# ECMO

# Past, Present and Future


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Organ Transplantation Center

Korea Artificial Organ Center

Anam-Hospital, Korea University Medical Center, SEOUL

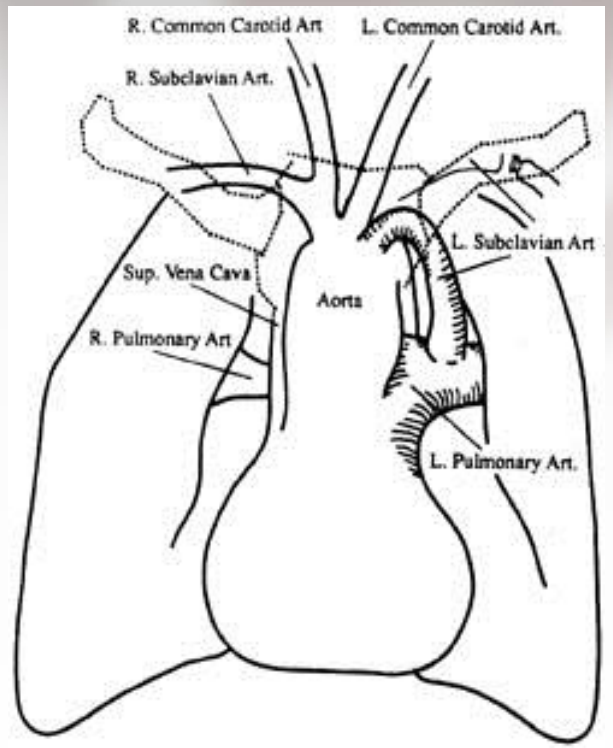
# Past

# 심장수술의 역사

# Pre-Heart-Lung Machine Era

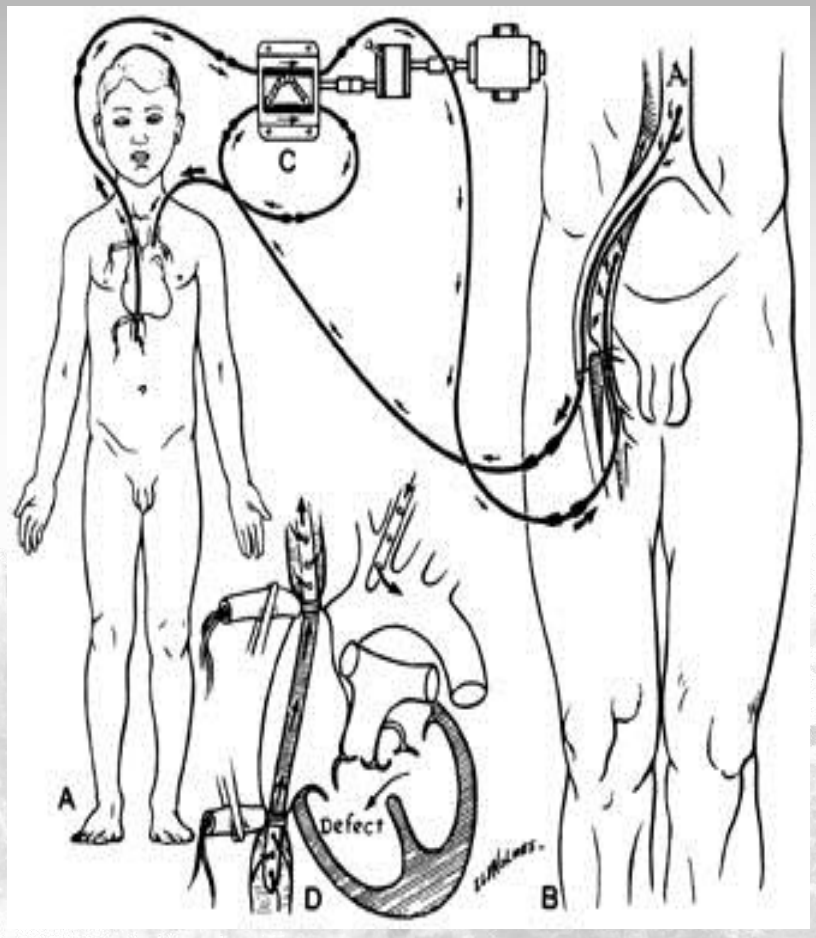
- 1938. Gross. First successful PDA ligation
- 1944. Crawford Resection of coarctation of aorta
- 1945. Blalock. Blalock-Taussig operation
- 1946. Gross. Surgical closure of AP window
- 1958. Glenn. Glenn shunt

# First Blalock-Taussig Shunt

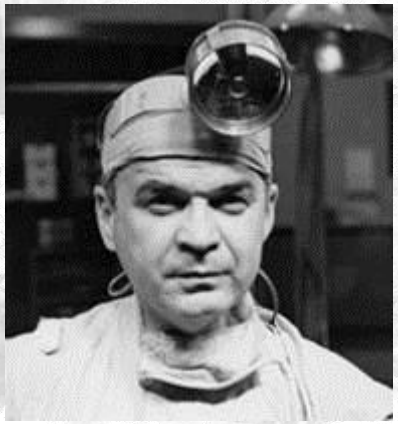



***" Most powerful stimulus to the development of cardiac surgery "***

# Controlled Cross-circulation



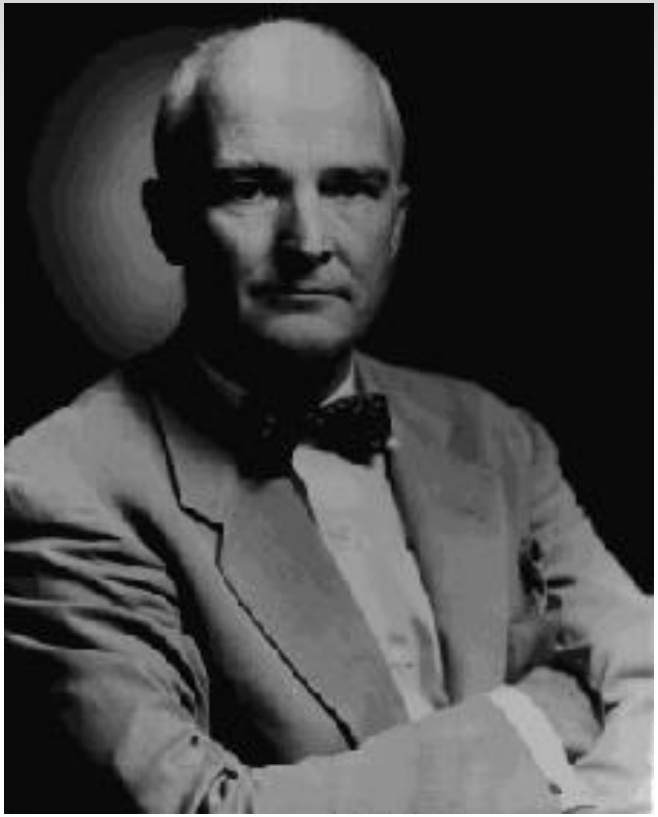

- **1954. Lillehei**
  **First surgical closure of VSD under controlled cross-circulation**
- **Used in 45 patients between 1954 to 1955**
- **VSD**
  **TOF**
  **AVSD**



# Development of CPB

- 1951. Dodrill. Mitral valve surgery under left heart bypass
- 1952. Dodrill. Relief of PS under right heart bypass
- 1953. Lewis. ASD closure under surface cooling
- 1953. Gibbon. ASD closure by heart-lung machine
- 1954. Lillihei. VSD closure under controlled cross-circulation
- 1954. Kirklin. Establishment of CPB with oxygenator in cardiac surgery

# J. Gibbon and Heart-lung Machine



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# ECMO의 역사



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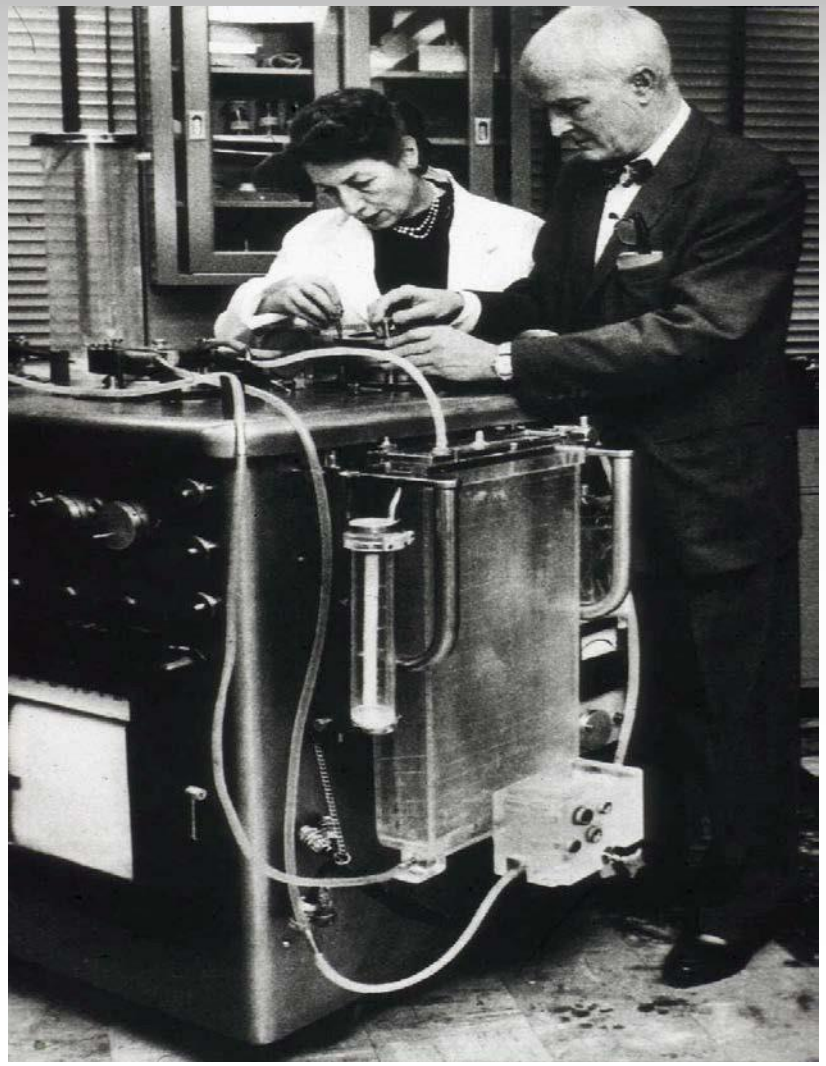
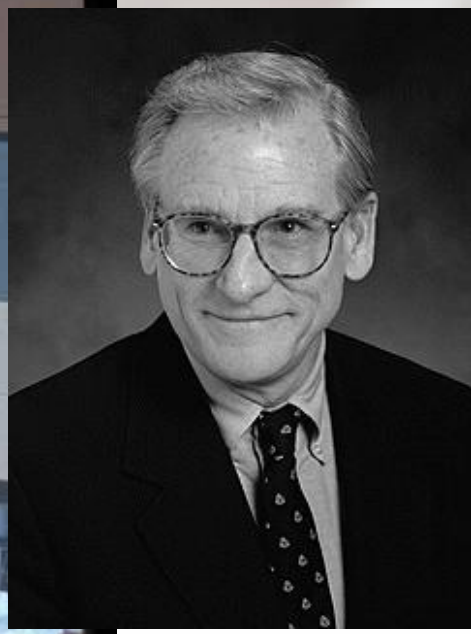
# ECMO – the beginnings



**John and Mary. Gibbon** –

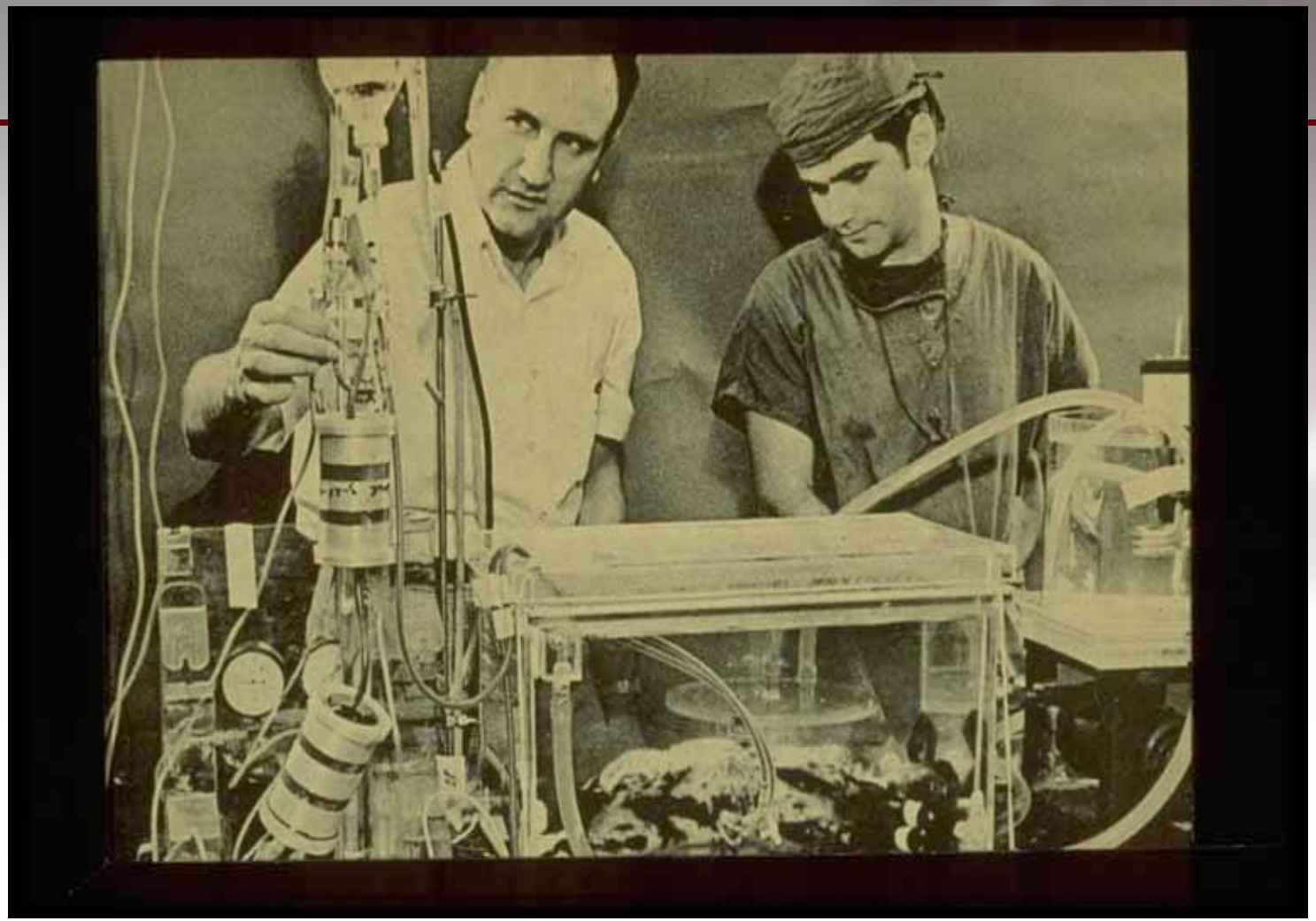
1930s begins work on extracorporal circulatory techniques, which eventually led to development of the heart and lung machine

# Early Animal experiments



Dr. R. Bartlett

Phil Drinker PhD, 1968 → First trial of Membrane Oxygenator



**Ted Kolobow and Warren Zapol 1969**

**→ membrane lung for CO2 removal**

# ECMO – the beginnings

- 1971 – first reports of bedside CPB used for long-term support *
- Prior to 1970s, attempts at long-term extracorporal support limited by gas-exchange devices ("oxygenators"), which did not separate the gas from the blood and led to hemolysis, thrombocytopenia, coagulopathy if used for hours at a time → bubble oxygenator

*Kolobow T, Spragg RG, Pierce JE, Zapol WM. Extended term (16 days) partial extracorporeal blood gas exchange with the spiral membrane lung unanesthetized lambs. *Trans Am Soc Artif Intern Organs* 1971; 17:350-354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# First successful ECMO patient, 1971

Auto Bicycle TA
→ Traumatic thoracic aortic rupture
→ Post Op ARDS

J Donald Hill MD and Maury Bramson BME, Santa Barbara, Ca, 1971. (Courtesy of Robert Bartlett, MD)

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# ECMO – the evolution

**1975, Bartlett et al.**

successfully apply bedside CPB to treat a newborn with meconium aspiration, marking the beginning of ECMO in critical care

# ECMO History


**VA ECMO due to Meconium Aspiration**

**Slide courtesy of Dr. R. Bartlett**

# ECMO History

Esperanza, age 21

Slide courtesy of Dr. R. Bartlett

*Reprinted from* THE LANCET *August 9, 1980, pp. 292-294*

# TREATMENT OF ACUTE RESPIRATORY FAILURE WITH LOW-FREQUENCY POSITIVE-PRESSURE VENTILATION AND EXTRACORPOREAL REMOVAL OF $CO_2$

L. GATTINONI*
A. PESENTI*
G. P. ROSSI*
S. VESCONI*
U. FOX‡
T. KOLOBOW§
A. AGOSTONI†
A. PELIZZOLA*
M. LANGER*
L. UZIEL†
F. LONGONI‡
G. DAMIA*

**Istituto di Anestesiologia e Rianimazione, †Istituto di Clinica Medica VII, and ‡Istituto di Clinica Chirurgica III, Università di Milano; and §National Institutes of Health, Bethesda, Maryland, U.S.A.*

# Low-Frequency Positive-Pressure Ventilation With Extracorporeal $CO_2$ Removal in Severe Acute Respiratory Failure

Luciano Gattinoni, MD; Antonio Pesenti, MD; Daniele Mascheroni, MD; Roberto Marcolin, MD; Roberto Fumagalli, MD; Francesca Rossi, MD; Gaetano Iapichino, MD; Giuliano Romagnoli, MD; Ljli Uziel, MD; Angelo Agostoni, MD; Theodor Kolobow, MD; Giorgio Damia, MD

**Gattinoni et al., *JA MA* , 1986; 256, 881-886**

Vol. XXXIV Trans Am Soc Artif Intern Organs 1988

*Registry Reports*

# National Experience with Extracorporeal Membrane Oxygenation for Newborn Respiratory Failure

## Data from 715 Cases

JOHN M. TOOMASIAN, SANDY M. SNEDECOR, RICHARD G. CORNELL,
ROBERT E. CILLEY, AND ROBERT H. BARTLETT

# Original ECMO Registry Report 1988



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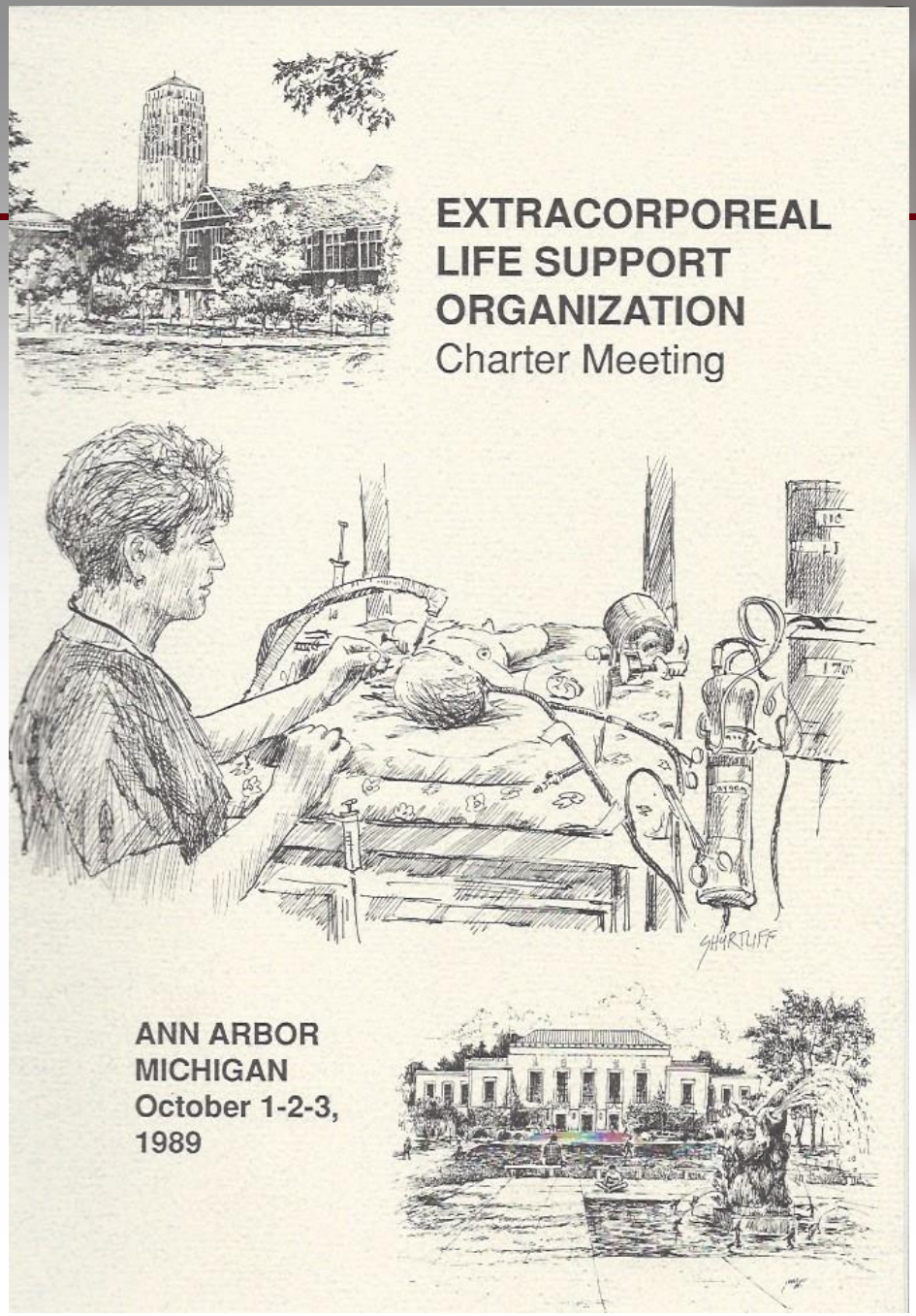
# ELSO CHARTER MEETING

Ann Arbor, Michigan
October 1, 2, 3, 1989


EXTRACORPOREAL
LIFE SUPPORT
ORGANIZATION
Charter Meeting
ANN ARBOR
MICHIGAN
October 1-2-3,
1989


EXTRACORPOREAL LIFE SUPPORT ORGANIZATION
ELSO
Established 1989

# EXTRACORPOREAL LIFE SUPPORT ORGANIZATION

## Charter Meeting

October 1-3, 1989 Ann Arbor, Michigan

# 한국 ECMO의 초기기록



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# ECMO History in Korea (1985~1990)

## 대한민국의 심장혈관수술 현황(Ⅱ)

김 형 묵*

—Abstract—

**Cardiovascular Surgery in Korea(Ⅱ)**

young Mook Kim, M.D.*

**Table 11.** Ventricular Assist Device

| site | Weaning from Device / No. of patients | | | | | | |
|---|---|---|---|---|---|---|---|
| | 85 | 86 | 87 | 88 | 89 | 90 | Total |
| LVAD | 1/4 | 7/10 | 6/8 | 5/12 | 6/8 | 7/8 | 32/50 |
| RVAD | | | | | | 1/1 | 1/1 |
| Total | 1/4 | 7/10 | 6/8 | 5/12 | 6/8 | 8/9 | 33/51 |

VAD : Ventricular Assist Device

r World War Ⅱ a great de
elating to the diagnosis and
ical data after the first open
9 up to 1984 revealed the tot
erformed in 22 institutes wit
Korea 1985).
rean Thoracic and Cardiova
urgical cases in Korea again
stitutes of open heart center

5%(38 out of 42 institutes).
cardiovascular surgery repor
tality of 4.7%(4.5% of the 21,761 operations for con-
genital, and 5.2% of the 8,300 operations for acquired heart diseases).

Out of the total congenital cases, 17,303 cases were acyanotic group with a operative mortality as 2.0%, and 4,458 cases were cyanotic group with a hospital mortality as 14.1%. The incidence of corrective operations for complex congenital cardiac anomalies were increasing recently with decreasing age group.

3. During the year in 1990, 38 institutes performed 5,427 cardiovascular surgery with a hospital mortality of 3.4%.

4. Of the total cummulative 6,458 cases for cardiac valve surgery more than 90% cases were put to prosthetic valve replacement with hospital mortality as 4.8%. And the incidence of re-Do valve surgery was increasing recently as 13.1% in 1990.

5. Coronary artery bypass graft was incresing recently with 7.9% of hospital mortality in total 440 cases. Intracardiac operation for intractable arrhythmia was started since 1987 as 49 cases in total. Experiences on VAD and ECMO were also reported sporadically in recent year.

6. Home made oxygenator(OXYREX) is now in clinical use, and under animal experiment for clinical trial in near future.

그 이외에 기계적인 심실보조장치와 ECMO에 의한 심장소생술의 시도가 근자에 활발히 이루어지고 있다. 특히 수년간에 걸친 연구와 결과로 국산 막형산화기가 국내에서 최초로 개발되어 임상에 사용단계에 있으며, 탄소를 이용한 인공심장기계판막의 국내개발도 상당한 진전을 보여 그완성을 목전에 두고 있고 인공심장의 개발에 대한 연구와 동물실험이 적극적으로 이루어지고 있어 한국흉부외과의 앞날을 밝게하고 있다.

# 1st ECMO Cases in Korea

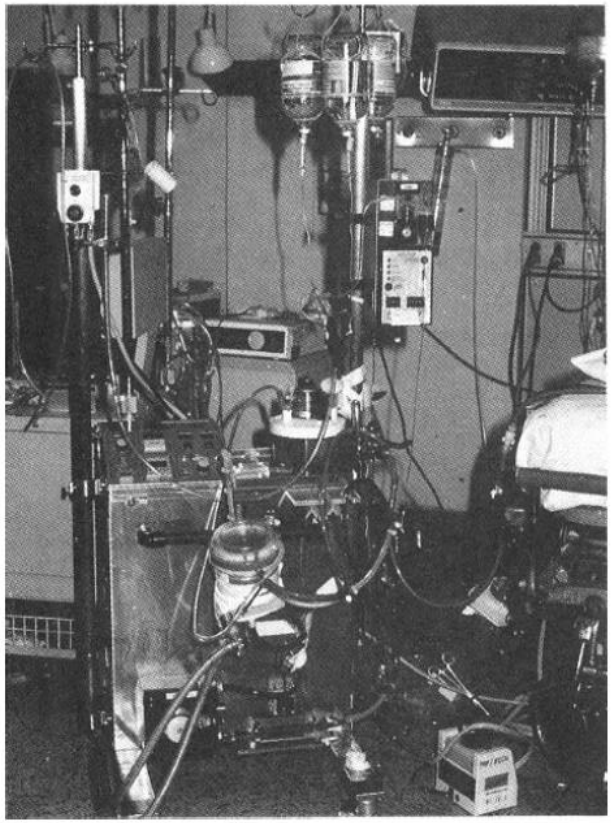
- 1st case report (4cases 1990.7~1991.12)

**Prolonged Extracorporeal Lung and Heart Assist**
**(Extracorporeal Membrane Oxygenation)**
−4 cases report−

**Hyun Choi, M.D., Wang Gyu Lee, M.D., Sang Min Lee, M.D.*, Hyun Soo Moon, M.D.***
**Young Kyun Chung, M.D.**, Kook Hyun Lee, M.D.[1], Byung Moon Ham, M.D.[1] and Kwang Woo Kim, M.D.[1]**

*Department of Anesthesiology, College of Medicine, Hallym University*
**Department of Anesthesiology, Sejong General Hospital*
***Department of Anesthesiology, College of Medicine, Kyung Sang University*
*[1]Department of Anesthesiology, College of Medicine, Seoul National University*

*- korean J Anestheisol 1992;025(02):424-32*



- 1st Respiratory support

*- KP Hong KJTC Surg 1994;27:60-.*

- 1st Extracorporeal Cardiopulmonary Resuscitation (E-CPR)

*- JH JUN KJTC Surg 1999;32:53-7*

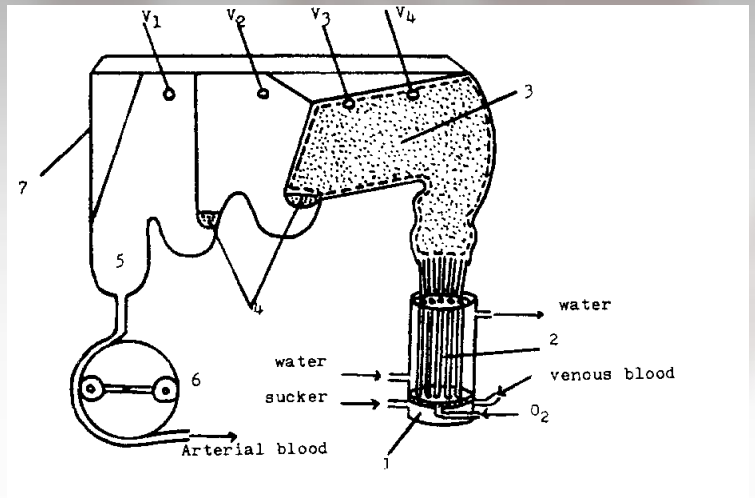
# 1st Korean Oxygenators

- 1st oxygenator (1982)

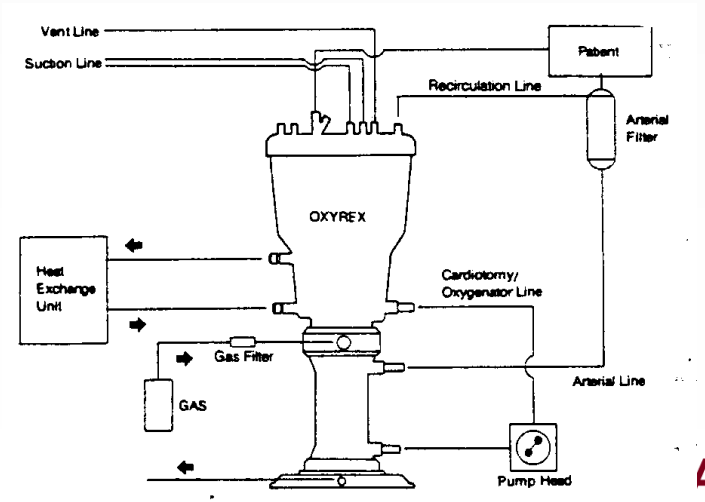
- Korea-Kim venotherm Oxygenator

- 1st clinical study (1990 Oxyrex)

*- HM KIM KJTCSurg 023(06):1049-56*




| Operations | No. of Patients |
|---|---|
| Mitral Valve Replacement | 14 |
| Aortic & Mitral Valve Replacement | 5 |
| Aortic Valve Replacement | 5 |
| Mitral & Tricuspid Vlave Replacement | 1 |
| Aortocoronary Bypass | 1 |
| VSD Repair | 3 |
| ASD Repair | 3 |
| Sinus Valsalva Rupture Repair | 2 |
| TOF, Total Correction | 1 |
| Cortriatriatum, Correction | 1 |
| Aortic Aneurysm Resection | 1 |
| Cardiac Tumor Resection | 1 |
| IVC Thrombosis Removal | 1 |
| Total | 40 |



# Present



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**Sep. 15~18, 2014 25th Anniversary ELSO, Ann Arbor, MI**

Extracorporeal Life Support Organization

Home | About Us | Members | Registry | Excellence | Resources | Publications | Meetings | e-Store

Home ▸ Members ▸ Center Directory

## Center Directory

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Canada
United States

### Latin America
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Colombia
Costa Rica
Mexico
Peru

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Croatia
Czech Republic
Denmark
Finland
France
Georgia
Germany
Greece
Iceland
Ireland
Italy
Netherlands
Norway
Poland
Portugal
Scotland
Spain
Sweden
Switzerland
Turkey
Ukraine
United Kingdom

### Asia-Pacific
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Indonesia
Japan
Malaysia
New Zealand
Singapore
South Korea
Taiwan
Thailand

### South and West Asia, Africa
Egypt
India
Iran
Israel
Kazakhstan
Qatar
Russia
Saudi Arabia
South Africa
United Arab Emirates

### South Korea
Seoul
Korea University Medical Center

Seoul National University Hospital

**Until now,**
**Total 468 ECMO centers were registered ELSO**





그린란드
아이슬란드
핀란드
러시아
캐나다
우크라이나
카자흐스탄
몽고
중국
스페인
이탈리아
북대서양
알제리
리비아
이집트
말리
니제르
수단
차드
나이지리아
이디오피아
콩고 민주 공화국
케냐
탄자니아
앙골라
나미비아
보츠와나
마다가스카르
남아프리카
남대서양
인도양
인도네시아
오스트레일리아
뉴질랜드
아르헨티나
볼리비아
콜롬비아
베네수엘라

# ECLS Registry Report

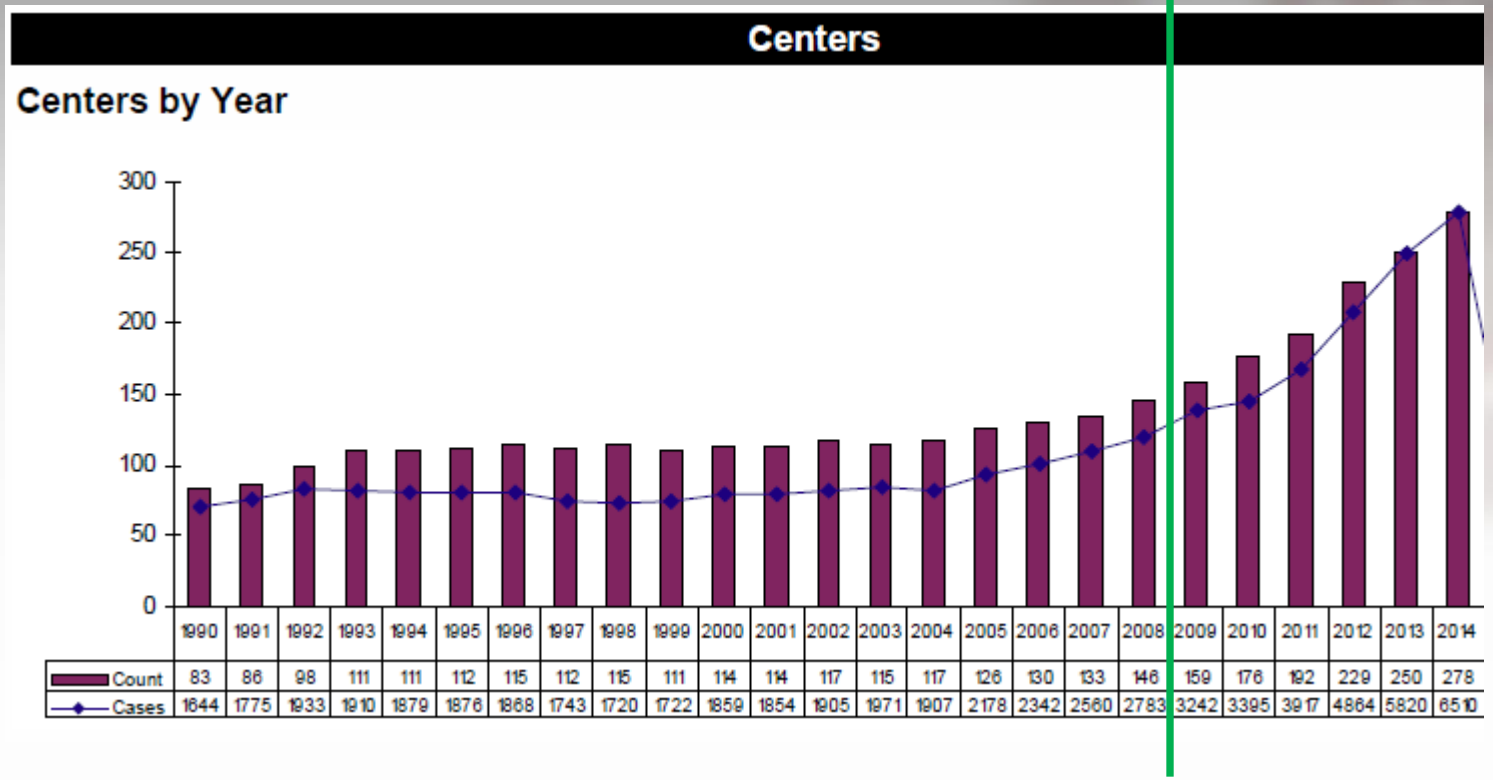
## International Summary

**July, 2015**

Extracorporeal Life Support Organization
2800 Plymouth Road
Building 300, Room 303
Ann Arbor, MI 48109

## Overall Outcomes

| | *Total Patients* | *Survived ECLS* | | *Survived to DC or Transfer* | |
|---|---|---|---|---|---|
| Neonatal | | | | | |
| Respiratory | 28,271 | 23,791 | 84% | 20,978 | 74% |
| Cardiac | 6,046 | 3,750 | 62% | 2,497 | 41% |
| ECPR | 1,188 | 766 | 64% | 489 | 41% |
| Pediatric | | | | | |
| Respiratory | 6,929 | 4,579 | 66% | 3,979 | 57% |
| Cardiac | 7,668 | 5,084 | 66% | 3,878 | 51% |
| ECPR | 2,583 | 1,432 | 55% | 1,070 | 41% |
| Adult | | | | | |
| Respiratory | 7,922 | 5,209 | 66% | 4,576 | 58% |
| Cardiac | 6,522 | 3,661 | 56% | 2,708 | 42% |
| ECPR | 1,985 | 791 | 40% | 589 | 30% |
| ***Total*** | 69,114 | 49,063 | 71% | 40,764 | 59% |




## After 2008 → Abruptly increased Adult ECMO cases

- ECMO was effective in cardiac originated arrest
- CESAR trial : ECMO was effective for Severe Lung failure

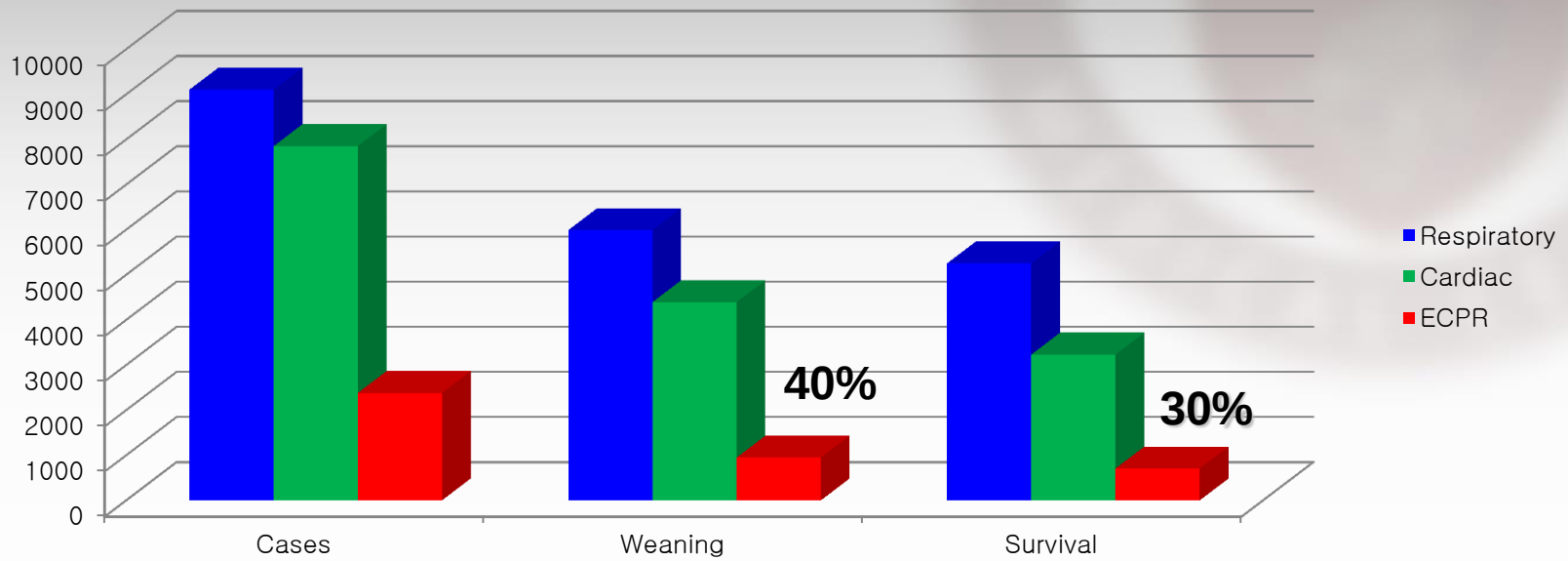
# ECLS Registry Report

International Summary

**January, 2016**

Extracorporeal Life Support Organization
2800 Plymouth Road
Building 300, Room 303
Ann Arbor, MI 48109

- ELSO **Adult** ECMO Results (2016.1)




| | Cases | Wean off | Survival discharge |
|---|---|---|---|
| **Respiratory** | **9102** | **5989 (66%)** | **5254 (58%)** |
| **Cardiac** | **7850** | **4394 (56%)** | **3233 (41%)** |
| **ECPR** | **2379** | **948 (40%)** | **707 (30%)** |
| **Total** | **19331** | **11331** | **9194** |

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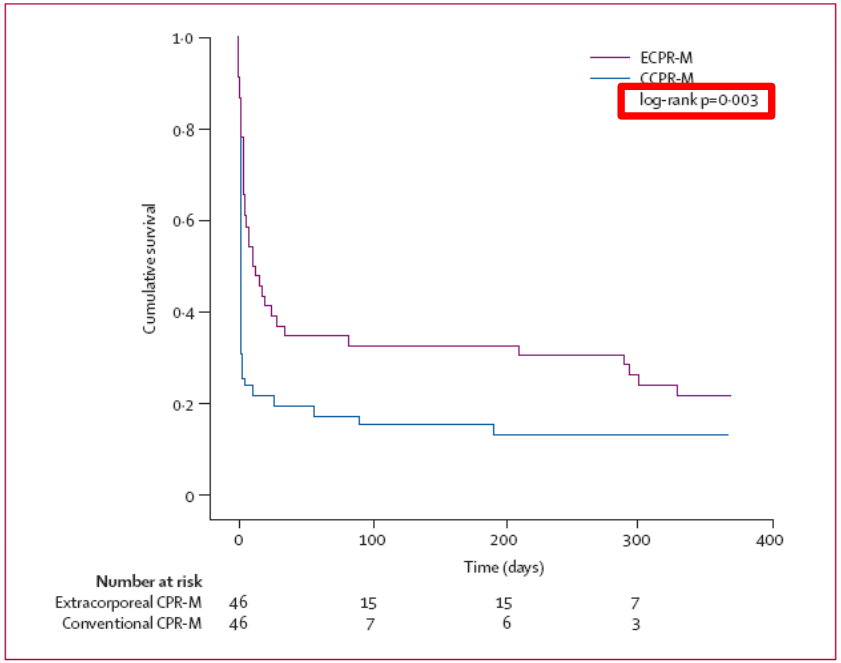
# Cardiopulmonary resuscitation with assisted extracorporeal life-support versus conventional cardiopulmonary resuscitation in adults with in-hospital cardiac arrest: an observational study and propensity analysis

*Yih-Sharng Chen*, Jou-Wei Lin*, Hsi-Yu Yu, Wen-Je Ko, Jih-Shuin Jerng, Wei-Tien Chang, Wen-Jone Chen, Shu-Chien Huang, Nai-Hsin Chi, Chih-Hsien Wang, Li-Chin Chen, Pi-Ru Tsai, Sheoi-Shen Wang, Juey-Jen Hwang, Fang-Yue Lin*

*Lancet* 2008; 372: 554–61

**In-hosp. Cardiac arrest of cardiac origin**

**→ conventional CPR 10 min → No ROSC → ECMO insertion**



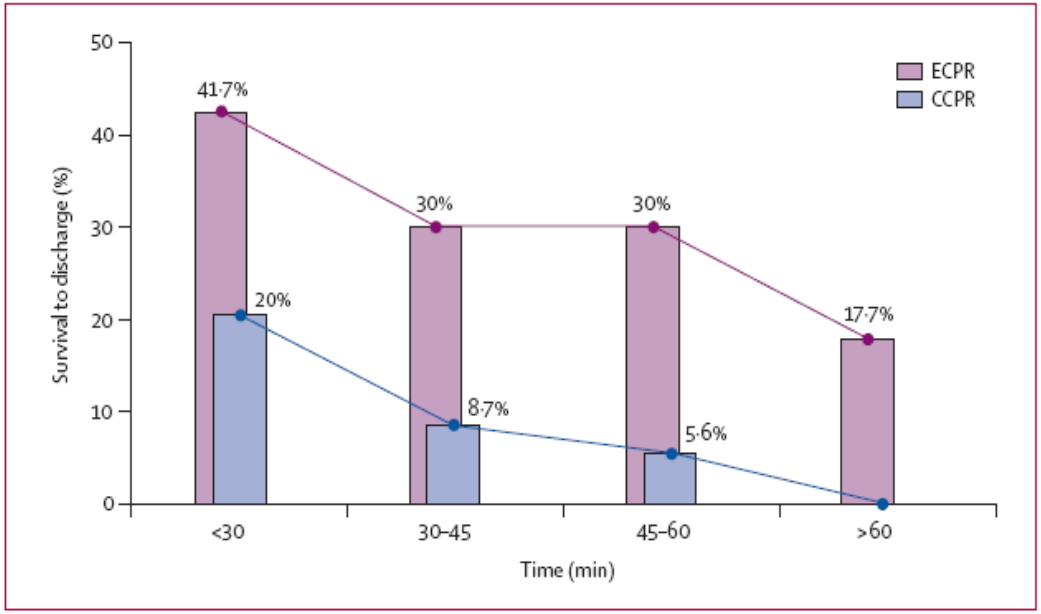




*Figure 1:* Relation between CPR duration and the survival rate to discharge
ECPR=extracorporeal CPR. CCPR=conventional CPR.

# Conventional ventilatory support vs. ECMO for Severe Adult Respiratory failure

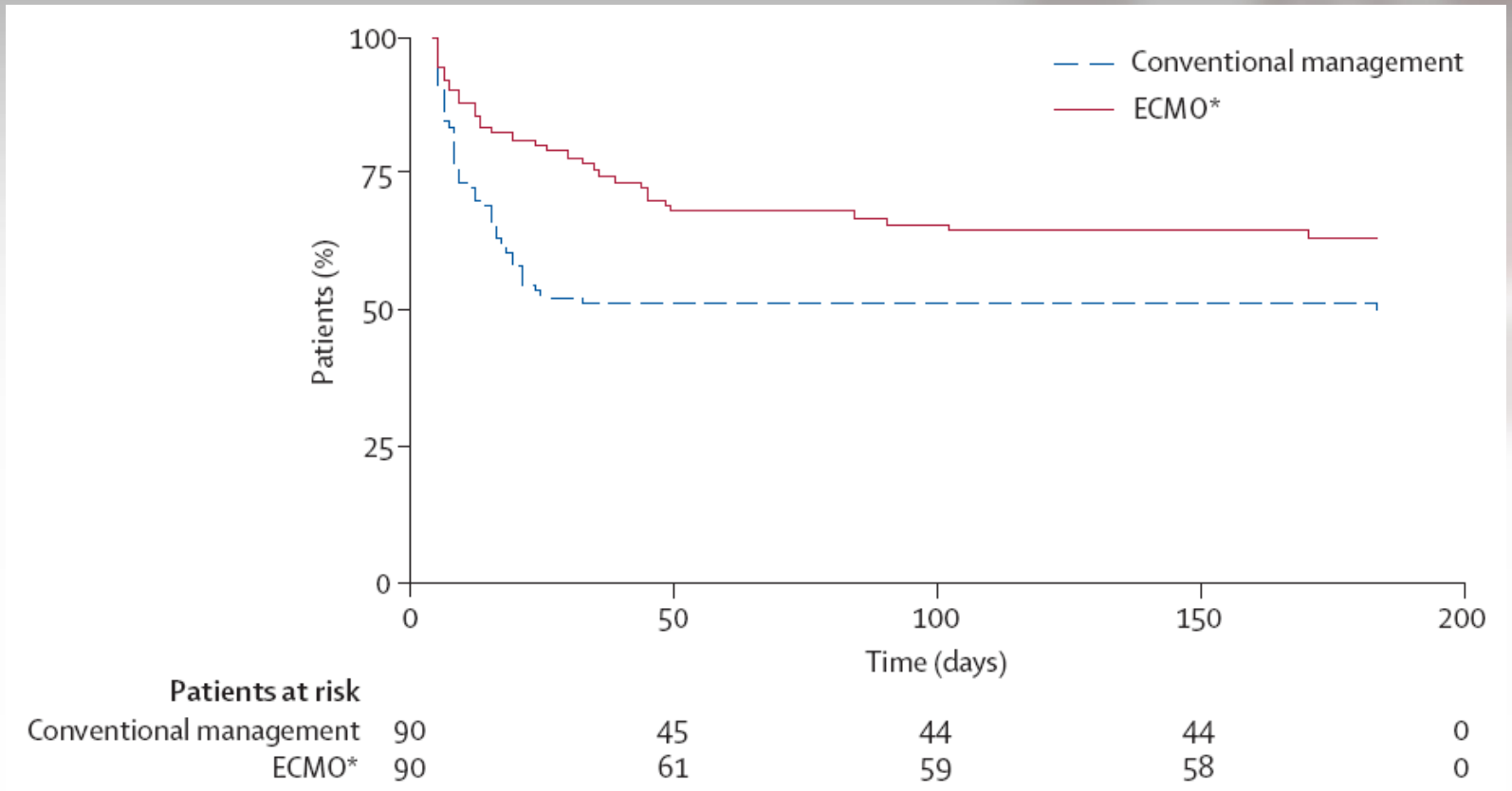
**Lancet 2009**

Articles

Efficacy and economic assessment of conventional ventilatory support versus extracorporeal membrane oxygenation for severe adult respiratory failure (CESAR): a multicentre randomised controlled trial

Giles J Peek, Miranda Mugford, Ravindranath Tiruvoipati, Andrew Wilson, Elizabeth Allen, Mariamma M Thalanany, Clare L Hibbert, Ann Truesdale, Felicity Clemens, Nicola Cooper, Richard K Firmin, Diana Elbourne, for the CESAR trial collaboration

# Kaplan-Meier survival estimates by allocation




| Patients at risk | | | | | |
|---|---|---|---|---|---|
| Conventional management | 90 | 45 | 44 | 44 | 0 |
| ECMO* | 90 | 61 | 59 | 58 | 0 |

- Time from randomization to death
- Log rank p = 0.03

# Improvement of Devices

# Miniaturized

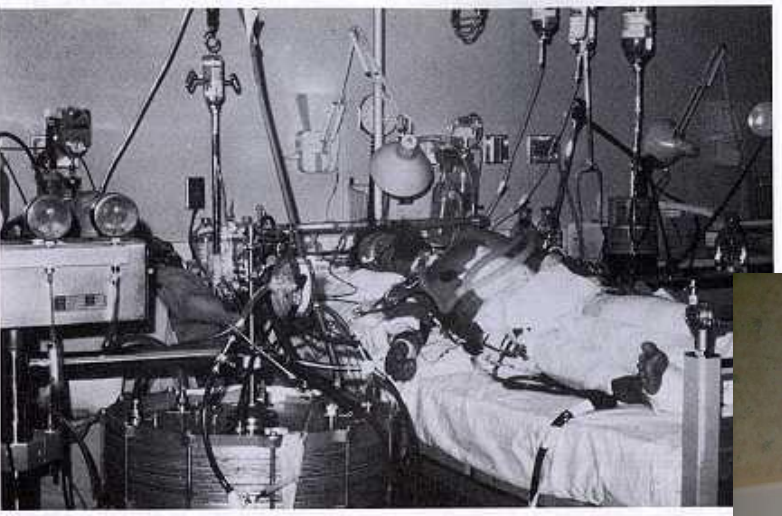


FIGURE 3.4 The first successful extracorporeal life support patient, treated by J. Donald Hill us
Bramson oxygenator (foreground), Santa Barbara, 1971.

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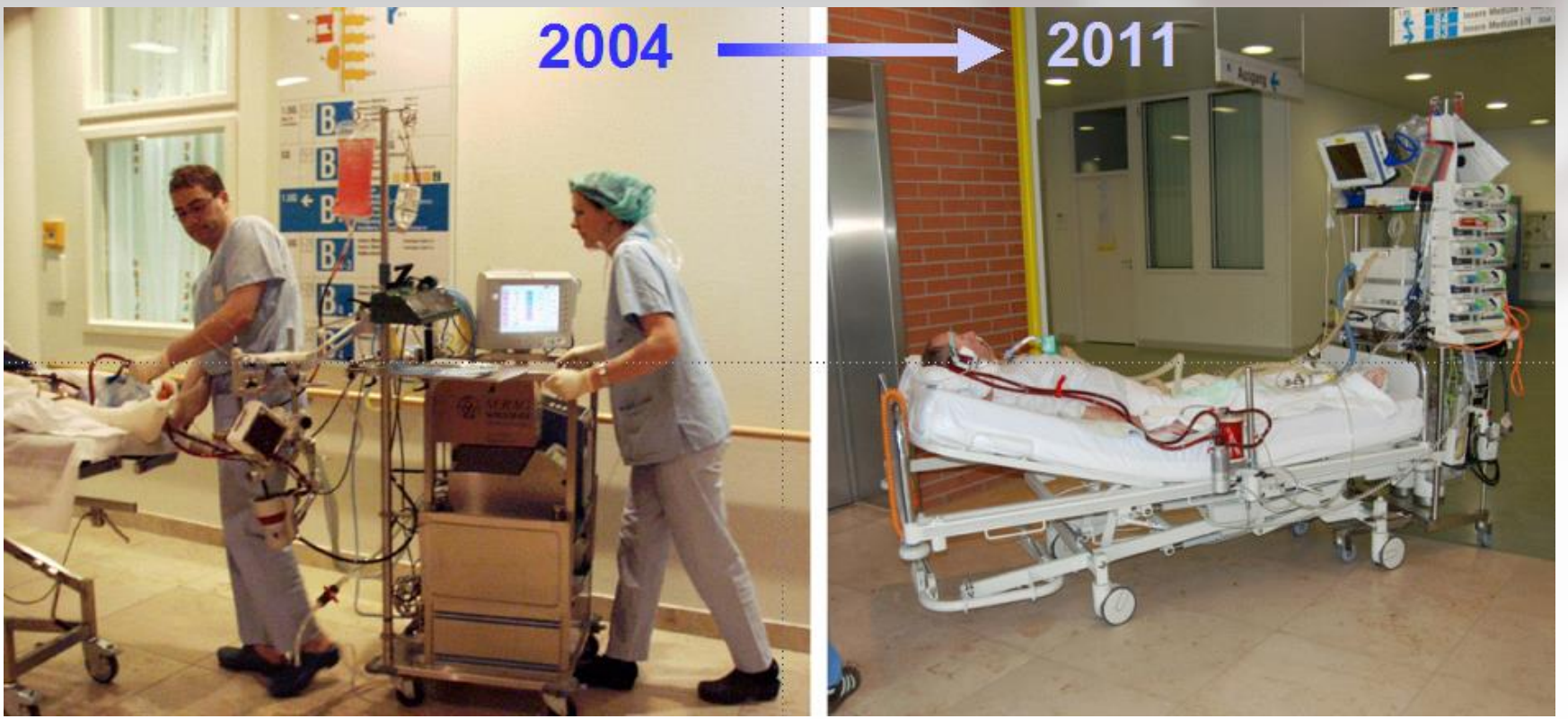
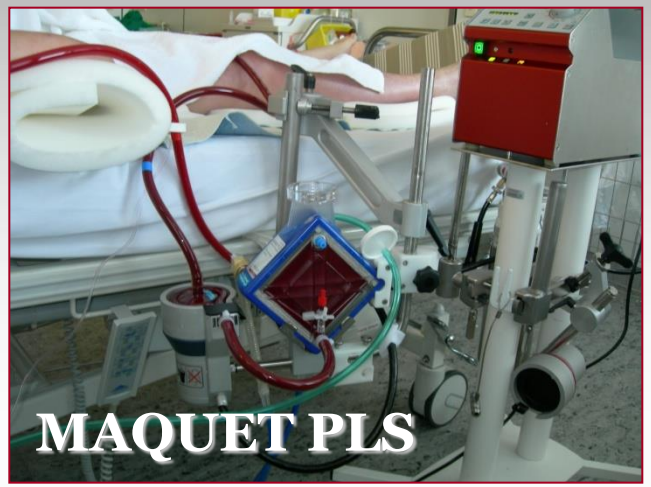
# Minituarization




Courtesy by Prof. C. Schmid

# Versatility

# Current systems




Novalung
ILA Active



# ECMO transportation

# Transport vehicle

- Hospital helicopter
- Medical air service
- Military equipment

Courtesy by Prof. C. Schmid

# ECMO transport in Norway

*Perfusion* 2008; 23: 101–106

## Transportation of critically ill patients on extracorporeal membrane oxygenation

K Wagner[1], GK Sangolt[1], I Risnes[2], HM Karlsen[2], JE Nilsen[3], T Strand[4], LB Stenseth[4] and JL Svennevig[2]

[1]*Department of Anesthesiology and Intensive Care Medicine, Rikshospitalet University Hospital, Oslo, Norway;* [2]*Department of Thoracic and Cardiovascular Surgery, Rikshospitalet University Hospital, Oslo, Norway;* [3]*Norwegian Air Ambulance, Droebak, Norway;* [4]*Prehospital Division, Air Ambulance Department, Ullevaal University of Oslo, Norway*

# ECMO transport in Sweden

## Transports on ECMO

Karolinska Hospital

# ECMO transport in Korea


Courtesy by Dr. YH Cho

# ECMO transport in Germany


**Team: anesthesiologist + cardiac surgeon + perfusionist**

Courtesy by Prof. C. Schmid

# ECMO Devices for transport

Courtesy by Prof. C. Schmid

# ECMO patients Mobilization



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# Patient mobilization in Korea (Samsung Medical Center)


ASAIO J. 61(5):564-568, 2015.

# Patient mobilization in Germanry (Regensburg Univ. Hosp)

Courtesy by Prof. C. Schmid

# Future



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# New Applications

- **Outside of Hospital ECPR**
- **ExtraCorporeal DCD (Donation after Cardiac Death)**
- **Artificial Placenta**
- **Artificial implantable Lung**, chronic respiratory support
- **Organ perfusion and culture**

# Outside the hospital ECPR

Courtesy by Prof. C. Schmid

# UMAC, Paris Marathon, 2010…


Case report

# Out-of-hospital extra-corporeal life
# cardiac arrest in a half-marathon ru

Guillaume Lebreton[a], Matteo Pozzi[a], Charles-Pascal Leprince[a], Benoît Vivien[c,*]

- **48 yrs. Man → sudden arrest durin**
- **No flow time < 1min → ECMO ins**

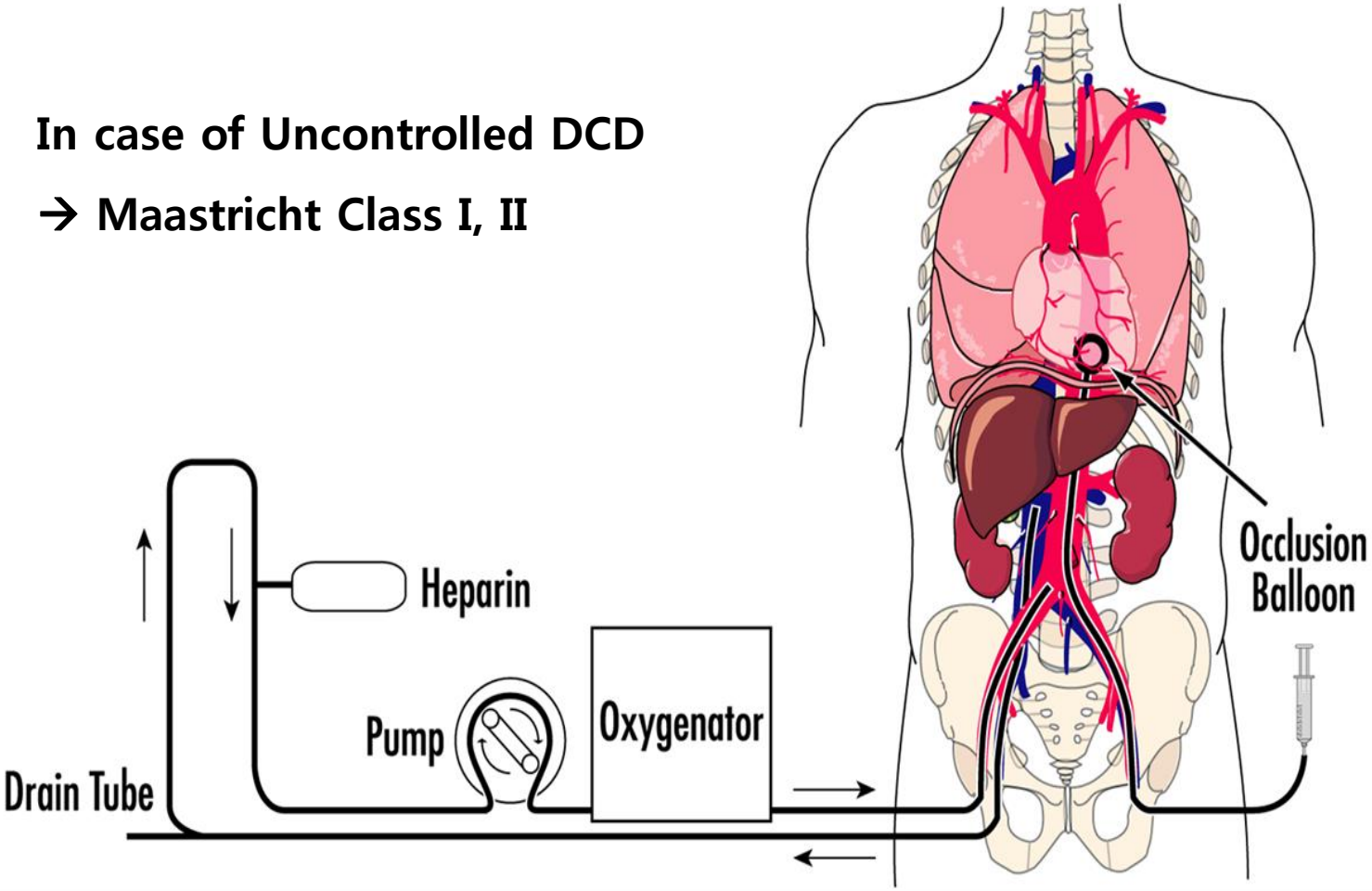
**Fig. 1.** Direct surgical access to right femoral vessels for veno-arteri
performed by cardiothoracic surgeons within the MICU ambulan
monary resuscitation was continued by EMS providers during cannul


**Fig. 3.** Patient under extra-corporeal life support (ECLS) within the MICU ambulance. Picture was taken a few minutes after end of veno-arterial femoral cannulation and ECLS initiation.

# EDCD - Normothermic Perfusion by ECMO

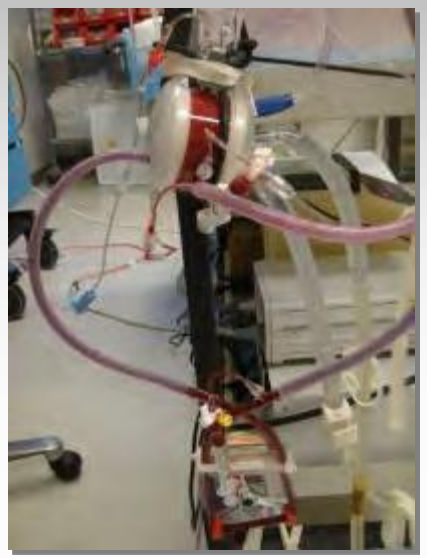
**In case of Uncontrolled DCD**

**→ Maastricht Class I, II**




From : S. Pelletier, MD, U of Michigan

# Artificial Placenta



- Maintaining fetal circulation, low $pO_2$, and fetal environment
- No mechanical ventilation
- Simulated breathing with fluid filled lungs
- VV-ECLS with inflow via umbilical vein and outflow via jugular vein

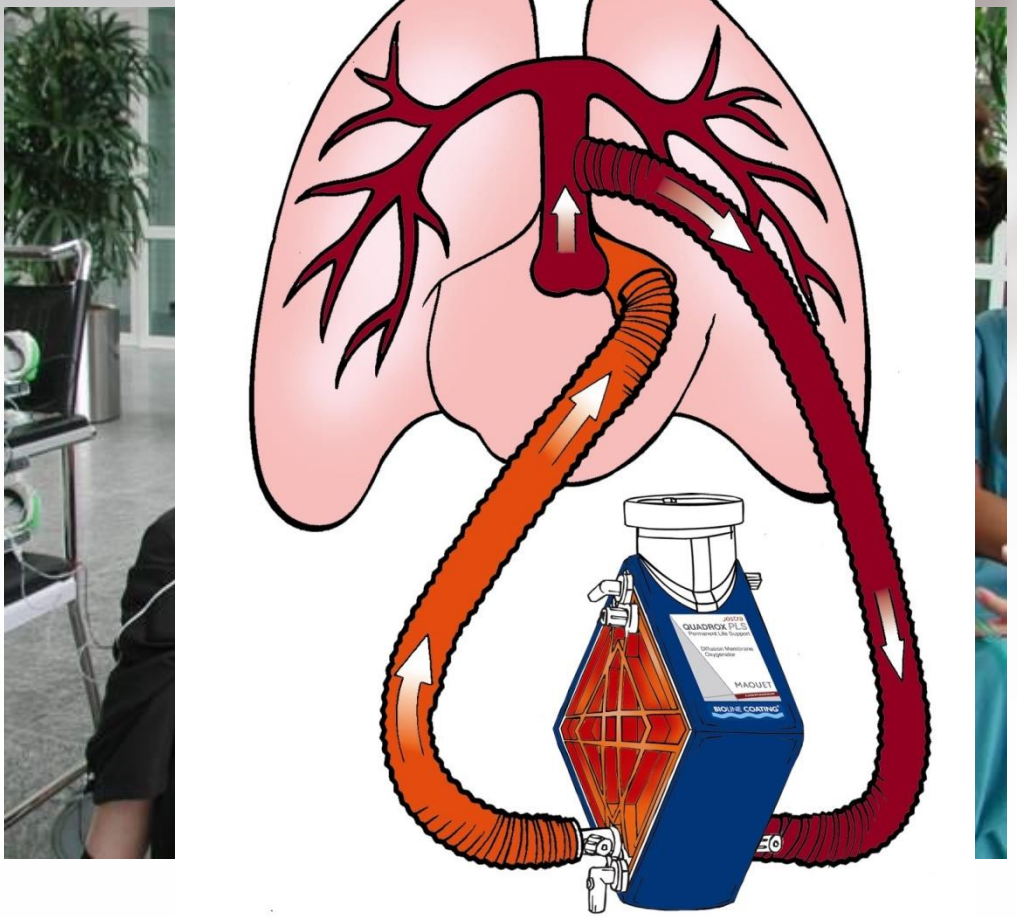
**Brian Gray MD and Margie**

**Premature fetal lamb, artificial placenta 3 days, 3 days post placenta**

# Is it possible in the future?

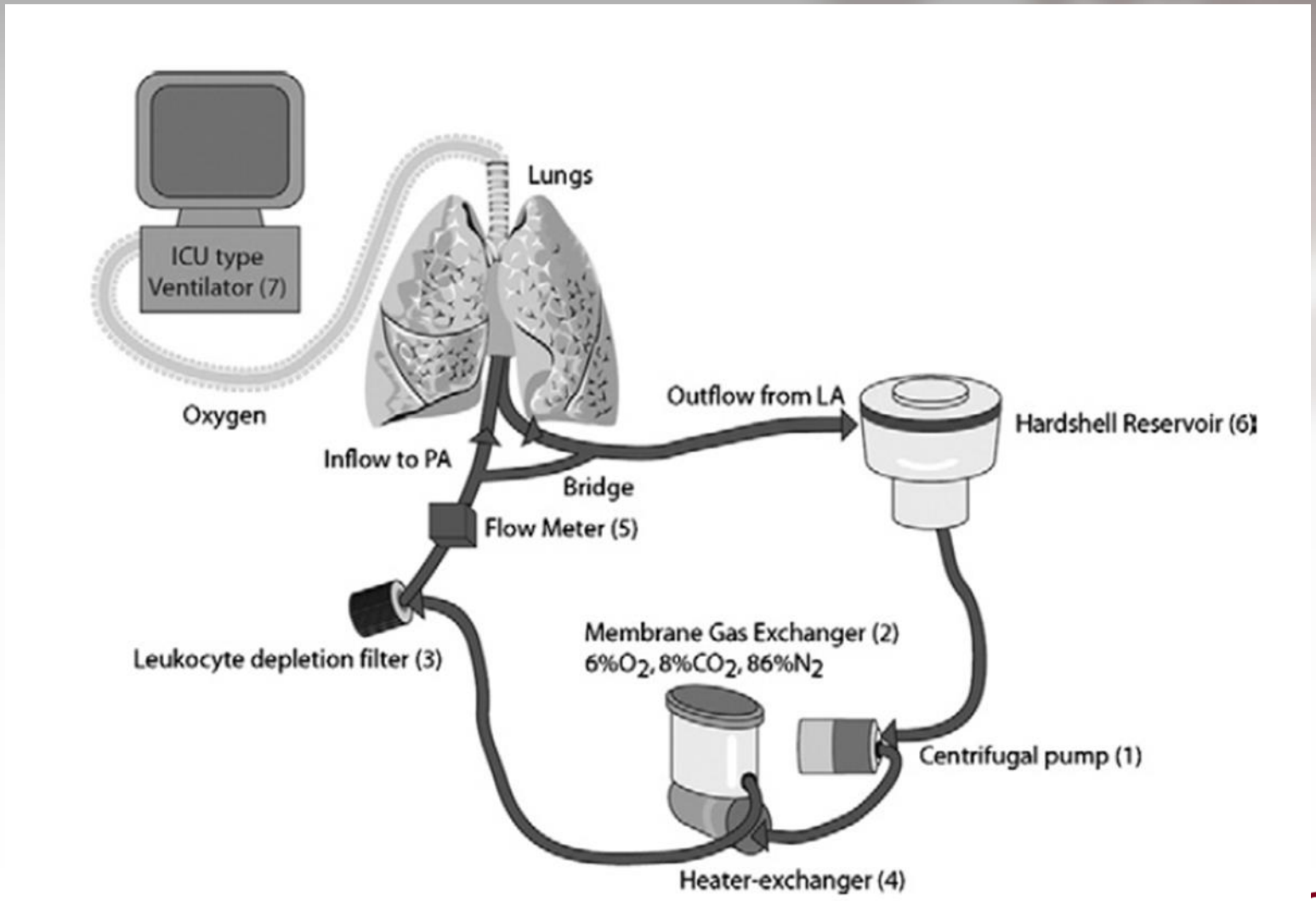
# Artificial lung

- **Oxygenator only**
- Transthoracic a/v lines to PA and LA
- Ambulatory lung assist




**Courtesy by Prof. C. Schmid**

# Ex Situ Perfusion of DCD Organ (Lung)






KOREA
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MEDICAL CENTER

# Ex Situ Perfusion of DCD Organ (Lung)

# Ex Situ Perfusion of DCD Organ (Heart)

**Functional evalu… …diac death donor hearts using a co… …usion technique: Potential for exp… …tion**

Satoru Osaki, MD, PhD, M… …hahab A. Akhter, MD, and Takushi Kohmoto, MD, Ph…

…g 2014;148:1123-30

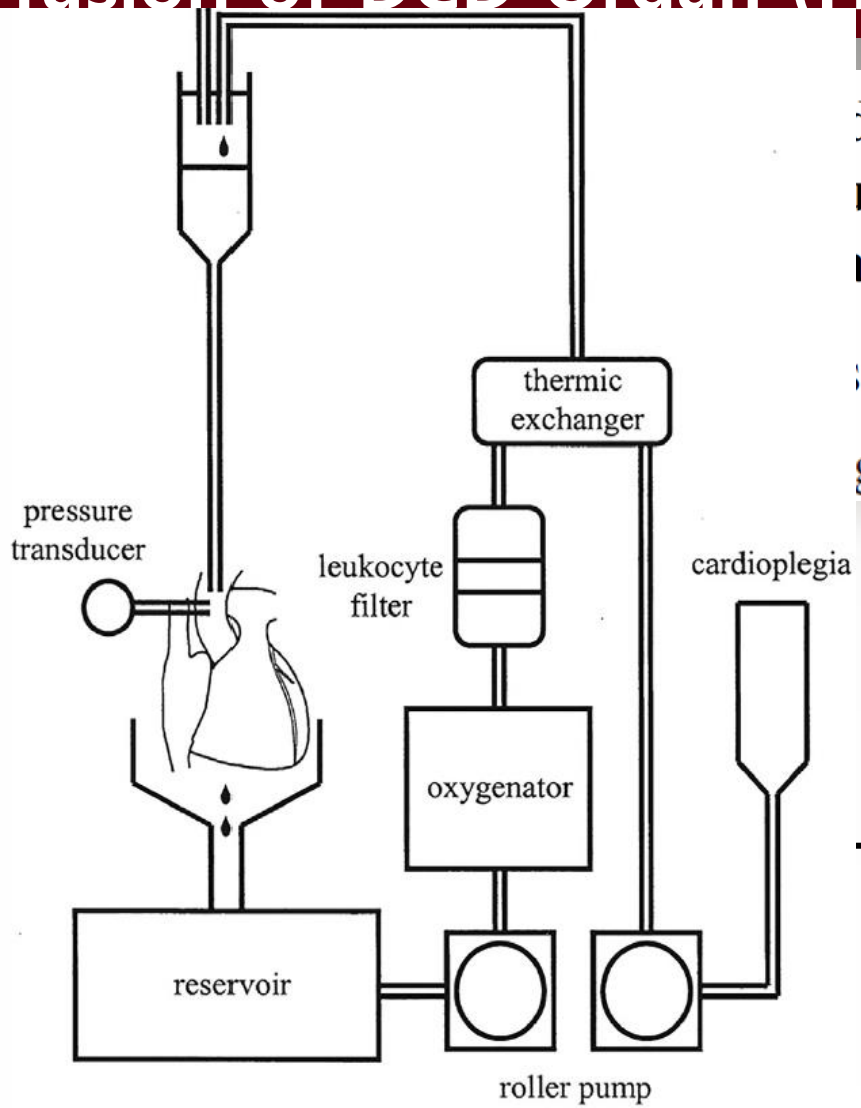


FIGURE 1. Ex vivo perfusion system.[9]

- 10 Discarded …
  → coronary dz…
- Resuscitation … → WIT < 40min

# Ex Situ Perfusion of DCD Organ (Heart)

# Devices and techniques

## Imagine !!!

- **Very Low flow CO2 removal devices**
- **Advanced Cannula → no complication, no anticoagulation**
- **Special Oxygenator** for

  → Bioartificial Liver, Sepsis, CRRT modules

- **Nonthrombogenic surfaces coating techniques for oxygenator**

# Thank you for your attention