SURGICAL HISTORY

The Early History of Cardiac Surgery in Stockholm

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ABSTRACT **Cardiac surgery in Stockholm grew on a sound foundation of well-developed general thoracic surgery. The portal figure is Clarence Crafoord (1899–1983) who already in 1927 had succeeded with the Trendelenburg pulmonary embolectomy operation. He went on to develop lung surgery in general. With foresight he stimulated the chemists of Karolinska Institute to purify heparin, first for prophylaxis against venous thromboembolism and later for use with the heart-lung machine. In 1944 he became the first surgeon to successfully operate on patients with coarctation of the aorta. With Viking Olov Bjork and Ake Senning the heart-lung machine was improved, finally allowing its clinical use in a patient operated in 1954 for a myxoma of the left atrium, with long-term survival. This was the first successful use of the heart-lung machine in Sweden and the second in the world. He and his coworkers, first at the Sabbatsberg hospital and from 1957 at the Karolinska hospital made major contributions to cardiology and radiology, apart from the progresses in cardiac surgery. Contributions such as pressure recording from the left atrium by needle puncture in 1950, the Senning operation for transposition of the great arteries and the first use of a totally implantable cardiac pacemaker in 1958 are indeed medical history.**
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The early era, defined as ca. 1940–1960, of cardiac surgery in Stockholm was not a chance occurrence. General thoracic surgery was already well developed, providing a sound foundation. The concurrent developments in invasive cardiology and radiology, i.e., angiocardiography, benefitted from the progress in cardiac surgery. The fact that Sweden had not been actively involved in World War II, an expanding postwar economy, and close cooperation with and generous sponsoring by innovative industrial companies such as AGA, Elema-Schonander, and Stille played decisive roles.

The portal figure of cardiac surgery in Sweden is Clarence Crafoord (1899–1984). He had the good fortune to start his surgical career in 1922 at Morby hospital near Stockholm where K.H. Giertz was chief of surgery. Giertz had a long-standing interest in thoracic surgery and had already 1914 taken two years leave of absence to study experimentally the ventilation of the lungs for thoracic surgery. Endotracheal intubation and positive pressure ventilation were found to best fill the demands.[1]

Giertz became the mentor and friend of the ambitious young surgeon. When in 1928 Giertz moved to the Sabbatsberg Hospital in the city of Stockholm to become chief of one of its two surgical services, Crafoord followed him. Crafoord was soon allowed to open up a ward for the treatment of patients with various forms of thoracic disease. In 1938 he presented his doctoral thesis "On the technique of pneumonectomy in man,"[2] which was well received and later opened many

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doors in the international surgical community. In 1939 Crafoord was appointed chief of the second surgical department at the Sabbatsberg hospital and finally of both services when Giertz retired in 1941.

TRENDELENBURG OPERATION

At the time when Crafoord started his surgical training deep vein thrombosis and pulmonary embolism were common and often fatal complications of otherwise uncomplicated surgery or child birth. It is thus not surprising that Crafoord after having witnessed a number of such fatalities decided to try the Trendelenburg embolectomy operation. He assembled the necessary instruments and practised the operation on corpses before finally attempting the operation clinically. In 1927 at age 28 he was successful in two cases,[3] which, of course, gave him both publicity and a good reputation. Twenty-two attempts were made between 1927 and 1949 with a total of three survivals. Clearly, the Trendelenburg operation was not the answer to the problems of thrombosis and embolism.

HEPARIN

Already in 1929 Crafoord repeatedly approached the well-known biochemist Erik Jorpes at Karolinska Institutet, asking him to purify the "heparin" described by Howell,[4] to be used as prophylaxis against vein thrombosis and pulmonary embolism. Jorpes, who had already visited Best's group, pioneers in heparin research, in Toronto could only answer that this was unfortunately not possible at the time. However, in 1935 Jorpes could offer Crafoord, now working at the Sabbatsberg hospital, a preparation sufficiently pure for human use. Crafoord embarked on a clinical study heparinizing postoperatively 325 patients.[5] Simultaneously, the Toronto group manufactured their heparin and commenced clinical studies. Both groups published impressive clinical results in 1937 and 1941.[6,7]

In the spring and summer of 1939 Clarence Crafoord, financed by a fellowship from the Rockefeller Foundation, made a 4-month-long tour of selected centers in the United States. At the meeting of the American Surgical Association in Hot Springs, Virginia in May 1939 Crafoord heard Robert Gross present his first four cases of surgical closure of persistent ductus arteriosus. Already before the meeting Crafoord had visited Gross in Boston and had been shown a ductus closure operation. Crafoord operated his first own ductus case in May 1941.

After Boston Crafoord visited Philadelphia and met John Gibbon who since 1934, when heparin became available to him, had conducted animal experiments with the intent to construct a machine to be used during pulmonary embolectomy.[8]

Crafoord was fascinated by Gibbon's research. He arranged to have his coworker, Engineer Emil Andersson of the AGA Company, visit Gibbon who graciously provided information about the heart-lung machine. Back in Sweden Crafoord and Andersson with generous sponsorship from AGA started to develop a machine, but it did not become ready for experimental use until 1945. During the war after 1942 Gibbon and Crafoord could not correspond, but in 1946 Crafoord again visited the United States and stayed in Gibbon's home. They had become very close friends and freely exchanged information.

SURGERY OF AORTIC COARCTATION

Crafoord developed his technique for the operation of aortic coarctation after thorough analysis of the problem. He mixed in the experiences he had accumulated during surgery of patent ductus arteriosus or rather experiences from the complications that had occurred during such surgery. Worrying that simple ligature of the ductus might lead to recanalization Crafoord from his first ductus case chose to divide the ductus between vascular clamps and to suture both ends of the ductus. In a very dramatic case operated in January 1943 there was severe bleeding. The aorta had to be clamped above and below the ductus for 26 minutes, luckily without causing spinal cord damage. Following this observation Crafoord reasoned that in a case of coarctation with well-developed collateral circulation, occlusion of the aorta for at least this period of time should be safe. True to his nature Crafoord planned an operation in detail. He convinced his cardiology colleagues that the operation of aortic coarctation was both indicated and feasible. In early 1944 two patients with coarctation were referred to him. On October 19, 1944 he operated successfully on the first case. This was an 11-year-old boy who during

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a 6-hour-long operation had the coarctation resected and the aorta reanastomosed. Already in June 1945 four cases were operated and a report submitted to the *Journal of Thoracic Surgery*. The manuscript was received by the journal June 1, 1945 and printed in the October issue.[9] Robert Gross operated his first successful case on July 6, 1945 and published his success in the *New England Journal of Medicine* on September 6, 1945. The priority issue has been much discussed, but it is clear that Crafoord met Gross only in 1939 and did not visit the United States again until after the end of World War II. Andreas P. Naef in his book *The Story of Thoracic Surgery*[10] convincingly shows that the two groups worked independently of each other.

In 1946 Viking Olov Bjork was given the task of developing the heart-lung machine previously constructed by Emil Andersson of the AGA company at the request of Crafoord. This early machine was equipped with a rotating disc oxygenator and crude pumps from a milking machine. The red rubber tubing in the machine was very rough and consumed platelets, which naturally caused bleeding problems. Bjork covered the surface of the rubber tubing with a silicone compound resulting in much reduced cell destruction. He gradually improved the machine and could in October 1946 successfully isolate and perfuse the brain of a dog for 33 minutes with survival and good brain function after. In 1948 Bjork presented his doctoral thesis on extracorporeal circulation,[11] strangely enough against the wishes of Crafoord. Following successful defense of his thesis Bjork continued his clinical training in surgery at the Sabbatsberg hospital. He gradually acquired expert knowledge of lung surgery and particularly tuberculosis surgery on which Crafoord was not personally very keen. Bjork was not encouraged to continue working on the heart-lung machine. Instead, in 1950 Ake Senning was given the task of further developing the heart-lung machine. Working together with P.A. Astradsson, again an engineer of the AGA company, the disc oxygenator was scaled up to allow its use in humans. It is unclear, however, whether the oxygenator used for the first clinical operation, removal of a left atrial myxoma,[12,13] was this disc oxygenator or an early version of the new Crafoord-Senning-AGA oxygenator equipped with rollers instead of discs and, in addition, a preoxygenator placed before the roller oxygenator, adding small oxygen bubbles through a ceramic filter to the blood. From 1955 the roller oxygenator was used exclusively.[13]

THE FIRST CLINICAL USE OF A HEART-LUNG MACHINE IN SWEDEN

The patient, a woman born 1911, developed in the fall of 1952 palpitations and dyspnea. In July of 1953 she was admitted under the presumptive diagnosis of mitral stenosis to "Serafimerlasarettet," the old University hospital of Karolinska Institutet. She was again admitted in November for further studies with surgery in mind, i.e., closed commissurotomy. A cardiac catheterization was performed at the Sabbatsberg hospital (Fig. 1). It included pressure measurements in the pulmonary artery during rest and exercise and pulmonary-capillary-wedge pressure measurement simultaneously with registration from the left atrium through a transthoracic needle introduced by the Bjork technique.[14] Approximately 30 minutes after the catheterization during routine chest X-ray the patient suddenly developed right-sided hemiparesis and aphasia. She made full recovery over the following weeks. The diagnosis remained mitral stenosis even after catheterization. In May 1954 she was admitted to the Sabbatsberg Hospital for further studies in anticipation of possible surgery on the mitral valve. It is probable that myxoma was now one of the differential diagnoses since she had remained in sinus rhythm. Furthermore, in another patient operated in March 1954 a myxoma had been found during digital exploration of the left

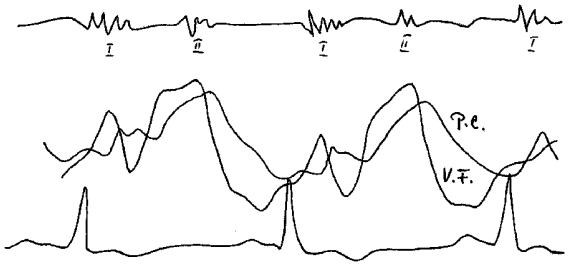

Figure 1. *Original record of preoperative cardiac catheterization of the myxoma patient operated in 1954. There was simultaneous recording of cardiac sounds, left atrial pressure (VF), PCW-pressure (PC), and ECG. Systolic, diastolic, and mean (Medel.) pressures are given in mmHg. V. förmak = Left atrium, A. pulmonalis = pulmonary artery, Höger kammare = right ventricle, Höger förmak = right atrium.*

atrium in preparation for mitral commissurotomy (blind removal was attempted, resulting in embolization and the patient's death). Angiocardiography with contrast injection in the pulmonary artery was then performed on May 26 in the Pediatric department of the Karolinska hospital, the new University hospital, which at the time possessed the best equipment for angiographic studies. The angiogram performed by S-R Kjellberg showed in the left atrium a filling defect, moving up and down through the valvular plane. The interpretation was "tumor or myxoma?"

A decision was made to offer the patient open heart surgery, the only possible treatment option although the available heart-lung machine was primitive, of limited capacity, and clinically untried.

On July 16, 1954 the patient was brought to surgery with Crafoord as surgeon and Ake Senning as his assistant. She was anesthetized, put in a collapsible tray placed on the operating table and at 08.00 a.m. external cooling was started by icewater poured into the tray. When the rectal temperature was 34.7°C and the temperature in skeletal muscle was 30.4°C, active cooling was interrupted, the tray emptied, and the patient positioned for a left lateral thoracotomy. The fifth rib was removed. At 10.00 a.m. rectal temperature had dropped to 28.6°C. An arterial return cannula was placed in the left subclavian artery and and a large bore venous cannula in the right atrial appendage. Extracorporeal circulation was commenced at 12.58 p.m. and the rectal temperature was now 30.2°C. The heart was fibrillated with a 50 millamp shock. The left atrium was broadly incised from the left atrial appendage to between the pulmonary veins. Unfortunately, this incision was too small for the size of the tumor. The tumor fragmented and had to be removed in pieces. At 13.25 p.m. the atrial incision was sutured. After manual compression of the heart, it was defibrillated. Sinus rhythm was restored and the heart-lung machine stopped at 13.31 p.m. at a rectal temperature of 30°C. The thoracotomy was closed. Protamine sulphate was administered and the patient warmed by warm water poured into the collapsible tray. At 16.25 p.m. there was respiratory standstill and pulselessness, subsequently shown by the ECG recording to have been due to a short period of ventricular fibrillation. Warming continued and at 17.40 p.m. the temperature was 36.9°C and the patient responded to verbal commands. During the evening and night the patient awoke without any signs of embolization or neurological injury. The patient made full recovery and lived until the year 2002. There was never a recurrence of the tumor.

This successful first operation may seem to indicate that problems with extracorporeal circulation were small and easily solved. That this was not the case is shown in Table 1. Of all 25 cases operated upon with the aid of extracorporeal circulation at the Sabbatsberg hospital, 13 died in conjunction with the operation. How could such a result be defended? The answer probably lies in the wise selection of cases. All or almost all were severely ill and could not have been treated surgically without the aid of the heart-lung machine. In the same time period the surgeons of the Sabbatsberg hospital chose to use the circumclusion technique[15,16] or surface hypothermia to allow closure of, for example, simple atrial septal defects, thus not exposing these patients to the more risky heart-lung machine procedure. The result of the ASD operation in hypothermia was usually successful and predictable.[17]

THORACIC CLINIC, KAROLINSKA HOSPITAL

In the spring of 1957 the construction of the new dedicated Thoracic Clinic at the Karolinska Hospital was completed. Crafoord had for a decade fought for this project. Ironically, when it finally was completed Crafoord was incapacitated having undergone surgery for a subdural hematoma. In his absence Viking Olov Bjork opened the clinic. Crafoord recovered and resumed his duties in the fall of 1957. With him came Senning as chief of the new Surgical Research Laboratory. The building of this laboratory, occupying a full floor above the operating suite was financed by a donation from the Rockefeller Foundation.

Between 1957 and 1962, 353 patients were operated upon with the aid of the heart-lung machine at the Karolinska Hospital[18] (Table 2). The great majority were operated upon for congenital heart disease. Over these years the mortality rate remained high, on an average 32%. The main cause of death was classified as respiratory insufficiency in 16%, technical errors in 40%, hemorrhage in 7%, infection in 7%, renal insufficiency in 5%, and cardiac failure in 14%.[18]

Crafoord was surrounded by many excellent surgeons, anesthetists, radiologists, and

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TABLE 1
Operations with Heart-Lung Machine at the Sabbatsberg Hospital 1953–1957

Case	Date	Gender, Age	Diagnosis	Operation	CPB (min)	Operation Survivor
1	July 1954	F 42	Myxoma	Exstirpation	33	Y
2	Nov 1954	F 1	VSD	Suture	?	N
3	Dec 1955	M 17	Aneur.sinus Valsalva	Suture	?	N
4	May 1956	M 5	VSD	Suture	?	N
5	June 1956	M 52	LV-aneurysm	Resection	20	Y
6	July 1956	M 16	Fallot	Correction	36	N
7	July 1956	F 31	ASD primum	Ivalon patch	21	Y
8	July 1956	M 6	VSD	Ivalon patch	41	Y
9	July 1956	F 2	ASD + VSD	Suture + Ivalon patch	40	N
10	Aug 1956	M 21	ASD primum	Ivalon patch	30	Y
11	Sept 1956	M 14	AS	Commissurotomy	7	Y
12	Sept 1956	M 4	Transp. + VSD	Switch + Ivalon patch	100	N
13	Oct 1956	F 41	AS	Commissurotomy	9	N
14	Oct 1956	M 17	Infundib. Stenosis	Resection	11	Y
15	Oct 1956	F 21	ASD	Ivalon patch	26	Y
16	Oct 1956	F 48	MS + AS + TI	Comm.tomies M + A	7	N
17	Nov 1956	M 34	VSD + valv. PS	VSD patchc + outflow patch	60	Y
18	Nov 1956	M 52	AS	Commissurotomy	?	N
19	Nov 1956	M 11	ASD	Ivalon patch	?	Y
20	Nov 1956	M 38	AS	Commissurotomy	?	N
21	Jan 1957	M 1	VSD	Suture	?	N
22	Feb 1957	M 15	ASD primum	Ivalon patch	?	Y
23	Mar 1957	F 10	Transp. + VSD	Switch + suture	?	N
24	Apr 1957	F 18	ASD	Ivalon patch	?	N
25	May 1957	F 30	ASD	Ivalon patch	?	Y

Table accumulated from Crafoord's patient cards and ref 13.

cardiologists, attracted by the fascinating new specialty—cardiac surgery (Fig. 4). Visitors and fellows from all over the world competed for a "place at the table." Of his early assistants two in particular reached independent "fame" because of their own achievements.

TABLE 2
Operations with Heart-Lung Machine at the Karolinska Hospital 1957–1962

Diagnosis	No. of Operations	No. of Deaths
Tetralogy of Fallot	95	41
VSD	62	14
ASD	61	7
AV commune	17	7
TAVR	2	0
AS	50	11
AI	7	6
MI	27	13
Inf PS	14	1
TGA	6	5
Cor. sclerosis	4	3
Heart tumor	3	1
LV aneurysm	1	0
Cor triloculare	2	2
Fibroelastosis	1	1
Aneur. Sinus Valsalvae	1	1
	353	113

Number of operations and deaths. Table condensed from reference 18.

AKE SENNING (1915–2000)

There is no doubt that Senning was a major driving force behind the successful start of open heart surgery at the Sabbatsberg hospital and later at the Karolinska hospital in Stockholm. His cooperation with the AGA Company led to a gradually improved heart-lung machine with an oxygenator based on rollers instead of rotating discs. Cooperation with the cardiologists and radiologists of the Pediatric Clinic at Karolinska exposed Senning to patients with very varied congenital malformations of the heart. It was truly a learning experience for surgeons and diagnosticians alike. Total anomalous pulmonary venous drainage of the supracardiac type was successfully corrected off-pump.[19] Already at Sabbatsberg treatment of the transposition of the great arteries by an arterial switch procedure was tried but without success due to lack of myocardial protection. In October 1958 a 9-year-old boy with simple transposition was then operated upon with a new method of hemodynamic correction at the inflow

Figure 2. *Clarence Crafoord (center) doing cardiac surgery at the Sabbatsberg hospital. On his right Nurse Inga, on his left Dr Goran Hambraeus, opposite Dr Ake Senning and Dr Stig Ekestrom. These early operations were often done through a bilateral transsternal thoracotomy with femoral arterial cannulation.*

level by an atrial switch procedure, since then called Senning's operation. The boy lived well for 19 years before dying from acute endocarditis.[20]

Coronary disease was then as now a major killer. Senning tried endarterectomy in animals and then in October 1958 operated with success upon a 54-year-old man with severe angina.[21] Cardioangiography showed occlusion of the right coronary artery and the LAD as well as stenosis of the circumflex artery. The patient was operated upon under deep hypothermia and ventricular fibrillation utilizing a double pump system without an oxygenator. The LAD and the circumflex arteries were endarterectomized and the vessels closed with vein patches. Postoperatively there was rapid recovery and no angina even during a stress test 15 months later.

Senning, together with Dr Rune Elmqvist of the Elema-Schonander Company, also conducted pacemaker experiments. Their experience was that transcutaneous pacemaker leads invariably resulted in infection, hence the search for a totally

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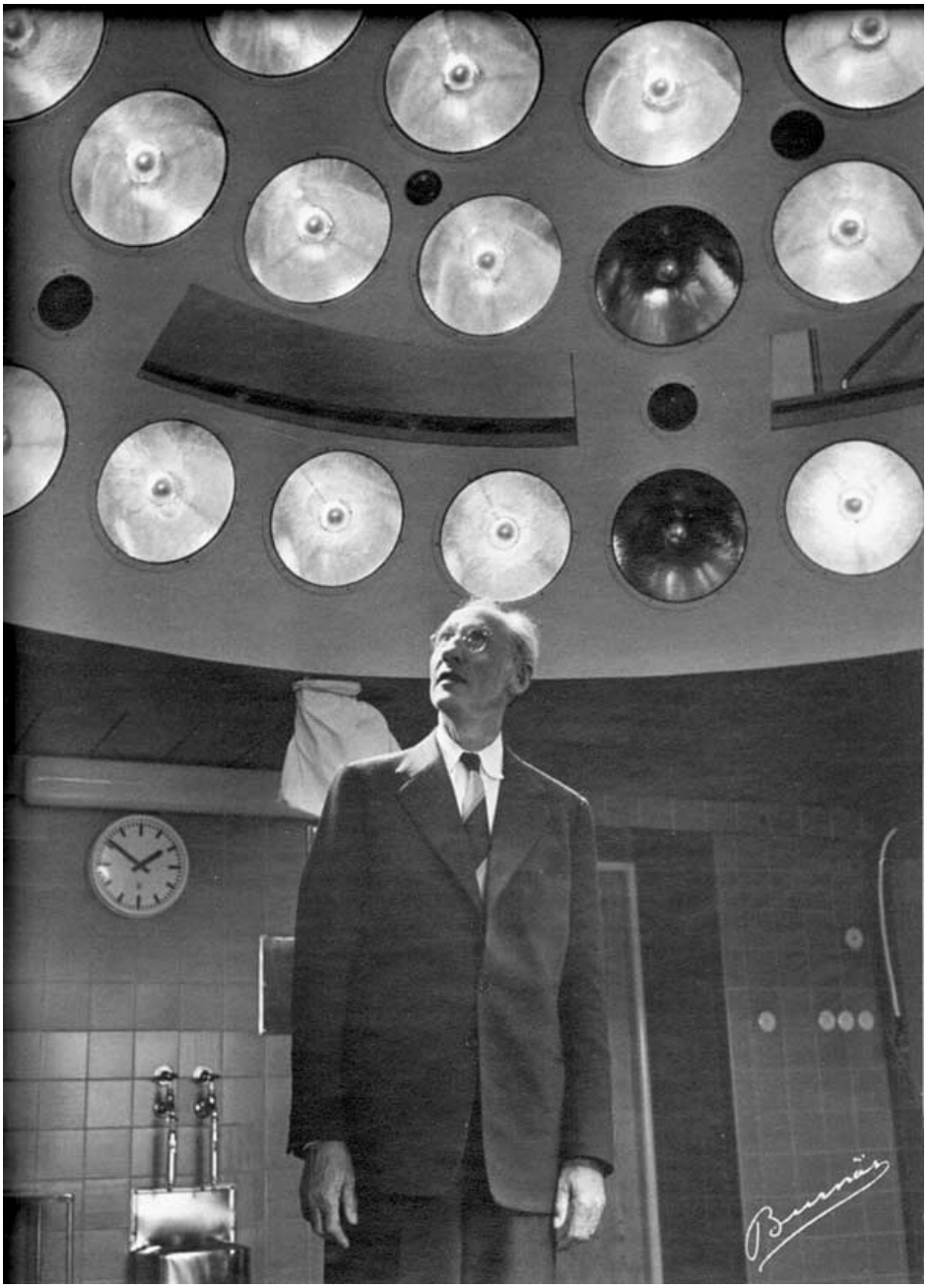

Figure 3. *Clarence Crafoord looking in awe at his new operating theatre at the Karolinska Hospital in 1957. Note the domed ceiling with lamps and the observation windows for visitors.*

implantable pacemaker. In October 1958 they were approached by a woman on behalf of her husband, who was desperately ill with numerous Stokes-Adams attacks daily. Based on their experiments of the preceding 2 years, Elmquist rapidly fabricated two pacemakers by molding the necessary electronics and battery into an epoxy shell. On October 8, 1958 the pacemaker was implanted in the posterior rectus sheet and the electrodes sutured to the myocardium through a left thoracotomy.[22] The first pacemaker failed after 8 hours and had to be exchanged with the backup

Figure 4. *Radiology round at the Karolinska Hospital 1961. Chief of radiology Bjorn Nordenstrom demonstrating for in the first row Eric Carlens, Clarence Dennis on a one-year sabbatical, Clarence Crafoord, Lennart Johansson, Ake Senning (left to right).*

system, which functioned for several months. The patient has since received many new pacemakers, lived an active life until dying at age 86, surviving his surgeon by a year.

Senning (1915–2000) was offered a professorship of surgery at the Kantonsspital in Zurich, Switzerland and moved there in 1961.

VIKING OLOV BJORK (1918–)

As already detailed Bjork successfully refined the original heart-lung machine with a disc oxygenator, produced by the AGA company for Clarence Crafoord. In 1950, however, further development was delegated to Ake Senning. Bjork later revived the disc oxygenator concept and produced with AGA a heart-lung machine based on the disc oxygenator, which was in clinical use worldwide for many years.

Following a study trip in 1950 to the United States Bjork returned to the Sabbatsberg hospital where he was detailed to work on lung surgery, and tuberculosis surgery in particular. He became a renowned expert in this field. Of particular importance for the progress of cardiac surgery was his application of artificial ventilation to the postoperative patient.[23]

The budding specialties of cardiology and cardiac surgery were in great need of techniques to measure pressures in the left heart as well as allowing the injection of contrast for angiocardiography. Bjork, during lung surgery had the idea of passing a very long needle through the right posterior chest wall paravertebrally into the left atrium.[14] He developed this idea and later combined the needle with a catheter passing through it for pressure measurements in the left atrium, the left ventricle, and the aorta.

Bjork with Crafoord described a variant of the circumclusion technique for off-pump closure of atrial septal defects.[15]

In 1958 Bjork moved to the University Hospital in Uppsala to start a new Cardiothoracic unit. Here he was very much his own boss and contributed

greatly to the progress of cardiac surgery, but that is besides the subject of this article. In 1966 Bjork was "called" to replace Crafoord as Professor of Thoracic Surgery at Karolinska Institutet and Chief of the Department of Thoracic Surgery at the Karolinska Hospital.

REFERENCES

1. Giertz KH: Studier over tryckdifferensandning enligt Sauerbruch och over konstgjord andning (rytmisk luftinblasning) vid intrathoracala operationer. Almqvist & Wiksells Boktryckeri, Uppsala, 1916.
2. Crafoord C: On the technique of pneumonectomy in man. Doctoral thesis at Karolinska Institutet. Acta Chir Scand 1938;81(Suppl. 54).
3. Crafoord C: Two cases of obstructive pulmonary embolism successfully operated upon. Acta Chir Scand 1928;64:172-186.
4. Howell WH: Heparin an anticoagulant. Am J Physiol 1922;63:434-435.
5. Crafoord C: Preliminary report on post-operative treatment with heparin as a preventive of thrombosis. Acta Chir Scand 1937;79:407-426.
6. Crafoord C, Jorpes E: Heparin as a prophylactic against thrombosis. JAMA 1941;116:2831-2835.
7. Murray DWG: Heparin and thrombosis and major blood vessel surgery. Surg Gynecol Obstet 1941;721:341-344.
8. Gibbon JH: Artificial maintenance of the circulation during experimental occlusion of the pulmonary artery. Arch Surg 1937;34:1105-1134.
9. Crafoord C, Nylin G: Congenital coarctation of the aorta and its surgical treatment. J Thorac Surg 1945;14:347-361.
10. Naef AP: The Story of Thoracic Surgery. Toronto, Hogrefe & Huber, 1990, pp. 86-87.
11. Bjork VO: Brain perfusions in dogs with artificially oxygenated blood. Doctoral thesis at Karolinska Institutet. Acta Chir Scand 1948;96(Suppl. 137).
12. Crafoord C, Senning A: Utvecklingen av extracorporeal circulation med hjart-lungmaskin. Nord Med 1956;56:1263-1268.
13. Crafoord C, Norberg B, Senning A: Clinical studies in extracorporeal circulation with a heart-lungmachine. Acta Chir Scand 1957;12:220-245.
14. Bjork VO, Malmstrom G, Uggla LG: Left auricular pressure measurements in man. Ann Surg 1953;138:718-725.
15. Bjork VO, Crafoord C: The surgical closure of interauricular septal defects. J Thorac Surg 1953;26:300-308.
16. Sondergaard T: The closure of atrial septal defects. Report of three cases. Acta Chir Scand 1954;107:492.
17. Johansson L, Senning A: Surgical correction of atrial septal defects. Acta Chir Scand 1959;(Suppl 245):283-296.
18. Crafoord C, Ekestrom S, Silva Iribarren CO: The causes of death after total cardio-pulmonary bypass. In Studies in Surgery. Lundgrens Soner boktr., Malmo, 1963, pp. 27-45.
19. Senning A: Complete correction of total anomalous pulmonary venous return. Ann Surg 1958;148:99-103.
20. Jonsson B, Ovenfors CO, Senning A: Surgically corrected case of transposition of the great vessels. Acta Chir Scand 1959;(Supp 245):297-306.
21. Senning A: Strip grafting in coronary areries. J Thorac Cardiovasc Surg 1961;41:542-9.
22. Elmqvist R, Senning A: An implantable pacemaker for the heart. In Smyth CN (ed): Medical Electronics. Proceedings of the Second International Conference on Medical Electronics. Iliffe & Sons, London, 1960.
23. Bjork VO, Engstrom CG: The treatment of ventilatory insufficiency by tracheostomy and artificial ventilation. A study of 61 thoracic surgical cases. J Thorac Surg 1957;34:228-241.