants (W. J. Potts et al.) [6]
1946: Removal of 134 missiles and other foreign bodies from the chambers of the heart and great vessels with no death (D. E. Harken, P. Zoll et al.) [7]
Tunneling of the internal mammary artery through the myocardium (A. M. Vineberg) [8]
1947/48: First saphenous bypass for bridging an obliterated artery [9]
Subclavian artery technique in a patient with coarctation (O. T. Clagett) [10]
First successful pulmonary valvotomy (H. Sellors) [11], also by the use of a cardioscope fitted with a retractable knife (R. C. Brock) [12]
Closed closure of atrial septal defects by invagination of the right atrial wall and performing a patch by mattress suture (R. Cohn, G. Murray) [13]
1948/52: Brain perfusion in dogs with artificial oxygenated blood (V. O. Björk) [14]
Transatrial commissurotomy (valvulotomy) with a mitral valve knife (C. P. Bailey et al) [15] and valvuloplasty (D. E. Harken, L. B. Ellis et al.) [16]
First use of an arterial homograft (R. Gross)
1949: Modified film oxygenator consisting of multiple rotating spiral coils combined with a Dale-Schuster pump was able to support the circulation and respiration of dogs for up to four hours (J. Jongbloed) [17]
1949/50: Decrease of body's oxygen requirement with the grade of hypothermia in linear fashion, when shivering and heightened muscle tone had been previously eliminated. Proposal of deep hypothermia for elective cardiac arrest and open cardiac procedures with the help of „inflow occlusion“ (W. G. Bigelow et al) [18].
1950: A successful closure of an atrial septal defect in a small child under elective cardiac arrest for 5 minutes (Budapest, II. Pediatric Clinic), only six months after

Bigelow's first publication [19]
Homoplastic transplantation of the heart and lungs in warm-blooded animals (dogs; V. P. Demikhov) [20]
1950/51: Partial right-heart bypass successfully tested (W. H. Sewell, W. W. L. Glenn) [21], and its first use as a pump oxygenator in a human patient (A. M. Dogliotti, A. Constantini) [22]
1951: Successful digital splitting (instead of a finger knife)* of a mitral stenosis (Á. Eisert and T. Sarvay) [23]
1951: Use of an arterial homograft in the repair of an abdominal aortic aneurysm (C. Dubost et al.) [24]
Man-made graft, a caged plastic ball device is well-tolerated in the bloodstream (C. A. Hufnagel) [25]
Initiation of modern carotid surgery by end-to-end anastomosis between external and internal carotid (M. Fischer, R. M. E. Carrea et al.) [26]
1950/54: „Parabiosis“ with the aid of a human donor as a biologic oxygenator [27]. After successful experiments in animals it was recommended for open cardiac operations (H. E. Warden, M. Cohen et al., C. W. Lillehei et al.) [28]
1952: Transventricular dilatation of the aortic stenosis using a three-bladed dilator (C. P. Bailey, H. P. R. Ramirez) [29]
1952: Closure of an atrial septal defect with atrio-septopexy (C. P. Bailey et al., R. E. Gross et al.) [30]
1952: Paul M. Zoll develops the first successful cardiac pacemaker [31]
1952: Closure of atrial septal defect with the aid of hypothermia and inflow occlusion in one case (J. F. Lewis, M. Taufic) [32] in Swan's ice bed (surface cooling) [33]
1950-54: Correction of Tetralogy of Fallot without heart-lung machine by means of controlled cross circulation (O. H. Wangensteen, C. W. Lillehei; et al.) [34]
1953: First successful carotid endarterectomy (M. DeBakey) [35]
1953: Successful surgical correction of aortic regurgitation (C. A. Hufnagel, W. P. Harvey) [36]
1954: Transatrial dilatation of mitral valve (Ch. Dubost)
1954-62: Modern treatment of dissecting aortic aneurysm is initiated by M. E. DeBakey et al.[37], F. C. Spencer and H. Blake [38]
1955: First closure of a ventricle septal defect using the heart-lung machine (J. W. Kirklin) [39]
1957: „Isthmusplastic“ operation for aortic coarctation by means of a homograft or a Dacron patch (K. Vosschulte) [40]
1958: Replacement of the heart in an animal with a mechanical device (T. Akutsu and W. J. Kolff) [41]
1958: Totally implanted pulse generator for pacing the heart in Adams-Stokes syndrome (A. Senning, R. Elmqvist) [42]
1965: Total correction of the Tetralogy of Fallot in small children using cardiopulmonary by-pass and deep hypothermia (L. K. R. McMillan et al.) [43]
1966: Balloon atrial septostomy as a palliative approach in complete transposition of the great arteries without thoracotomy (W. J. Rashkind, W. W. Miller) [44]
1966: Prolonged circulatory arrest under deep hypothermia induced by surface cooling for open heart surgery in infants (H. Mohri, E. A. Hessel, R. J. Nelson et al.) [45]

[1] R. E. Gross, J. P. Hubbard: J.A.M.A. 1939; 112:729, [2] A. Cournand, H. A. Ranges: Proc. Soc. Exp. Med. Biol. Med. 1941; 46:462, [3] C. Crafoord, K. G. V. Nylin: J. Thorac. Surg. 1945; 14: 347, [4] R. E. Gross, C. A. Hufnagel: N. Engl. J. Med. 1945; 233: 287, [5] A. Blalock, H. E. Taussig: J.A.M.A. 1945; 128:189 (In 1947 Blalock and Taussig toured Europa to demonstrate their operations in London, Paris and Stockholm. An analysis of the first 1000 operations at Johns Hopkins Hospital between 1945 and 1952 showed an operative mortality of 15,7%. The subclavian artery was originally chosen because of the need to preserve blood flow through one lung while the anastomosis was being performed, for there was no heart-lung machine at the time), [6] W. J. Potts, S. Smith, S. Gibson: JAMA 1946; 183:283, JAMA 1955; 159:95, [7] D. E. Harken: Surg. Gynec.Obstet. 1946; 83:117), [8] A. M. Vineberg: Can. Med. Assoc. J. 1946; 55:117, [9] J. Kunlin: Arch. Mal. Coeur 1949; 42:371, [10] O. T. Clagett: Proc. Staff Meetings Mayo Clinic 1947; 22:131, [12] R. C. Brock, M. Campbell: Br. Heart J. 1950; 12:403 (The combined procedure of pulmonary valvotomy

and pulmonary resection, the Brock's technique had been replaced **by** a total one-stage correction of Fallot's Tetralogy when open heart surgery became possible with the heart-lung machine.), [13] R. Cohn: Am. Heart J. 1947; 33:453, G. Murray: Ann. Surg. 1948; 128:843, [14] V. O. Björk: Acta Chir. Scand. 1948; 96, Suppl. 137:1-122, [15] C. P. Bailey: Dis. Chest 1949; 15:377, Sir R. C. Brock: Br. Heart J. 1952; 132:629, [16] D. E. Harken, L. B. Ellis, et al: N. Engl. J. Med. 1948, 239:804, J. Thorac. Surg. 1950; 19:1, [17] J. Jongbloed: Surg. Gynec. Obstet. 1949; 89:684, J. Appl. Physiol. 1951; 3:642, [18] W. G. Bigelow, W. K. Lindsay et al.: Ann. Surg. 1950; 132:849, Am. J. Physiol. 1950; 160:125, Ann. Surg. 1950; 132:849, [19] P. G. Forbáth: Semmelweis Egyetem újság 2004; 4. sz., [20] V. P. Demikhov: Problems of Thoracic Surgery (Medigiz) 1949/1950; Nr. 5, 7, [21] W. H. Sewell, W. W. L. Glenn: Surgery 1950; 28: 474, [22] A. M. Dogliotti, A. Constantini: Minerva Chir. 1951; 6:657, [23] Á. Eisert: Magyar Sebészet 1951; 4:274, [24] C. Dubost et al.: Mem. Acad. Chir. 1951; 77:381, [25] C. A. Hufnagel: Bull. Georgetown Univ. Med. Center 1951; 4:128 (However, the idea wasn't a new one; his forerunner, a caged ball valve as bottle stopper was invented by J. B. Williams in 1858.) [26] M. Fisher: AMA Arch.Neurol. Psychiatr. 1951; 65:346, R. M. E. Carrea, M. Molins and G. Murphy: Acta Neurol. Lationam 1955; 2:71, [27] L. Blum, S. Megibow: J. Mount Sinai Hosp. NY 1950; 17:38, [28] H. E. Warden, M. Cohen et al: J. Thorac. Surg. 1954; 28:331, C. W. Lillehei, M. Cohen, H. E. Warden et al.: Surg.Gynec.Obstet. 1955; 101:447, [29] C. P. Bailey, H. P. R. Ramirez: J. Thorac. Surg. 1952; 150:1647, [30] C. P. Bailey, D. F. Downing, G. D. Geckeller et al.: Ann. Intern. Med. 1952; 37:905, R. E. Gross, A. A. Pomeranz, E. Watkins Jr. et al.: N. Engl. J. Med. 1952; 247:455, [31] P. M. Zoll: N. Engl. J. Med. 1952; 247:768, W. G. Bigelow: Pace:1987; 10:142, [32] J. F. Lewis, M. Taufic: Surgery 1953; 33:52. (In the international literature this case is quoted as the *first* open closure of an ASD in hypothermia until now!) [33] H. Swan, I. Zeavin et al: J.A.M.A. 1953; 153:1081, Ann. Surg. 1954; 139:385, [34] C. W. Lillehei et al: Ann. Surg. 1955; 142:418, C. W. Lillehei, M. Cohen, H. E. Warden et al.: Ann. Surg. 1955; 142:447, [35] M. E. DeBakey: J.A.M.A. 1975; 233:1083. [36] C. A. Hufnagel, W. P. Harvey: Bull Georgetown Univ Med Cent. 1953; 6 (3):60-1, [37] M. E. DeBakey, D. A. Cooley, O. Creech, Jr.: Ann. Surg. 1955; 142:586, [38] F. C. Spencer, H. Blake: J. Thorac. Cardiovasc. Surg. 1962; 44:238, [39] J. W. Kirklin: Proc. Staff. Meetings Mayo Clin. 1955; 30:201, [40] K. Vosschulte: Thorax 1961: 16:338, [41] T. Akatsu, W. J. Kolff: Trans. Am. Soc. Artif. Intern. Organs 1958; 4:230, [42] S. Senning: J. Thorac. Surg. 1959; 38:369, R. Elmqvist et al.: Am. Heart J. 1963;65:731, [43] I. K. R. McMillan, A. M. Johnson, E. S. Machell: Br. Med. J. 1965; i:348, [44] W. J. Rashkind, W. W. Miller: JAMA 1966; 196:99, [4] H. Mohri, E. A. Hessel, R. J. Nelson, I. Matano, H. N. Anderson, D. H. Dillard, K. A. Merendino: Am. J. Surg. 1966; 112 (2):241-50

d) Since 1953: era of the open heart and great vessel surgery with the aid of extracorporeal bypass : valvular surgery under direct vision and coronary bypass operations:

1953: Successful closure of an atrial septal defect using a heart-lung machine (J. Gibbon) [1]
1956: Resection of a fusiform aneurysm of the entire ascending aorta using cardiopulmonary bypass (D. A. Cooley, M. E. DeBakey) [2]
1956: Repair of a pure mitral insufficiency by suture plication of the valve commissures under direct vision (annuloplasty; C. W. Lillehei et al.) [3]
1958: Bypassing the right side of the heart using a shunt between the superior vena cava and the right pulmonary artery (W. W. L. Glenn) [4]
1960: Total mitral valve replacement with flap valves covered with Teflon (F. H. Ellis et al) [5]
1961-68: Mechanical ball-valve prosthesis for mitral and aortic valve replacement (A. Starr, M. L. Edwards) [6]
1961: Free-floating disk for valve replacement (Björk-Shiley valve)
Outline of the concept of arterial counterpulsation for assisted circulation (R. H. Clauss, W. C. Birtwell et al.) [7]
1961: External direct current shock immediately after the R wave is able to avoid the vulnerable phase (method of the synchronized cardioversion, B. Lown et al.) [8]
1962: Valve plastic repair for correction of mitral insufficiency (G. H. Wooler, P. G. Nixon, V. A. Grimshaw, D. A. Watson) [9]
1962/1967: Aortic valve replacement with cadaver valves or using the patient's own pulmonary valve (D. N. Ross) [10]
1962/67: Autogenous saphenous vein as a coronary artery bypass graft (CABG; D. C. Sabiston Jr, R. Favaloro) [11]
1963: Left ventricular assist device, a bypass pump used in a human: the first implanted artificial heart [12]
1964: Internal mammary artery-coronary artery anastomosis for coronary revascularization V. I. Kolesov) [13], from 1967 with the help of mechanical suturing and the heart-lung machine in

standby position
1964: Homograft aortic valve replacement in aortic incompetence and stenosis (B. G. Barratt-Boyes) [14]
1967: Mitral valvulopathy with the use of aortic heterografts (experimental and one clinical case; A. Carpentier, J. C. Chanard, P. Laurens et al.) [15]
1967: First human heart transplantation (Chr. Barnard) [16]
1969: Pig's aortic valve for replacement (K. A. Kaiser et al.) [17]
1970/71: Isolation of the cyclosporin from the fungus Tolypocladium inflatum and discovery of its immunosuppressive effect (J. F. Borel, Z. L. Kis) [18]
1971: Prosthetic ring annuloplasty (A. Carpentier)
1978/83: Cyclosporin is approved for clinical use to prevent graft rejection after organ transplantation (R. Y. Calne et al) [19]. The careful experimentation of the Stanford group (N. E. Shumway) and the realisation of Medawar's concept about the acquired immune tolerance (1961) using cyclosporin A, azathioprene, anti-thymocyte globuline and steroids improved gradually the survival rate after heart transplantation.
1980: Chordoplasty (A. Carpentier) [20]
1982: W. C. De Vries attempts a permanent replacement of the heart with a mechanical prosthesis, and shortly after with a Jarvik pump in another cardiac cripple
1985: First implantable cardioverter defibrillator (AICD; M. Minkowski, M. M. Mower et al.) [21]
1989: World Congress on Heart Valve Replacement states: the Starr-Edwards valve still remains the gold standard (J. S. Swason, A. Starr, G. G. Siposs) [22]

(1955: First human renal transplant (J. E. Murray, J. P. Merril, J. H. Harrison: Surg. Forum 1955; 6:432
1962: First successful limb retransplantation (R. A. Malt, C. F. McKhann: JAMA. 1964; 189: 716)

[1] J. H. Gibbon: Am. J. Surg. 1978; 135:608, [2] D. A. Cooley, M. E. DeBakey: JAMA 1956; 162:1158, [3] C. W. Lillehei, V. L. Gott, R. A. DeWall et al: Lancet 1957; i:446, [4] W. W. L. Glenn: N. Engl. J. Med. 1958; 259:117, [5] F. H. Ellis Jr., J. A. Callahan: Proc. Staff Meetings Mayo Clin. 1961; 36:605, [6] A. Starr, M. L. Edwards: Ann. Surg. 1961; 154:726, J. S. Swanson, A. Starr: Ann. Thorac. Surg. 1989; 48:551-2, [7] R. H. Clauss, W. C. Birtwell, G. Albertal et al.: J. Thorac. Cardiovasc. Surg. 1961; 41:447, [8] B. Lown, R. Amarsasingham, J. Neumann: JAMA 1962; 182:548, [9] G. H. Wooler, P. G. Nixon, V. A. Grimshaw, D. A. Watson: Experience with the repair of the mitral valve in mitral in competence. Thorax 1962; 17:49-57, [10] D. N. Ross: Lancet 1962; ii:487, Lancet 1967; ii:956, [11] D. C. Sabiston Jr: Johns Hopkins Med. J. 1974; 134:314, R. G. Favaloro: Ann. Thorac. Surg. 1968; 5:334, [12] C. W. Hall: JAMA 1988; 259:1650. (D. A. Cooley et al. inserted an artificial heart in 1969 for total bypass without previous trials in experimental animals. The patient survived only for 65 hours.) [13] V. I. Kolesov, L. V. Potashov: Exp. Chir. Anaesth. 1965; 10:3, A. S. Olearchyk: J. Thorac. Cardiovasc. Surg. 1988; 96:13, [14] B. G. Barratt-Boyes: Thorax 1964; 19:131-50, [15] A. Carpentier, J. C. Chanard, P. Laurens, J. Guéry, H. Harada, D. Laurent, C. Dubost: Mem. Acad. Chir. (Paris) 1967; 93 (19):617-22, [16] C. N. Barnard: J. Thoracic. Cardiovasc. Surg. 1968; 56:457 (Barnard was a trainee with Shumway at the University of Minnesota. His first patient died from acute rejection 18 days after surgery, but the world was electrified **by** his announcement. Centers around the world blindly followed Barnard's example with predictabl**y** tragic results.) [17] G. A. Kaiser, W. D. Hancock et al.: Surg. Forum 1969; 20:137, [18] The story of the discovery of cyclosporin A can be found in: J. F. Borel, Z. L. Kis: Transplantation Proceedings 1991; 23:1867, [19] R. Y. Calne, D. J. G. White et al: Lancet 1978; 1182:1185, [120] A. Carpentier et al: J. Thorac. Cardiovasc. Surg. 1980; 79:338, [21] M. Minkowski, M. M. Mower in: P. Brugada, H J. J. Wellens, eds: Cardiac Arrhytmias: Where to go from Here, pp655-62 (1987), [22] J. S. Swanson, A. Starr: Ann. Thorac. Surg. 1989; 48:551-2, G. G. Siposs: Ann. Thorac. Surg. 1989; 48:56-7

e) Coronary surgery on beating heart without extracorporeal bypass:

1994-96: G. Ribakove introduces the revolutionary ‚port-access' procedure, a clinically applicable less invasive system for cardiac surgery [1]
1996: First less invasive mitral valve repair via small left anterior small thoracotomy or small sternotomy (MIDCAB) instead of full sternotomy (St. B. Colvin,

Galloway, Schwartz, Ribakove and Grossi) [1]
Mid 1990's: By developing myocardial wall stabilizers cardiac surgeons reintroduced less invasive surgical techniques in beating heart for aortic valve replacement, mitral and tricuspid valve repair, congenital heart defect surgery and multi-vessel coronary artery bypass grafting (CABG) without using extracorporeal bypass [2]
Late 1990's: Robotics appear as experimental procedures even in the cardiac surgery .
Since 2000: Beating-heart surgery is recognized as a valid and beneficial approach. First clinical use of robotic devices (F. W. Mohr, J. F. Onnasch, V. Falk et al. 1999) [3]
Totally endoscopic coronary artery bypass using robotic surgery (TECAB)
Coronary bypass grafting on beating heart with stabilization of the myocard (Shennib, Lee and Akin 1997, Kappert, Cichon, Schneider et al. 2001) [4]
2002: Resection of the mitral valve by means of robot surgery (Deutsches Herzzentrum, München)
2004: Percutaneous replacement of the aortic and mitral valve stents in a non-invasive manner (A. Cribier, H. Eltchaninoff, C. Tron et al., H. Mehmanesh, R. Henze and R. Lange, D. S. Schwartz, G. H. Ribakova, E. A. Grossi et al.) [5]
2006: Autologous bone marrow-derived stem-cell transfer in myocardial infarction [6]
Transplantation of a beating conserved heart (R. Körfer, Bad Oeynhausen)

Ongoing *tendency in the cardiac surgery*: stem-cell therapy, tissue engineering, minimal invasive access for the aortic valve replacement, restitution of the tendon cords at mitral valve prolapse, endoscopic graft harvesty, robot surgery, e. g. TECAB (total endoscopic coronary artery bypass), intra-uterine heart surgery and endoscopic placed aortic prosthesis

Literature

[1] D. S. Schwartz, G. H. Ribakove, E. A. Grossi et al: Minimally invas**ive** mitral valve replacement: port-access technique, feasibility, and myocardial functional preservation. J. Thorac. Cardiovasc. Surg. 1997; 113 (6):1022-30
[2] A. M. Calafiore, G. Di Giammarco, G. Teodori et al.: Left anterior descending coronary artery grafting via left anterior small thoracotomy without cardiopulmonary bypass. Ann. Thorac. Surg. 1996; 61: 1658-65
[3] F. W. Mohr, J. F. Onnasch, V. Falk et al: The evolution of minimally invasive valve surgery – 2 year experience. Eur. J. Cardiothorac. Surg. 1999; 15 (3): 233-38
[4] H. Shennib, Allan G. L. Lee, Jodi Akin: Safe and effective method of stabilization for coronary artery bypass grafting on the beating heart. Ann. Thorac. Surg. 1997; 63: 988-92, U. Kappert, R. Cichon, J. Schneider et al: Technique of closed chest coronary artery surgery on the beating heart. Eur. J. Cardiothorac. Surg. 2001; 20: 765-69,
[5] A. Cribier, H. Eltchaninoff, C. Tron et al.: Treatment of calcific aortic stenosis with the percutaneous heart-valve: mid-term follow-up from the initial feasibility studies: the French experience. J. Am. Coll. Cardiol. 2006; 47 (6):1214-23, H. Mehmanesh, R. Henze, R. Lange: Totally endoscopic mitral valve repair. J. Thorac. Cardiovasc. Surg. 2002; 123 (1):96-7,
[6] In a double-blind, randomised controlled trial in 67 patients the intracoronary stem-cell transfer was associated with a significant reduction in myocardial infarct size and a better recovery of regional systolic function (University of Leuven: S. Janssens, Chr. Dubois, J. Bogaert et al.: Lancet 2006; 367:113). In Hungary the first attempt **of** such a stem-cell transfer was made at the Debrec**en** University in 2005, too (Á. Péterffy et al.).

f) Evolution of the heart-lung machine and the extracorporeal circulation (s. also table 4/a):

1915: Rotating disk oxygenator (D. R. Hooker) [1]
1928: Modified disk oxygenator using a columns of cones that rotated within a series of stationary plates (L. E. Bayless et al) [2]
1934: The idea of the heart-lung machine for use in humans is born (J. Gibbon) [3]
1935: Perfusion pump by means of pulsatile gas pressure (A. Carrel and C. A. Lindbergh)[4]
1948: Modern rotating disk oxygenator for brain perfusion (V. O. Björk) [5]
1949: Film oxygenator with a Dale-Schuster pump [6] for mechanically sustained circulation and respiration (J. Jongbloed) [7]
1950: Bypassing the right side of the heart with shunting the venous blood directly into

the pulmonary artery (W. H. Sewell Jr., W. W. L. Glenn) [8]

1951: First use a pump oxygenator for a partial bypass of the right heart in human (A. M. Dogliotti, A. Constantini) [9]

Bypassing the left side of the heart for entry into the left heart to expose the mitral valve (G. H. A. Clowes Jr.) [10]

First unsuccessful use of a heart-lung machine in humans (Cl. Dennis, Minnesota) [11] (This tragically ending case and the inability of Gibbon's to repeat his initial atrial septal closure success in 1953 created a dampening effect on the further evolution of the heart-lung machine.. At the same time the Lillehei group also realized the limitations of biologic oxygenation with the cross circulation.)

1950-54: Human donor as a biologic oxygenator for cross circulation: experimental closure of intraventricular septal defects (L. Blum, S. Megibow, H. E. Warden, M. Cohen, R. C. Read, C. W. Lillehei, R. A. DeWall et al.) [12]

1951-1952: Use of an isolated homologous lung as a donor oxygenator (H. J. Sugarman, S. A. Weselowski, J. Anzolo, C. S. Welch) [13] using monkey or dog lung (W. T. Mustard et al.) [14]

1953: Successful closing of an atrial septal defect using a heart-lung machine (J. Gibbon) [15]

1955: Direct vision closure of ventricular septal defects in 8 patients using cross circulation (C. W. Lillehei et al) [16]

1955/56: Elective cardiac arrest with cardioplegic solutions (D. G. Melrose, D. B. Effler)

1956: Modified rotating disk oxygenator by substituting stainless steel, Teflon-coated disks and a pyrex silicone-coated chamber (E. S. Cross et al) [17]

Total cardiac bypass in humans utilizing a pump and heterologous (dog) lungs (G. S. Campbell, N W. Crisk et al.) [18]

1956: Direct vision intracardiac surgery in man using a simple disposable artificial bubble oxygenator in conjunction with a vertical blood-oxygen mixing tube (to remove the large bubbles) and a DeBakey pump (C. W. Lillehei, R. A. DeWall et al)[19]

Disposable membrane oxygenator (W. J. Kolff, D. B. Effler et al.) [20]

1958: Disk oxygenator of E. B. Kay and F. S. Cross (PEMCO) [21]

1959: Bilateral bypass without an oxygenator and with deep hypothermic circulatory arrest (C. E. Drew and I. M. Anderson) [22]

1978: Coronary artery surgery with patient's lung as oxygenator (B. Glenville, D. N. Ross) [23]

2000: Re-introduction of the Drew-Anderson technique in coronary artery bypass grafting (attenuates Systemic Inflammatory Response Syndrome, SIRS) [24]

[1] D. R. Hooker: Am. J. Physiol. 1915; 38:200, [2] L. E. Bayliss, A. R. Fee, E. Ogden: J. Physiol. 1928; 66:443, [3] J. Gibbon: Am. J. Surg. 1978; 135:608, [4] A. Carrel, C. A. Lindbergh: Science 1935; 81:621, [5] V. O. Björk: Act. Chir. Scand. 1948; 96 (suppl. 137): 1-122, [6] H. H. Dale, E. H. J. Schuster: J. Physiol. 1928: 64:356, [7] J. Jongbloed: Surg. Gynec. Obstet. 1949; 89:684, J. Appl. Physiol. 1951; 3:642, [8] W. H. Sewell Jr, W. W. L. Glenn: Surgery 1950; 28:474, [9] A. M. Dogliotti, A. Constantini: Minerva Chir. 1951; 6:657, [10] G. H. A. Clowes: Ann Surg. 1951; 134:957, [11] C. Dennis, D. S. Spreng Jr., G. E. Nelson et al: Ann. Surg. 1951; 134:709, [12] L. Blum, S. Megibow: J. Mount Sinai Hosp. NY 1950; 17:38, H. E. Warden, M. Cohen, R. C. Read, C. W. Lillehei: J. Thorac. Surg. 1954; 28:331, H. E. Warden, M. Cohen, R. A. DeWall et al: Surg. Forum 1954; 5:22, [13] H. J. Sugarman, S. A. Weselowski, J. Anzolo, C. S. Welch: Bull. N. Engl. Med. Center 1951; 13:107, [14] W. T. Mustard, A. L. Chute, E. H. Simmons: Surgery 1952: 32:803, [15] J. H. Gibbon: Am. J. Surg. 1978; 135:608. The next two patients died due to false diagnosis in one case, and owing to the fatal postoperative hemorr**hage** in the second one. Thereafter Gibbon declared a moratorium on bypass surgery until more work could be done on the coagulation problems. Having been d**eeply** depress**ed**, Gibbon performed **no more** cardiac surger**y** and returned to the thoracic surgery again. [16] C. W. Lillehei, M. Cohen, H. E. Warden et al: Surg. Gynec. Obstet. 1955; 101:447, [17] E. S. Cross et al: Proc. Soc. Exp. Biol. 1956; 93:210, [18] G. S. Campbell, N. W. Crisp, E. B. Brown Jr: Surgery 1956; 40:364, [19] C. W. Lillehei, R. A. DeWall, M. Paneth et al: Surg. Clin. North Am. 1956; 36:1025, [20] W. J. Kolff, D. B. Effler, L. K. Groves et al: J. Thorac. Surg. 1956:32:620, [21] E. B. Kay, J. E. Galajda, A. Lux, F. S. Cross: J. Thorac. Surg. 1958; 36:268, [22] C. E. Drew, I. M. Anderson: Lancet 1959; 1:748, [23] B. Glenville, D. N. Rosse: Lancet;1986; 4:1005, [24] J. A. Richter, H. Meisner, P. Tassani, A. Barankay et al: Ann. Thorac.Surg. 2000; 69:77

g) Evolution of the interventional techniques <u>in cardiology</u>:

1964: Relieving stenosis of peripheral arteries by means of a guidewire, catheter and then a rigid dilator (C. T. Dotter, M. P. Judkins) [1]

1968: Beginning of arrhythmia surgery by interrupting the reentrant circuit through destroying the accessory Kent bundle in WPW syndrome (W. C. Sealy) [2]

1974: Percutaneous transluminal angioplasty (PTA) with a balloon-tipped catheter for the dilating of peripheral arteries (A. Gruentzig, D. A. Kumpe) [3]

1977: Percutaneous transluminal coronary angioplasty (PTCA; A. Gruentzig, A. Senning, W. E. Siegenthaler) [4]

1979/1984: Recanalization of thrombotic coronary vessels by means of intracoronary thrombolyse with streptokinase infusion (E. L. Chazov, P. Rentrop, H. Blanke et al., W. Gans, N. Marcus et al.) [5]

1980: Contrast vizualization of the coronary arteries is safe in acute myocardial infarction M. A. DeWood, J. Spores et al)

1**981/82**: Successful treatment of recurrent ventricular tachycardia using electrode catheter ablation technique (R. Gonzalez et al., J.J. Gallagher et al.) [7]

1982: Balloon dilatation to split the commissures for relief of pulmonary valve stenosis in children (balloon valvuloplasty; J. S. Kan, R. I. White et al.) [8]

1982/83: Creation of a functional atrial septal defect using a balloon catheter (W. J. Rashkind) or by attaching a surgical blade to the catheter (S. C. Park, W. H. Neches et al.) [9]

1983: Percutaneously introduced ‚double-disk prosthesis' for closing an atrial septal defect or a patent ductus arteriosus [10]

1983: Reintroduction of intravenous infusion of a high dose of streptokinase for thrombolyse in acute myocardial infarction

(The development of clot-specific antithrombolytic agents with little or no systemic lytic action and the search for an ideal thrombolytic agent are still in progress.)

1986: Coronary stent implantation[12] gains widespread acceptance after the succesful reduction of early stent thrombosis by the use of thienopyridines and high pressure stent implantation [13].

2003: Drug-eluding stents achieve further decrease in restenosis [14] and target lesion revascularization, but generate great concerns about hypersensitivity reaction and late stent thrombosis [15]

2003-2006: Absorbable magnesium alloy stents show in animals complete and rapid endothelisation, low intima proliferation, very small inflammatory changes and complete absorption within 2 months [16].

[1] C. T. Dotter, M. P. Judkins: Circulation 1964; 30:654, [2] In: W. C. Sealy: NCMJ 1983, 44:489, [2] A. Gruentzig, D. A. Kumpe: Am. J. Radiol. 1979; 132:547, [4] A. Gruentzig, A. Senning, W. E. Siegenthaler: N. Engl. J. Med. 1979; 301:61, [5] P. Rentrop, H. Blanke, K. Kostering, K. R. Karsch: Clin. Cardiol. 1979; 2:354, W. Gans, N. Buchbinder, H. Marcus et al.: Am. Heart J. 1981; 101:4, [6] M. A. DeWood, J. Spores, R. Notske et al: N. Engl. J. Med. 1980; 303;897, [7] R. Gonzalez, M. Scheinman et al: Am. J. Physiol. 1981; 241:H283, M. Scheinman, F. Morady et al: JAMA 1982; 284:851, J. J. Gallagher, R. H. Swenson, J. H. Kasell et al.: N. Engl. J. Med. 1982; 306:194, [8] S. Kan, R. I. White, S. E. Mitchell and T. J. Gardner: N. Engl. J. Med. 1982; 307:540, [9] W. J. Rashkind: Circulation 1983; 67:711, S. C. Park, W. H. Neches, C. E. Mullins et al.: Circulation 1982; 66:258, [10] W. J. Rashkind: Circulation 1983; 67:711, [11] R. Schröder, G. Biamino, L. Enz-Rudiger et al: Circulation 1983; 63:536, [12] U. Sigwart, J. Puel, V. Mirkovitch et al.: N Engl J Med 316 (1987) 701-706, [13] A. Colombo, M. Ferrato, A. Otho et al.: J Am Coll Cardiol 28 (1996) 830-836, [14] E. Grube, S. Silber, K.E. Hauptmann: Circulation 107 (2003) 38-42, J. W. Moses, M. B. Leon, J. J. Popma et al: N Engl J Med 349 (2003) 1315-1344, J. Fajadet, M. C. Morice, C. Bode et al.: Circulation 111 (2005) 1040-1044, [15] J. R. Nebeker, R. Virmani, C L. Bennett et al.: J Am Coll Cardiol 47 (2006) 175-181, M. Joner, A. V. Finn, A. Farb et al.: J Am Coll Cardiol 48 (2006) 193-202, A. J. Nordmann, M. Briel, H. C. Bucher: Eur Heart J 27 (2006) 2784-814, [16] B. Heublein, R. Rohde, V. Kaese et al.: Heart 89 (2003) 651-656, C. Di Mario, H. Griffiths, O. Goktekin et al.: J Interv Cardiol 17 (2004) 391-395, R. Waksman, R. Pakala, P. K. Kuchulakanti et al.: Catheter Cardiovasc Interv 68 (2006) 607-617

Landmarks in open heart surgery (after St. Westaby, C. Bosher 1997, Richter J. 2003)

11. April 1949: First experimental method for biventricular bypass with deep-core cooling using a heat exchanger (Charles E. Draw) and circulatory arrest for 30-45 minutes in three children with great atrial septal defect (ASD) in deep hypothermia to 15°C (C. E. Drew, I. A. Anderson; s. 1959)

2. **September 1952**: Successful closure of a VSD (ventricle septal defect) with the help of surface cooling hypothermia and inflow occlusion (F. J. Lewis)

6. May 1953: first successful open cardiac surgery using a heart-lung machine (J. Gibbon)

26. March 1954: controlled cross circulation with a living donor (parabiosis) for correction of the VSD (C. Walton Lillehei)

1954->: Successful closure of VSD with the help of disk oxygenator (J. Webster Kirklin, Mayo Clinic, Rochester)

1957: Bubble oxygenator (R. A. De Wall, C. Walton Lillehei, Minneapolis)

1959: Biventricular bypass combined with autologe lung perfusion as a biological oxygenator (C. E. Drew, I. M. Anderson)

Historically developed conditions which should have been established before performing successful intracardiac surgery:

-teamwork between surgeons and anaesthetists in each heart centre.
-intratracheal anesthesia, controlled ventilation and intensive care unit
-availability of special cardiac anaesthesia techniques
-blood bank, hemodilution, cell saver and rapid estimation of coagulation disorders
-large-scale shock treatment, resuscitative techniques and internal defibrillation (Cl. Beck, 1947) as well as external DC shock cardioversion (B. Lown, 1961)
-invasive and non-invasive haemodynamic monitoring and diagnosis (e.g. Holter monitoring, CT, MRI, heart catheterism, angiocardiography, TEE) as well as interventional cardiology procedures
-full-scale perioperative hemodynamic monitoring
-possibility of acute bypass
-IABP (intraaortal balloon pump) and other assist-devices
-cardioplegia and other cardioprotective drugs
-hypothermia
-extracorporeal circulation, heart-lung machine
-xenograft, biological prosthesis and artificial valves
-donor bank, transplantation team, homograft tissue bank, tissue typifying and immunosuppression (antilymphocyte serum, glucocorticoids, monoclonal T-cell antibodies OKT-3, anti-thymus cell globuline ATG, Rapamycine, cell antibodies and cyclosporin A) in case of heart transplantation
-continuous survey on morbidity and mortality as a national and international project (EuroSCORE)
-availability of sufficient financial support for instrumentation, donor conditioning, operative procedures, intensive care beds and staff, as well as for scientific research, postgraduate training, and for -rehabilitation centres

Literature:

Acierno, Louis J: The History of Cardiology. London, Casterton, New York, The Parthenon Publ. Group 1994, 758p

Blair, Emil: Clinical Hypothermia. New York, Toronto, London, McGraw-Hill Book Comp. 1964, 272p

Comroe, Julius H., Jr: Exploring the Heart. Discoveries in Heart Diseases and High Blood

Pressure. New York, London, W. W. Norton & Comp.,1983
Currie, James: Medical Reports on the Effects of Water, cold and warm, as a Remedy in Fever and other Diseases. Liverpool, J. M'Creery 1798
Hardaway, Meade Richard: A History of Thoracic Surgery. Springfield, C. C. Thomas Publ. 1961
Hurt, Raymond, ed.: The History of Cardiothoracic Surgery. From Early Times. New York, London, The Parthenon Publ. Co. 1996, 514p
Keown, Kenneth K: Anesthesia for Surgery of the Heart. Springfield, Illinois, Charles C. Thomas Publ. 1956, 109p
Morton, Leslie T: A Medical Bibliography (Garrison and Morton). An Annotated Check-List of Texts Illustrating the History of Medicine. Frome and London, Butler & Tanner Ltd 1983, 961p
Safar, Peter, Bircher, Nicholas G: Cardiopulmonary Cerebral Resuscitation. 3rd ed., London, Philadelphia, Toronto, Sydney, Tokyo, W. B. Saunders Comp. Ltd 1988, 464 p

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