PRINCIPLES AND PRACTICE OF CARDIOPULMONARY BYPASS (CPB): A SUB-REGIONAL EXPERIENCE

VAN-OSTERWELL S. AMUZU
CHIEF PERFUSIONIST/BIOMEDICAL SCIENTIST, NCTC, ACCRA. GHANA
WILLIAM HARVEY 1578 – 1657

1628 Published  DE MOTU CORDIS

“ON THE MOTION OF THE HEART AND BLOOD”

Describing the function of the heart and circulation of blood around the body
• 1896 Ludwig Rehn operated on a man who had been stabbed in the heart

• 1944 Dwight Harkem operated on soldiers with shrapnel in their hearts

<table>
<thead>
<tr>
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<th>14</th>
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<th>Animal Experiments</th>
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</thead>
<tbody>
<tr>
<td>1st</td>
<td></td>
<td>all died</td>
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<tr>
<td>2nd</td>
<td></td>
<td>7 died</td>
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<tr>
<td>3rd</td>
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<td>2 died</td>
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<tr>
<td>4th</td>
<td></td>
<td>Soldiers</td>
<td>All survived</td>
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In all he did 130 with no mortality
WILFRED GORDON BIGELOW

- Worked on hypothermia experimenting on animals to reduce O2 consumption (basic metabolism) by 50% by dropping temp by 7 degrees. He published the results of his work in 1952.

- Pioneered first pacemaker

- He was beaten to first open heart case by John Lewis and his team
1\textsuperscript{st} Case

(Jacqueline Johnson 5yr ASD)

• She was surface-cooled to 28\textdegree{} C and her HR \(\downarrow50\%\)
• The surgeons reckoned they had 6 minutes
• All the heart vessels were clamped, the atrium opened, and the hole sutured
• The patient was then rewarmed in a bath
• She left hospital 11 days later
CARDIOPULMONARY INFRASTRUCTURE

• THE HEART PUMPS 5 LITRES / MINUTE

• BLOOD VESSELS ARE 75,000 MILES (app 120,000km)

• LUNGS SURFACE AREA IS 100m²

HOW CAN WE SUBSTITUTE THE HEART AND LUNGS?
THE WORK OF DR. JOHN H. GIBBON, JR.

• He spent a substantial part of his work life, about three decades, pursuing artificial circulation.

• The impetus for Dr. John H. Gibbon, Jr., to develop a heart-lung machine was the witnessing of a patient's death due to pulmonary embolism and failed pulmonary embolectomy in 1930.
• The concept of organ and tissue perfusion with oxygenated blood was demonstrated several times in the 1800s, beginning with the work of Cesar-Julian-Jean LeGallois in 1813.

• He reasoned/suggested that if there could be a way of external perfusion of an isolated organ or tissue of the body, one could preserve such an organ/tissue for a long period of time...

• It wasn’t until the middle of the century that Charles Edward Brown-Sequard pointed out that the success of such perfusion depended on oxygenated blood.
• The early perfusion devices had limited capability to exchange gases, which limited their use in isolated organ experiments.

• But there was no link with heart surgery in humans at the time.
• In 1929, Brukhonenko speculated that artificial circulation of blood might someday be applicable for cardiac surgeries in humans. We can say that he conceived the ultimate value of CPB and its potential use in humans

• After three decades of experimenting on animals, Dr. J. Gibbon finally developed the first HLM with help from IBM corporation… The method of oxygenation was the screen film type
John gibbon’s first attempt at using the heart-lung machine failed.....

The patient was a 15yr old with congestive heart failure who was diagnosed with an ASD

There was no ASD to be found and on post mortem a huge PDA was discovered

His next patient survived an ASD closure but the next two patients died

Gibbon declared a moratorium on the heart-lung machine

HE NEVER DID ANY MORE CARDIAC SURGERY
John W. Kirklin et al. at the Mayo Clinic modified the IBM-Gibbon screen film oxygenator and used it in a large series of patients in the mid to late 1950s.

Walton Lillehei et al used cross circulation to close a VSD, however that patient died 11 days post op with respiratory problems.

The technique was continued with great success in repairing VSD’s, Fallot’s and AVSD’s.

45 patients in two years until abandoned in 1955.
The first heart lung support - Gibbon’s Pump or Another Human (Cross circulation)
Early prototypes of HLM, built by pioneers like Dr. John Gibbon, were cumbersome and dangerous—often leaking blood, damaging blood cells and causing air embolisms. It wasn't until 1958, when a system that involved bubbling blood was perfected, that "heart-lung" machines came of age.
• Dr. Dennis Melrose of London further increased chances for success of Heart surgery using CPB when he pioneered an injection that stopped the heart from beating during surgery (Cardioplegia).
The first oxygenators
Re-sterilised and single use products

Disc Oxygenator

Bubble Oxygenator
Membrane Oxygenators

Silicone Membrane

Polypropylene Membranes
Blood Pumps

Roller Pumps

Centrifugal Pumps
Monitored And controlled

1. Oxygen supply
2. Blood Flow
3. Blood pressure
4. Blood gases and electrolytes and acid base status
5. Haemodilution
6. Coagulation status
7. Temperatures
CARDIOPLEGIA

- 1955 Dr. Denis Melrose experimented with potassium to induced cardiac arrest

- 1975 Bretschneider developed the first multi component solution

- 1970’s Buckberg introduced blood cardioplegia
Perfusionist

- Alert, attentive, well-trained perfusionists are required to assemble and operate the heart-lung machine. Current standards encourage assignment of two perfusionists to each patient, but often only one is present. Perfusionists are responsible for the safe, smooth, and continuous operation of the machine.
PRESENT DAY

• SMALLER PRIMING VOLUMES
• IN LINE BLOOD GAS MONITORING
• VENOUS SATURATIONS
• CEREBRAL SATURATIONS
• HEPARIN TITRATIONS, ACT’s
• ECG’s
• PRESSURE’s
Gibbon-IBM machine
The Kay-Cross rotating disc heart-lung machine manufactured by Pemco Inc.
The Dodrill-GMR heart pump.
Heart-lung machine developed by C.R. Cowan and William Mustard.
**D100 Kids**

Maximum Flow Rate: 0.7LPM
Prime Volume: 31mls

**D902**

Maximum Flow Rate: 2.3LPM
Prime Volume: 105mls

**D905**

Maximum Flow Rate: 5LPM
Prime Volume: 160mls
FUTURE ADVANCES

- BLOOD FREE CPB
- POTASSIUM FREE CARDIoplegia
- ISCHEMIC PRECONDITIONING
- STEM CELL TECHNOLOGY
- PERFLUOROCARBON EMULSIONS
  - ABILITY TO ABSORB NITROGEN
• BIOCOMPATIBLE SURFACES AND COMPONENTS

• ULTRAFILTRATION

• DATA MANAGEMENT SYSTEMS

• SAFETY ALARMS
  ▪ BLOOD LEVEL
  ▪ ARTERIAL LINE BUBBLE
GHANA’S EXPERIENCE

• The first cardiac surgery employing CPB was performed in Ghana in January 1992, almost 40yrs after Dr. John Gibbon

• The National Cardiothoracic Centre, Ghana, was dreamt, pursued and accomplished by Prof. Kwabena Frimpong-Boateng with financing from government.

• I was part of the initial core group of people selected to be trained in Germany in preparation for the set up of this centre
• The initial consumable extracorporeal circuits were supplied by the project contractor. We subsequently had to look for our own source

• Our own customized extracorporeal circuits were designed in December 1994 and has since been modified three times to meet our changing demands.

• Started with bubble oxygenators and by 1997/98 membrane oxygenators were introduced.

• Bubble oxygenators were completely faced out by 2000.
• Began with Stokert HLM (CAPS model) until 2003 when it was changed to SIII model (sorin group).

• We have three sets of CPB custom packs:

- **D100 Kids**
  - Maximum Flow Rate: 0.7LPM
  - Prime Volume: 31mls

- **D902**
  - Maximum Flow Rate: 2.3LPM
  - Prime Volume: 105mls

- **D905**
  - Maximum Flow Rate: 5LPM
  - Prime Volume: 160mls
• Till date CPB has been a routine procedure in our centre in Ghana and will continue to be.
• Going it alone has not been the best and a regional cooperation would held improve and sustain the quality of the CPB service in the countries of our part of the world.
Thank you very much for your attention!