

PAST, PRESENT AND FUTURE OF THE CARDIO- PULMONARY BYPASS —SPECIAL LECTURE—

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In 1883, Dr. Billoth of Berlin had claimed that a surgeon who would attempt such an operation such as cardiac suture should lose the respect of his colleagues.

However history thereafter showed aortic valvotomy was done by Tuffier in 1913 and decortication for constrictive pericarditis by Rehn in 1920. Among the congenital heart diseases, patent ductus arteriosus was cured by ligation technic by Gross in 1938.

Introduction of intubation anesthesia, bronchography and sulfonamides encouraged many surgeons to convert from thoracoplasty to pulmonary resection in treating overwhelmingly large number of pulmonary tuberculosis patients with increasing safety.

History and references about extracorporeal gas exchange in blood are so multiple and are not easily described. As possible consequences the followings were in mind of many pioneers: immediate resuscitation after death, the medical treatment of acute and chronic cardiac and pulmonary failure, major surgical replacements of defective portions of circulatory system, open reparative or direct vision quiescent intra-cardiac operations, accurate measurements of coronary blood flow and many other unattainable objectives in the early 1950.

However popularization of cardiac surgery was delayed until during the IInd world war when improvements in intubation anesthesia and wide spread use of penicillin made Harken to successfully remove foreign bodies of cardiac chambers in over one hundred sixty patients.

As soon as the war was over, coarctation of the aorta was operated by Blalock and pulmonary valvotomy was performed by Sellors and Brock.

During the same time influence of low temperature on the living body, local and general hypothermia, were experimentally study which led another way to treat heart diseases under low temperature.

The work directed to cardiac surgery was extensively conducted by Bigelow and his group. In parallel with their work I was working under the late S. Yanagi on my Ph.D. thesis titled as "Influence of low temperature on living body especially on general freezing and its protection and treatment" at the Hokkaido Imperial University which was published in 1944. However very unfortunately all of the work at that time was conducted without anesthesia therefore they remained as purely experimental studies not applicable in clinical cardiac surgery.

Although closure of atrial septal defect was successfully performed by Lewis in 1953 which was followed by many surgeons, real opening of intracardiac direct vision surgery with the use of extracorporeal setup was initiated with success by Gibbon in the same year. The latter was followed by four successive deaths resulted in his discouragement in this new epochmaking trials.

It is interesting to note the statement made by Baily, who was known as pioneer of closed mitral valvotomy against Harken's mitral valvuloplasty in 1948, "hence, to date, I think it is fair to say that the heart lung apparatus has caused death of more patients than it has helped.

Pivoting heart valves the first Clinical Application

Valve	Aortic	Midral
Wada-Cutter	1967 Feb.	1966 Sepr.
Björk-Shiley	1967 Jan.	1967 Jan.
Lillehei-Kaster	1970 Sepr.	1970 Lepr.

Introduction of Pyrolite Carbon made WADA's concept "Hingeless Hinge" concept to popularity and bileafer valves became available.

Where do we stand IN 1985, in Japan.

Cardiac Operations		
Congenital	7326	49.4(%)
Valve	4069	27.5
C.A.B.G.	3042	20.5
Others	382	2.6
Total	14819	100

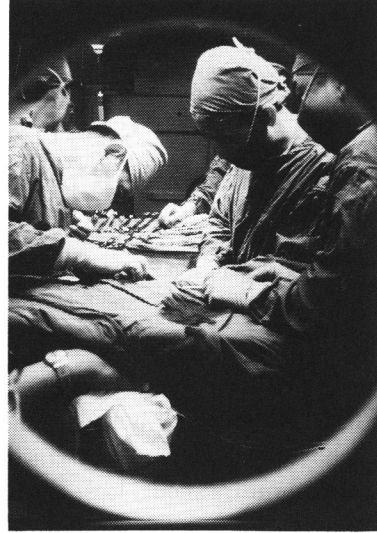
General trends are : Congenital, slight in crease, Valve gradual decrease, and CABG slowly in creasing.

Automatic control of CPB

1959	Kantrowitz Waldhausen
1961	Bernhard
1962	Lewis
1970	Anderson

In addition to antibiotics, anesthesia and Heparin, availability of plastic materials and ethyl-oxoxide were essential to make extracorporeal circulation a safe procedure for daily use on the basis of increased knowledge of surgical anatomy of cardiac diseases and introduction of sternotomy incision. Also how to combine extracorporeal circulation and hypothermia in clinical setting was another important issue to modernize the extracorporeal circulation. In the book "to mend the heart"* forwarded by Harken (page 154) it says. "In the 1950s Juro Jerry Wada, a Japanese doctor at the Boston City Hospital as a research worker, has experimented on dogs. He bubbled their blood with oxygen, thus, saturating it, and then debubbled it, but at the time no one appreciated the great significant this experiment would one day

*L. Wertenbaker, The Viking Press, NYC, 1980

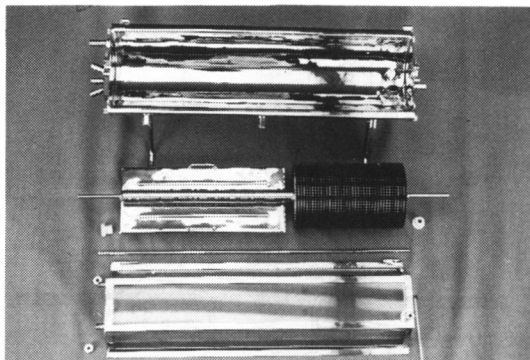


Intra-hyperbaric chamber cardiac operation for cyanotic children was tried clinically by the author in the early 1960th.

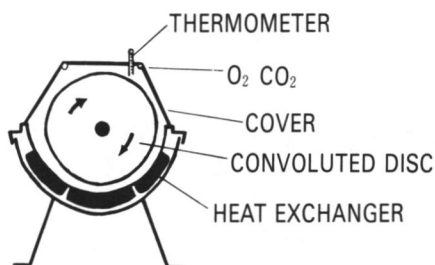
have for cardiopulmonary bypass. Isolated organ were one thing. The hart which sent blood everywhere in the body was another. Getting all the bubbles out was the major problem" Harken also wrote "You Jerry I do know that you worked with the original bubble oxygenator while I missed the boat".

When I left for Japan in 1954, still postwar poverty prevailed and modern thoracic surgery was still in prenatal stage. Starting from right cardiac bypass technic, DeWall type oxygenator was imitated with the use of copper with nickel plating and named as Thermo-Helix-Oxygenator. Soon Thermo-Disc-Oxygenator (Fig.) was designed and clinically used in hundreds of various cardiac cases. It was so designed to fit to baby as well as adult by employing "caisson" or obturator to change space for blood reservoir as well as double layered bottom for circulation of heart exchange. This TDO was exported to the Peter Bent Brigham Hospital of Harvard University in June 1963 to my pleasure.

Introduction of sheet oxygenator made me to design Wada All-In-One Oxygenator which was followed by various make of all-in one type oxygenator. Soon thereafter with the same idea hard



CROSE SECTION OF THERMO DISC OXYGENATOR

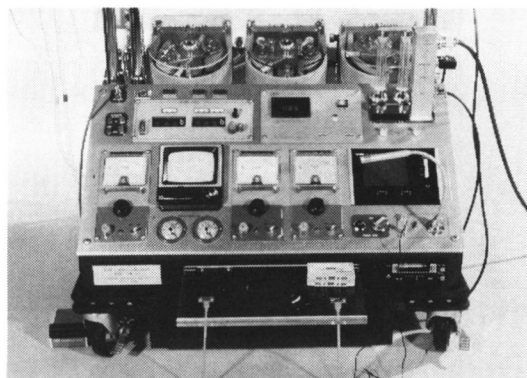


For the first the De-Wall Lillehei oxygenator was modified with the use of chromplated copper and the Thermo-Helioxoxygenator was made. Then the popular Kay-Cros Oxygenator was modified by the author with the use of Nickel Plated Copper. The bottom of the collecting chamber was made double for heat exchanging water circulation. The volum of the chamber was adjusted to the size of patient with the use of "caisson". Up to 4 cases were bypassed in succession when blood type were identical to economize the priming blood.

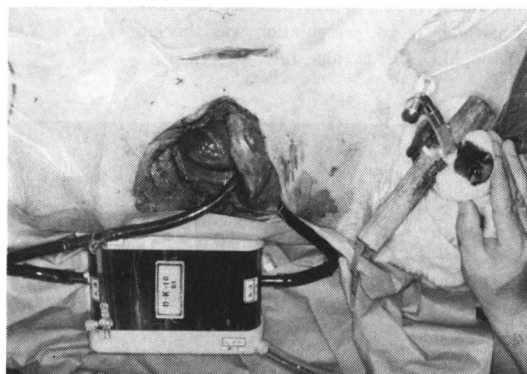
shell oxygenator of plastic material was introduced with popularity. About at the same time refined membrane oxgenator started to attract surgeons interest again particularity in complicated and prolonged procedures in infants.

Now we have reached to a stage where total extracorporeal circulation can be performed with safety up to six hours. Introduction of hemodilution and cardioplegia technic which was invited by preservation of heart in heart transplantation made quality of cardiac surgical technic much more easier and better. I was privileged to organize Japanese Society of cardioplegia in 1978.

Improvement of membrane of membrane oxygenator may increase more popularity against



Pump started with Metal Finger Pump to DeBaakey Rotary Pump. We currently use Pump Unit "J.W.101" which incorporate colored television screen of operating field, multiple monitoring devices and a music player for background music. The feautres were quickly introduced to the world pump manufactures. More recently as pump head "centrifugal pump" became available.



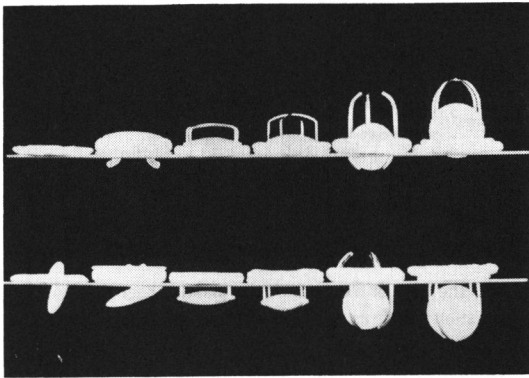
As to the lung or oxygenator the plastic sheet then to the bard shell bubble as well as membrane oxygenators became popular. For prolonged exracorporeal oxygenation (for pulmonary insufficiency) better membrane was sought. The compact membrane oxygenator shown here is for the unilateral lung exclusion from circulation for more than seveal hours with right ventricular pressure as pump power. (T. Kawamura & J. Wada).

bubble oxygenator in the coming years. It may not be too long to see in clinical setting in operating room, compact membrane oxygenator of all-in-one-type design can be placed on the head of patient as surgical instrument while pump is remote-controlled by anesthesiologist during performance.

To this direction we have developed an automatic control method using the central venous



Improvement of extracorporeal circulation invited to develop better valve design. The Wada valve was disclosed for the first time in USA, Society of Thoracic Surgeons. Chairman of my presentation was the late, Francis X. Byron, M.D. City of Hope, LA.

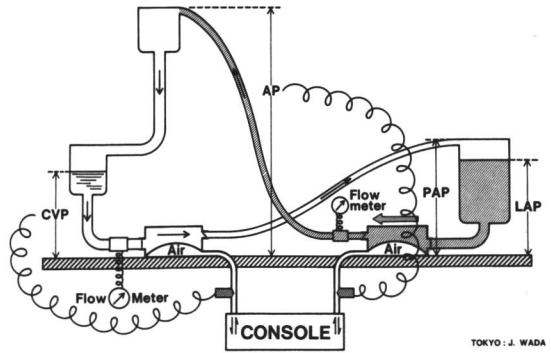


Changing concept of valve design is shown.

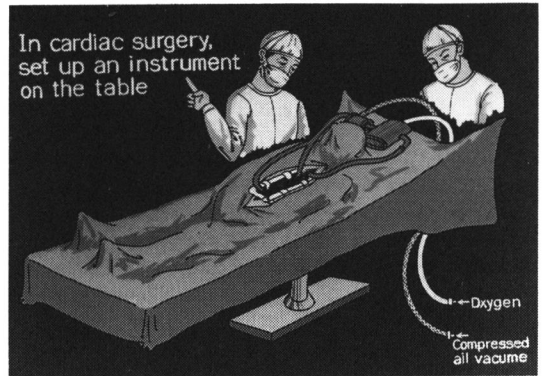
- Harken-Davol
- Starr Edwards in 1960
- Smeloff-Cutter
- Kay-Suzuki
- Kayshirley
- Alvabez
- Wada-Cutter
- Upper—Aortic Position, Lower—Mitral Position

pressure. The central venous pressure, that is nearly equal to the venous return, is considered to be an useful reflection of the circulating blood

Pulsatile APLEC (J. Wada & T. Hino)



APLEC (Automatic Pressure Limited Extra-corporeal circulation) which has a new concept of the Total Artificial Heart is incorporated into our current thought of pump system, so that, extracorporeal cardiac surgery can be maneuvered by doctor-anesthetist.



Part of this paper was presented by the author as a key-note speaker at the 5th Sandiego Cardiothoracic Surgery Symposium Feb. 8~10, 1985 and a faculty at the 7th Sandiego Cardiothoracic Surgery Symposium Feb. 5~7, 1987 in Sandiego, California.

volume during cardiopulmonary bypass.

A central venous pressure adjustment circuit is developed for triggering the system. The pump-oxygenator, using this method showed satisfactory function during CPB.

The results are the following:

- 1) CPB was maintained safely and stationary by venous return.
- 2) The central venous pressure varied during CPB cyclically with an interval of 2 to 5 seconds and an amplitude of 3 to 10 cmH₂O around the preset highest level of the central venous pressure, that was equal to the overflow level of the

central venous pressure adjustment circuit.

3) The blood volume in the arterial reservoir was kept within the safety level and massive air embolism due to emptying of the reservoir was completely avoided by the reserved blood volume control using a photosensor.

This device seems promising to function sufficiently as a venous return triggered pump oxygenator.

This made us to further develop idea to use the air driven artificial hearts in automatic control of the ECC as pumps in extracorporeal circuits with

bubble oxygenator, made us to have total system at the head of the operating table.

We have successfully excluded oxygenator in the circuit for perfusing coronary artery bypass operation in which only heart is excluded from circulation and is put into cardioplegic stand still. (J.J. Wada, Tsunekazu Hino and Masahide Murasugi)

Reference:

WADA J., HINO T., KAIZUKA H., WOLFGANG A.R.
Automatic Regulation of the Cardiopulmonary Bypass Perfusion I: 117, 1986.