대한흉부심장혈관외과학회
제7차 전공의2,3,4년차 학술세미나

Troubleshooting of ECMO Management

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전남대학교병원 흉부외과 정인석

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2. ECMO in present: various indication
3. Trouble shooting

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General Introduction

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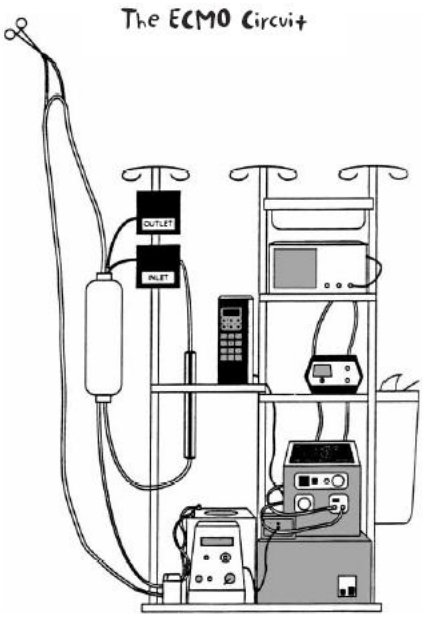
What is ECMO?



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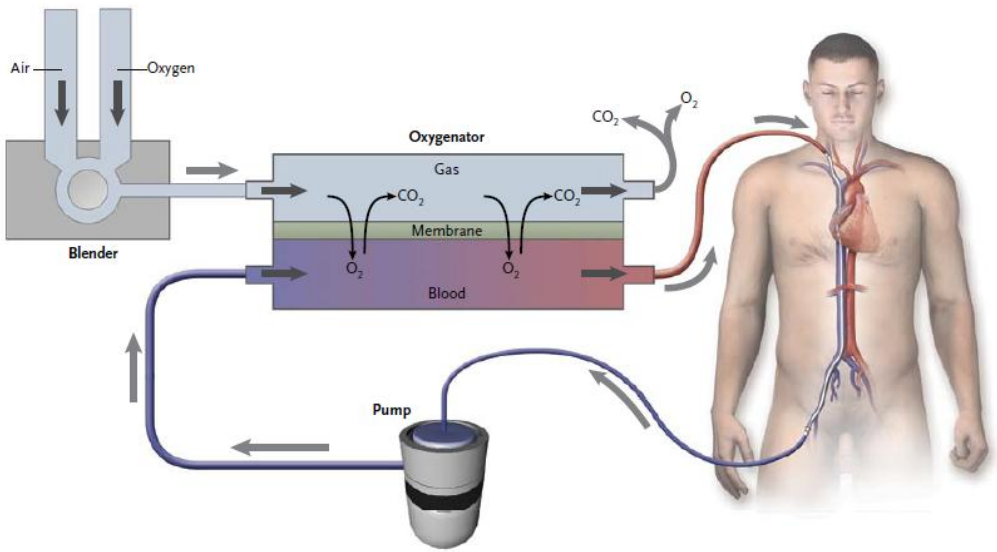
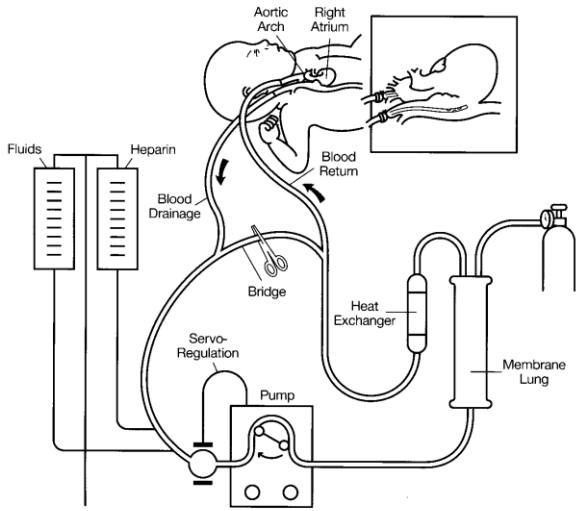
ECMO ?

- ExtraCorporeal Membrane Oxygenation
- developed in late 1960
- mainly neonatal respiratory failure





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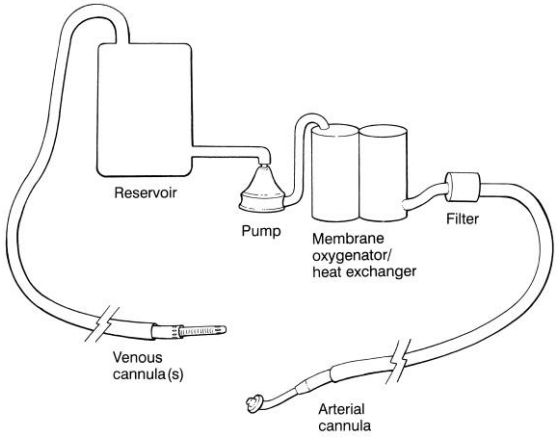
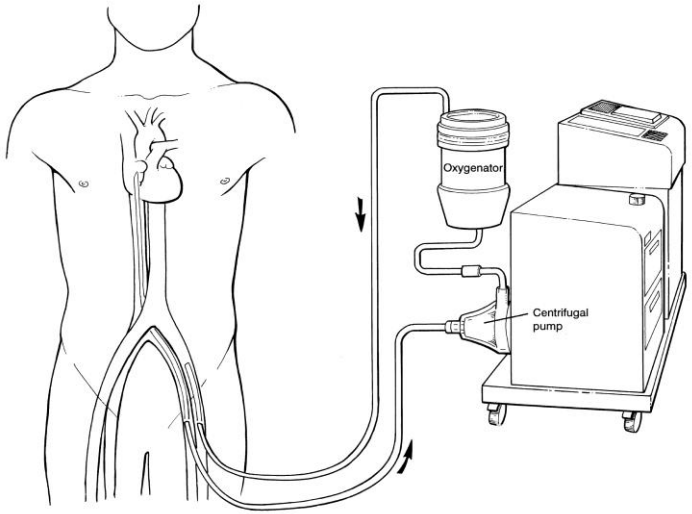
CPB vs ECMO

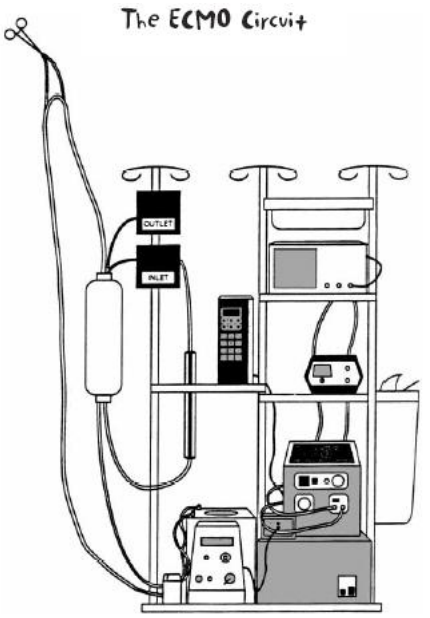


CPB



- A modification of the heart / lung machine which can be used for an extended period of time.
- ECMO is temporary support of heart and lung function by partial cardiopulmonary bypass (up to 75% of cardiac output).

Who need ECMO?



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Adults
Pediatrics
Neonates

Circulatory failure
Respiratory failure

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- Post-cardiac surgery myocardial dysfunction
- Myocarditis
- Medically intractable arrhythmia

- Adult respiratory failure
  - ARDS, pneumonia

- Transplantation related condition
  - Bridge to transplantation / bridge / recovery
  - Post-transplantation failure

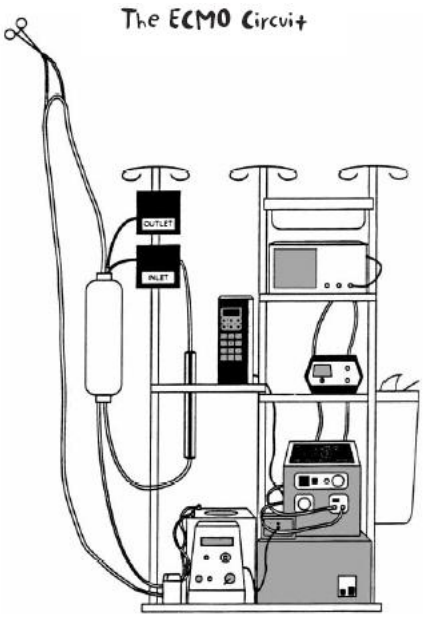
- Neonatal or pediatric respiratory failure
  - MAS, RDS, PPHN, CDH …

- Extracorporeal CPR(ECPR)

- Procedure related condition
  - Tracheal surgery , Coronary intervention

- Shock associated with various causes
  - Sepsis
  - Drug intoxication
  - Malignancy

How does the ECMO work?



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Therapeutic goals of ECMO support

- A treatment option for when conventional treatment has been failed.
- Dose not treat the underlying disease process.

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Therapeutic goals of ECMO support

- Provision of adequate blood flow for cellular metabolic demands in circulatory shock.
- Provision of adequate oxygenation and carbon dioxide clearance in respiratory failure.

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Therapeutic goals of ECMO support

- Prevention of complications from other therapies
  - Ventilator induced lung injury (VILI)
  - Increased myocardial oxygen demand and end organ injury d/t high dose of inotropics and vasoconstrictors

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Components

- Cannulation
- Pump, Oxygenator, Tubing
- Anticoagulation (UFH, others..)

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Cannulation Site

- Central Cannulation
  - Trans sternal approach

- Peripheral Cannulation
  - Cervical approach
  - Femoral approach
  - Axillary approach

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2 Configurations for ECMO

- VA (Veno-arterial) ECMO
  - venous drainage of deoxygenated blood from venous circulation
  - return to arterial circulation
  - Both circulatory and respiratoy support
  - Biventricular support

- VV (Veno-veno) ECMO
  - drainage of deoxygenated blood from venous system
  - return to venous system.
  - Only provides respiratory support

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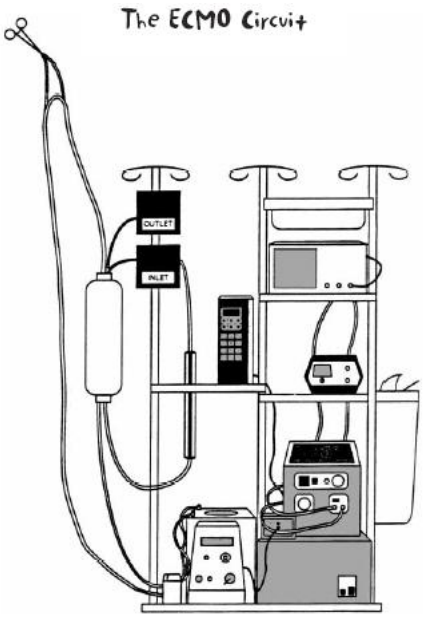
What are the ECMO complications?



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Complications

Table 2. Adverse Events Associated with ECMO in Adults with Respiratory Failure.*

Event	Rate
	%
Directly related to the ECMO circuit	
Oxygenator failure	17.5
Blood clots	
Oxygenator	12.2
Other circuit	17.8
Cannula-related problems	8.4
Other mechanical complications	7.9
Not directly related to the ECMO circuit†	
Bleeding	
Surgical-site bleeding	19.0
Cannulation-site bleeding	17.1
Pulmonary hemorrhage	8.1
Gastrointestinal hemorrhage	5.1
Intracranial hemorrhage	3.8
Hemolysis	6.9
Disseminated intravascular coagulation	3.7
Culture-confirmed infection at any site (related or unrelated to ECMO)‡	21.3

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3 major complications

- Bleeding and thrombosis
  - associated with anticoagulation
- Infection
  - < 7 days: about 5-10%
  - > 30days: more than 30%
- Brain injury
  - Hemorrhage, infarction, hypoxia/ischemia, Seizure, Cognitive impairment, Motor/Sensory disorder

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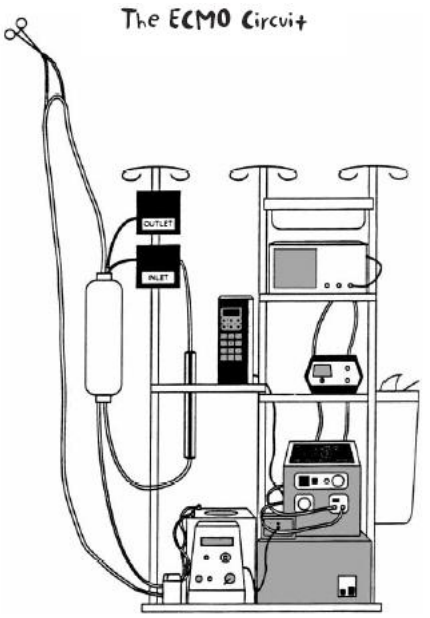
Anticoagulation



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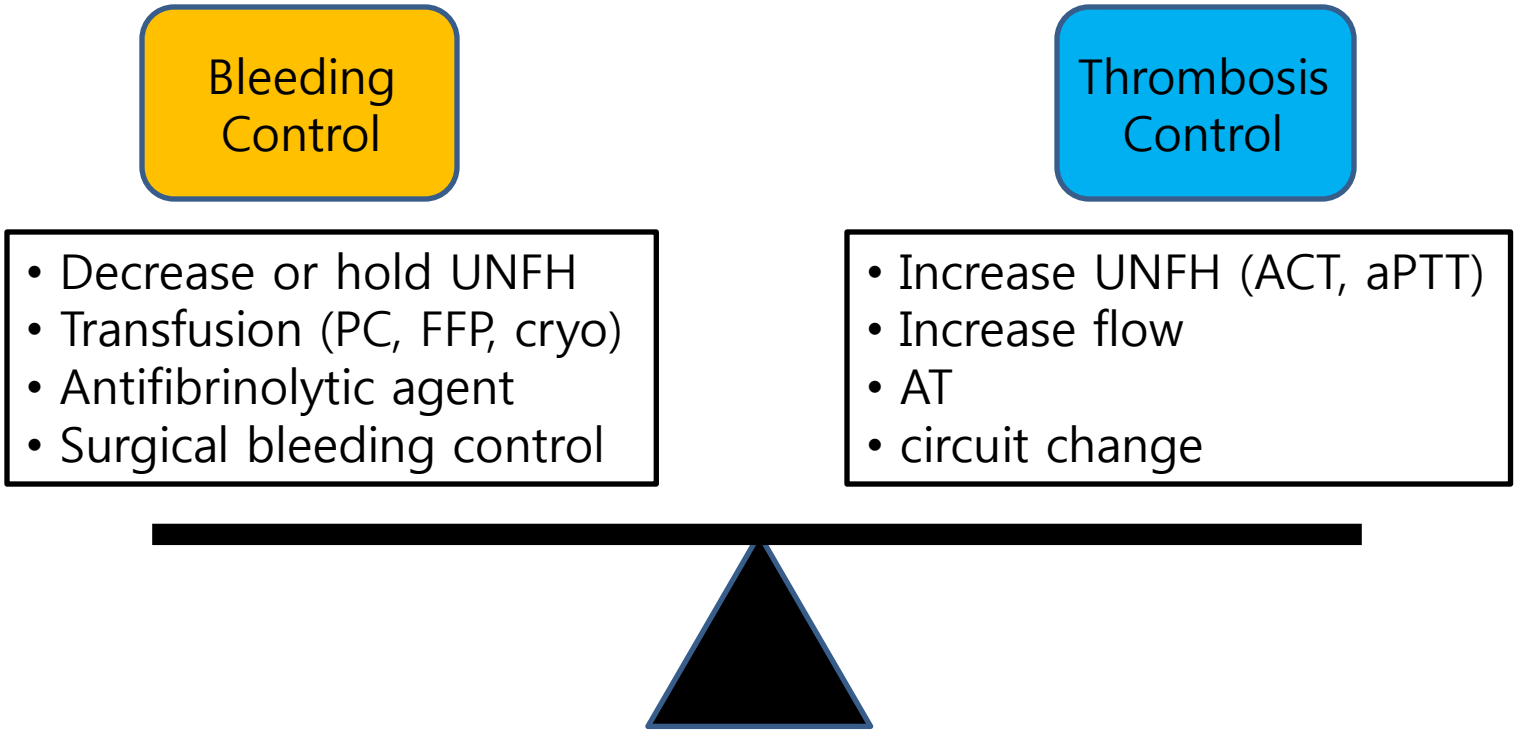

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- Yet, no strong evidence of anticoagulation guideline during ECMO
- Currently, device do not need a high level of anticoagulation.
- Individual decision can be necessary and avoid invasive procedure during ECMO.

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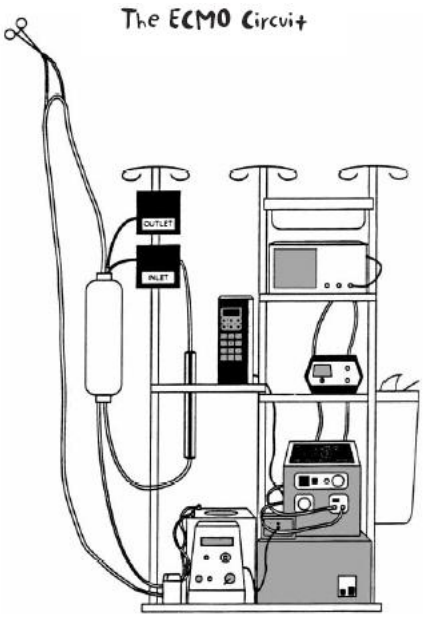
Inotropics



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Problems of catecholamines

- Increased myocardial oxygen demand
- Receptor desensitization

- Attenuated physiological response occurs with prolonged exposure to elevated levels of either endogenous or exogenous catecholamines

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Current strategy

- ***You can't beat a dead horse***
- New agents may provide some benefit
- Any drug may produce undesirable effects
- ***Vasoconstrictor*** are better than inotropic agents
- To promote cardiac recovery, IABP may be considered rather than inotropic support
- Early intervention with mechanical circulatory support.

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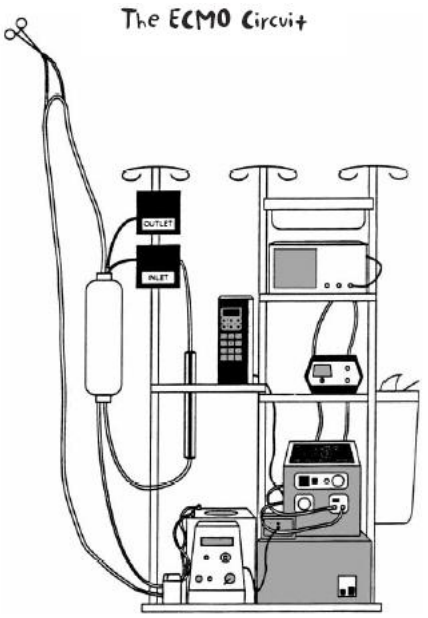
Mechanical ventilation



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Initial VV ECMO Management

- Vent to "**lung rest**" : PIP 20-25, PEEP10-15, fio2 40%, RR 10~30 (*avoid lung collapse*)
- Volume resuscitation and pressor wean
- Wean pressors to off
- D/C paralytics, hold sedation for N/E
- Tx of primary ds – AB, Antiviral
- no prophylactic AB

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VV ECMO sheet

- **Pump Flow**

- just pump flow to keep:
- PaO_2 beetween 50 to 70
- SaO_2 beetween 80 to 90

- **Sweep Gas**

- Keep patient's $PaCO_2$ between 40 to 50
- Keep post membrane PO_2 between 300 to 400

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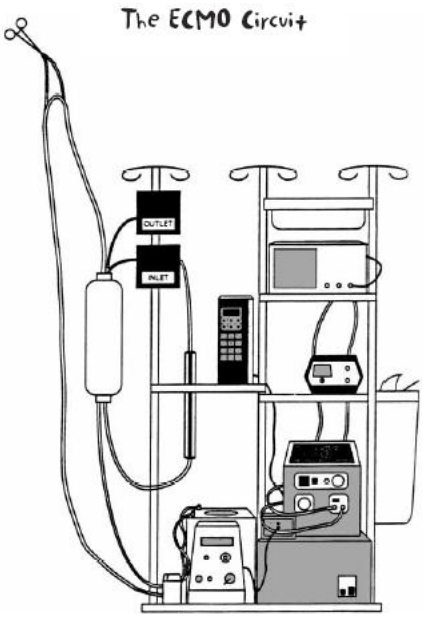
How does the ECMO Weaning ?



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Weaning

- Recovery of underlying disease
  - Optimal demand of inotropics and vasoconstrictors
  - lung protective ventilator setting
  - Maintenance of U/O
  - CXR, Echo
  - Lab: ABGA, EtCO2, lactate….

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Weaning

- Gradual decrease of ECMO flow and increase of native cardiopulmonary function.

- Continuation of anticoagulation during weaning period and after decannulation

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VA ECMO

- An early sign : presence of pulsatility on the arterial waveform.
- The majority of patients who are able to be weaned from VA ECMO for cardiac failure do so within 2 to 5 days.
- Patients with an ejection fraction 30% after 2 days of ECMO are significantly less likely to be successfully weaned than those with an ejection fraction 30% (*8% v 54%, p 0.001).*

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VV ECMO

- Recovery of pulmonary function usually takes 1 to 3 weeks, but occasionally longer.
- Signs of recovery of pulmonary function
  - (1) an improvement in SaO2 for a given circuit flow (or a reduced circuit flow required to achieve the target SaO2),
  - (2) a progressive increase in SaO2 above SvO2,
  - (3) improving lung compliance
  - (4) an improving chest radiograph.

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- Patients who are failing to improve after 1 to 2 weeks should receive aggressive diuresis (+/- RRT)
- S-G catheter, Echocardiogram
- Indicative of irreversibility.
  - Progressive PHT c RVF (+)
  - a mPAP (> 2/3 sys Pr.)

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ECMO in present

Current evidence of various indication

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ECLS Registry Report

International Summary

January, 2014

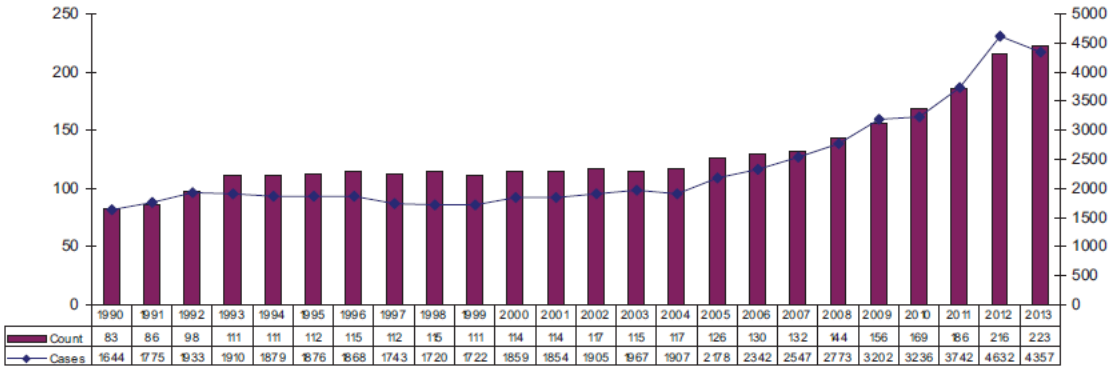
Extracorporeal Life Support Organization
2800 Plymouth Road
Building 300, Room 303
Ann Arbor, MI 48109

Overall Outcomes

	Total Patients	*Survived ECLS*		*Survived to DC or Transfer*	
Neonatal					
Respiratory	27,007	22,782	84%	20,093	74%
Cardiac	5,425	3,339	62%	2,206	41%
ECPR	980	626	64%	388	40%
Pediatric					
Respiratory	6,149	4,034	66%	3,496	57%
Cardiac	6,784	4,443	65%	3,388	50%
ECPR	2,071	1,123	54%	840	41%
Adult					
Respiratory	5,146	3,317	64%	2,905	56%
Cardiac	4,042	2,255	56%	1,636	40%
ECPR	1,238	476	38%	355	29%
Total	58,842	42,395	72%	35,307	60%

Centers

Centers by Year



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Refractory cardiogenic shock

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ACC/AHA guidelines

Class IIb

1. Alternative LV assist devices for circulatory support may be considered in patients with refractory cardiogenic shock. (*Level of Evidence:C*)

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Circulation.2013;127:529-555

ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure 2012

European Heart Journal (2012) **33**, 1787–1847

EUROPEAN SOCIETY OF CARDIOLOGY®

LV assist devices may be considered for circulatory support in patients in refractory shock.

IIb	C

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The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 OCTOBER 4, 2012 VOL. 367 NO. 14

Intraaortic Balloon Support for Myocardial Infarction with Cardiogenic Shock

Holger Thiele, M.D., Uwe Zeymer, M.D., Franz-Josef Neumann, M.D., Miroslaw Ferenc, M.D., Hans-Georg Olbrich, M.D., Jörg Hausleiter, M.D., Gert Richardt, M.D., Marcus Hennersdorf, M.D., Klaus Empen, M.D., Georg Fuernau, M.D., Steffen Desch, M.D., Ingo Eitel, M.D., Rainer Hambrecht, M.D., Jörg Fuhrmann, M.D., Michael Böhm, M.D., Henning Ebelt, M.D., Steffen Schneider, Ph.D., Gerhard Schuler, M.D., and Karl Werdan, M.D., for the IABP-SHOCK II Trial Investigators*

ABSTRACT

BACKGROUND

In current international guidelines, intraaortic balloon counterpulsation is considered to be a class I treatment for cardiogenic shock complicating acute myocardial infarction. However, evidence is based mainly on registry data, and there is a paucity of randomized clinical trials.

METHODS

In this randomized, prospective, open-label, multicenter trial, we randomly assigned 600 patients with cardiogenic shock complicating acute myocardial infarction to intraaortic balloon counterpulsation (IABP group, 301 patients) or no intraaortic balloon counterpulsation (control group, 299 patients). All patients were expected to undergo early revascularization (by means of percutaneous coronary intervention or bypass surgery) and to receive the best available medical therapy. The primary efficacy end point was 30-day all-cause mortality. Safety assessments included major bleeding, peripheral ischemic complications, sepsis, and stroke.

RESULTS

A total of 300 patients in the IABP group and 298 in the control group were included in the analysis of the primary end point. At 30 days, 119 patients in the IABP group (39.7%) and 123 patients in the control group (41.3%) had died (relative risk with IABP, 0.96; 95% confidence interval, 0.79 to 1.17; P=0.69). There were no significant differences in secondary end points or in process-of-care measures, including the time to hemodynamic stabilization, the length of stay in the intensive care unit, serum lactate levels, the dose and duration of catecholamine therapy, and renal function. The IABP group and the control group did not differ significantly with respect to the rates of major bleeding (3.3% and 4.4%, respectively; P=0.51), peripheral ischemic complications (4.3% and 3.4%, P=0.53), sepsis (15.7% and 20.5%, P=0.15), and stroke (0.7% and 1.7%, P=0.28).

CONCLUSIONS

The use of intraaortic balloon counterpulsation did not significantly reduce 30-day mortality in patients with cardiogenic shock complicating acute myocardial infarction for whom an early revascularization strategy was planned. (Funded by the German Research Foundation and others; IABP-SHOCK II ClinicalTrials.gov number, NCT00491036.)

From the University of Leipzig–Heart Center, Leipzig (H.T., G.F., S.D., I.E., G.S.), Klinikum Ludwigshafen and Institut für Herzinfarktforschung, Ludwigshafen (U.Z., S.S.), Heart Center Bad Krozingen, Bad Krozingen (F.-J.N., M.F.), Asklepios Clinic Langen-Seligenstadt, Langen (H.-G.O.), German Heart Center Munich, Munich (J.H.), Heart Center–Segeberger Kliniken, Bad Segeberg (G.R.), SLK Kliniken Heilbronn, Heilbronn (M.H.), Ernst-Moritz-Arndt University Greifswald, Greifswald (K.E.), Klinikum Links der Weser, Bremen (R.H.), Zentralklinik Bad Berka, Bad Berka (J.F.), University Clinic of Saarland, Homburg/Saar (M.B.), and Martin-Luther University Halle-Wittenberg, Halle (H.E., K.W.) — all in Germany. Address reprint requests to Dr. Thiele at the University of Leipzig–Heart Center, Department of Internal Medicine/Cardiology, Strümpellstr. 39, 04289 Leipzig, Germany, or at thielh@medizin.uni-leipzig.de.

Drs. Schuler and Werdan contributed equally to this article.

*Investigators in the Intraaortic Balloon Pump in Cardiogenic Shock II (IABP-SHOCK II) trial are listed in the Supplementary Appendix, available at NEJM.org.

This article was published on August 27, 2012, at NEJM.org.

N Engl J Med 2012;367:1287-96.
DOI: 10.1056/NEJMoa1208410

ELSEVIER

The Journal of Heart and Lung Transplantation
http://www.jhltonline.org

ORIGINAL CLINICAL SCIENCE

Clinical outcome of mechanical circulatory support for refractory cardiogenic shock in the current era

Hiroo Takayama, MD, PhD,[a] Lauren Truby, BS,[a] Michael Koekort, MD,[a] Nir Uriel, MD,[b] Paolo Colombo, MD,[b] Donna M. Mancini, MD, FACC,[b] Ulrich P. Jorde, MD,[b] and Yoshifumi Naka, MD, PhD[a]

From the [a]Departments of Surgery, Columbia University Medical Center, New York, New York.; and the [b]Medicine, Columbia University Medical Center, New York, New York.

KEYWORDS:
cardiogenic shock;
ventricular assist device;
extracorporeal membrane oxygenation;
mechanical circulatory support device;
cardiopulmonary resuscitation;
bridge-to-decision

BACKGROUND: Mortality for refractory cardiogenic shock (RCS) remains high. However, with improving mechanical circulatory support device (MCSD) technology, the treatment options for RCS patients are expanding. We report on a recent 5-year single-center experience with MCSD for treatment of RCS.

METHODS: This study was a retrospective review of adult patients who required an MCSD due to RCS in the past 5 years. We excluded those patients with post-cardiotomy shock and post-transplant cardiac graft dysfunction. In the setting of RCS, a short-term ventricular assist device (VAD) was inserted as a bridge-to-decision device. Veno-arterial extracorporeal membrane oxygenation (VA ECMO) was chosen in cases of unknown neurologic status, complete hemodynam

RESULTS: From January 2007 through January 2012, 90 patients re of whom had active cardiopulmonary resuscitation (CPR). The myocardial infarction in 49% and acute decompensated heart failu years, 71% were male, and 60% had an intra-aortic balloon pum short-term VAD in 49% and VA ECMO in 51%. Median length days). Exchange to implantable VAD was performed in 26% of p myocardial recovery in 18% and heart transplantation in 11%. Surv Multivariate analysis showed ongoing CPR to be an independent r 95% CI 1.285 to 26.08, $p = 0.022$).

CONCLUSIONS: In the current era, roughly half of the patients wh and roughly half of these survivors require an implantable VAD hospital mortality.

J Heart Lung Transplant 2013;32:106–111

JHLT 2013
Columbia Univ. MC

2007-2012 (5yrs)
90. RCS c MCSD

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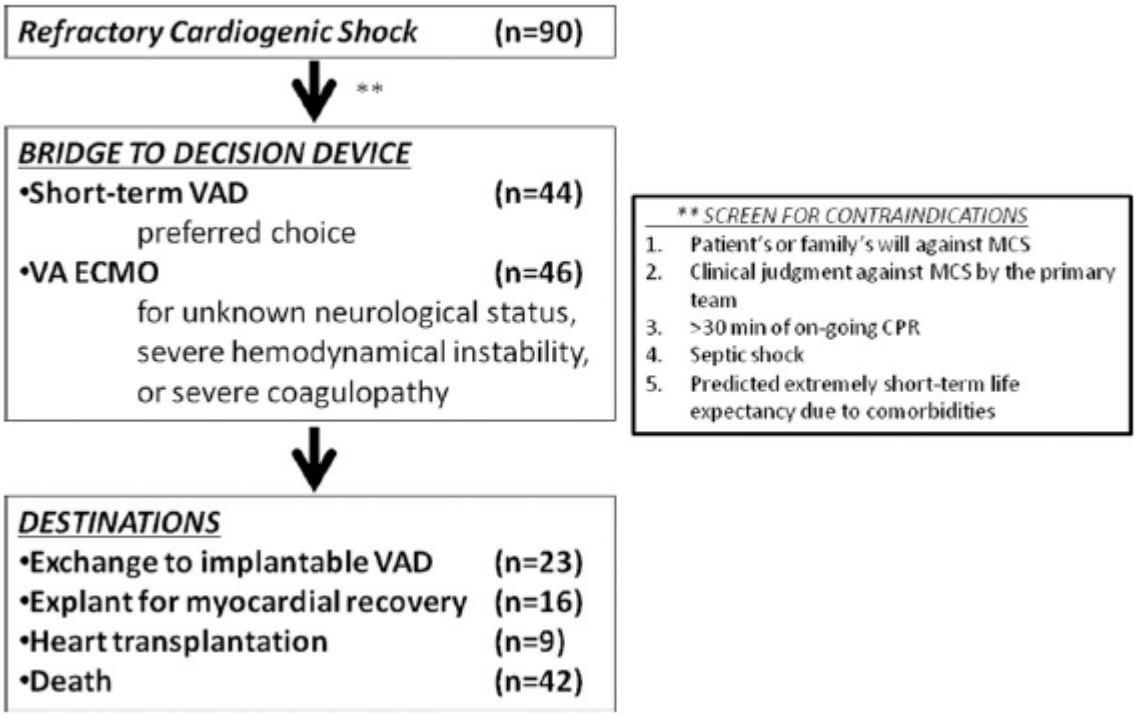

Table 4 Causes of Death During Support With Bridge-to-Decision Device

Cause of death	n[a]
MSOF	21
Neurologic injury	15
Thromboembolic complication	2
Bleeding	1
Other	3

MSOF, multisystem organ failure.
[a]Total deaths = 42.

ARDS

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- Incidence: 64 cases per 100,000 person/yr
  Mortality: up to 40 ~ 50 % (in 2005 , US)

- Lung protective ventilation
  - low tidal volume
  - optimal PEEP
  - low FiO
- Steroid therapy
- Other rescue or salvage treatment
  - prone position
  - inhaled NO
  - HFOV
  - ECMO

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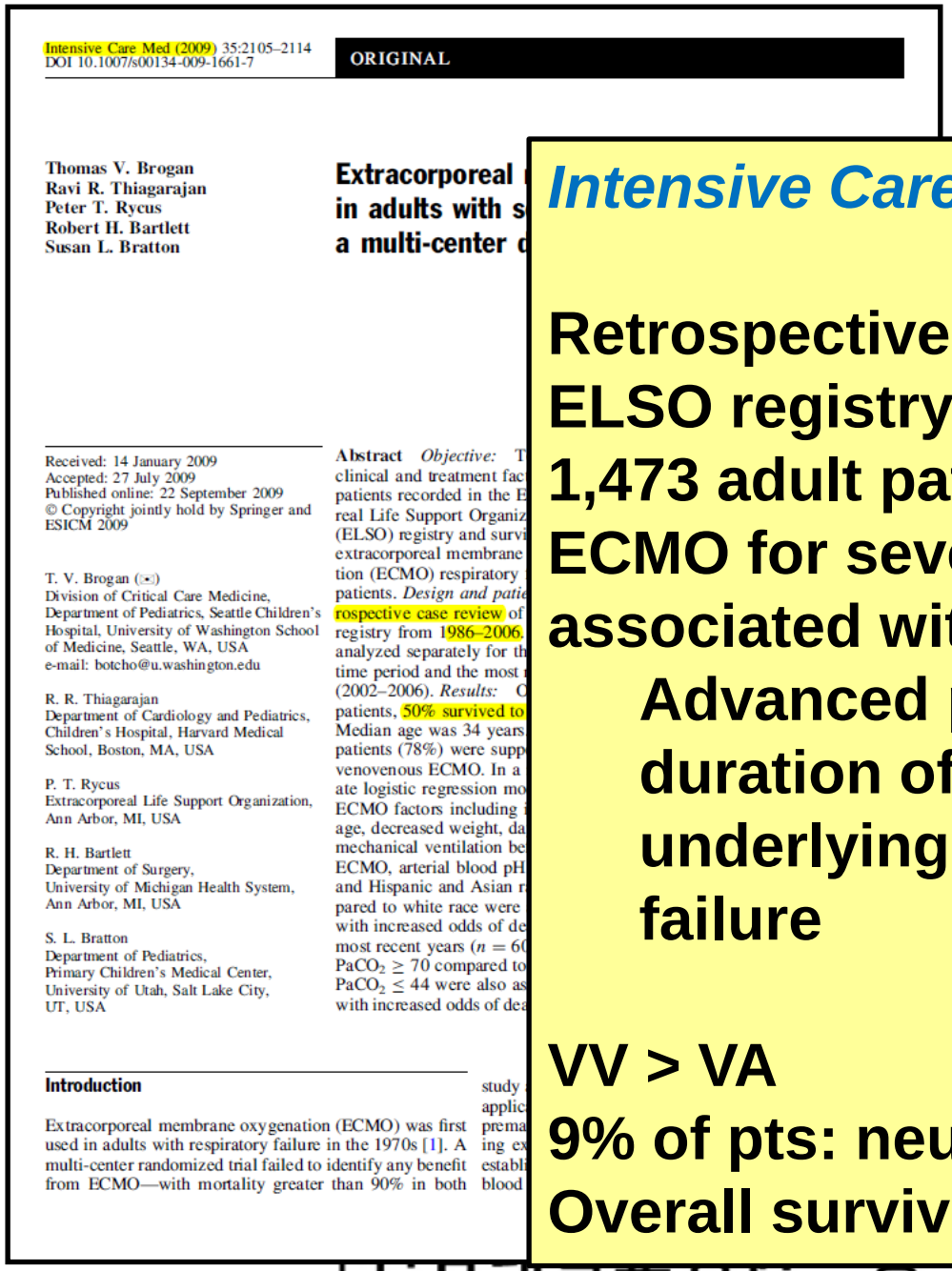

Intensive Care Med (2009) 35:2105–2114
DOI 10.1007/s00134-009-1661-7

ORIGINAL

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Peter T. Rycus
Robert H. Bartlett
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Extracorporeal
in adults with s
a multi-center

Received: 14 January 2009
Accepted: 27 July 2009
Published online: 22 September 2009
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UT, USA

Abstract *Objective:* T
clinical and treatment fac
patients recorded in the E
real Life Support Organiz
(ELSO) registry and survi
extracorporeal membrane
tion (ECMO) respiratory
patients. *Design and patie*
rospective case review of
registry from 1986–2006.
analyzed separately for th
time period and the most
(2002–2006). *Results:* O
patients, 50% survived to
Median age was 34 years
patients (78%) were supp
venovenous ECMO. In a
ate logistic regression mo
ECMO factors including
age, decreased weight, da
mechanical ventilation be
ECMO, arterial blood pH
and Hispanic and Asian r
pared to white race were
with increased odds of de
most recent years ($n = 6$
$PaCO_2 \geq 70$ compared to
$PaCO_2 \leq 44$ were also as
with increased odds of dea

Introduction

Extracorporeal membrane oxygenation (ECMO) was first used in adults with respiratory failure in the 1970s [1]. A multi-center randomized trial failed to identify any benefit from ECMO—with mortality greater than 90% in both

study
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Intensive Care Med 2009

Retrospective
ELSO registry (1986-2006)
1,473 adult patients who received ECMO for severe respiratory failure associated with increased mortality.

- **Advanced patient age**
- **duration of pre-ECMO ventilation**
- **underlying cause of respiratory failure**

VV > VA
9% of pts: neurologic C.
Overall survival to discharge was 50%.

Conventional Ventilation or ECMO for Severe Adult Respiratory Failure

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

Summary

Background Severe acute respiratory failure in adults causes high mortality despite improvements in ventilation techniques and other treatments (eg, steroids, prone positioning, bronchoscopy, and inhaled nitric oxide). We aimed to delineate the safety, clinical efficacy, and cost-effectiveness of extracorporeal membrane oxygenation (ECMO) compared with conventional ventilation support.

Methods In this UK-based multicentre trial, we used an independent central randomisation service to randomly assign 180 adults in a 1:1 ratio to receive continued conventional management or referral to consideration for treatment by ECMO. Eligible patients were aged 18–65 years and had severe (Murray score >3·0 or pH <7·20) but potentially

Lancet 2009; 374: 1351–63

Published Online September 16, 2009 DOI:10.1016/S0140-6736(09)61069-2

See Comment page 1307

See Department of Error page 1330

Department of Cardiothoracic

Lancet 2009, CESAR trial

UK-based multicenter RCT
2001-2006
180 adult respiratory failure pt. (18-65 yrs)
- 90:Conventional management
- 90: VV-ECMO
Inclsuion: severe, but potentially reversible, ARDS (Murray score > 3 or pH < 7.20)

- Primary endpoint
- : survival w/o severe disability at 6 months
- 63% vs 47% (p=0.03).

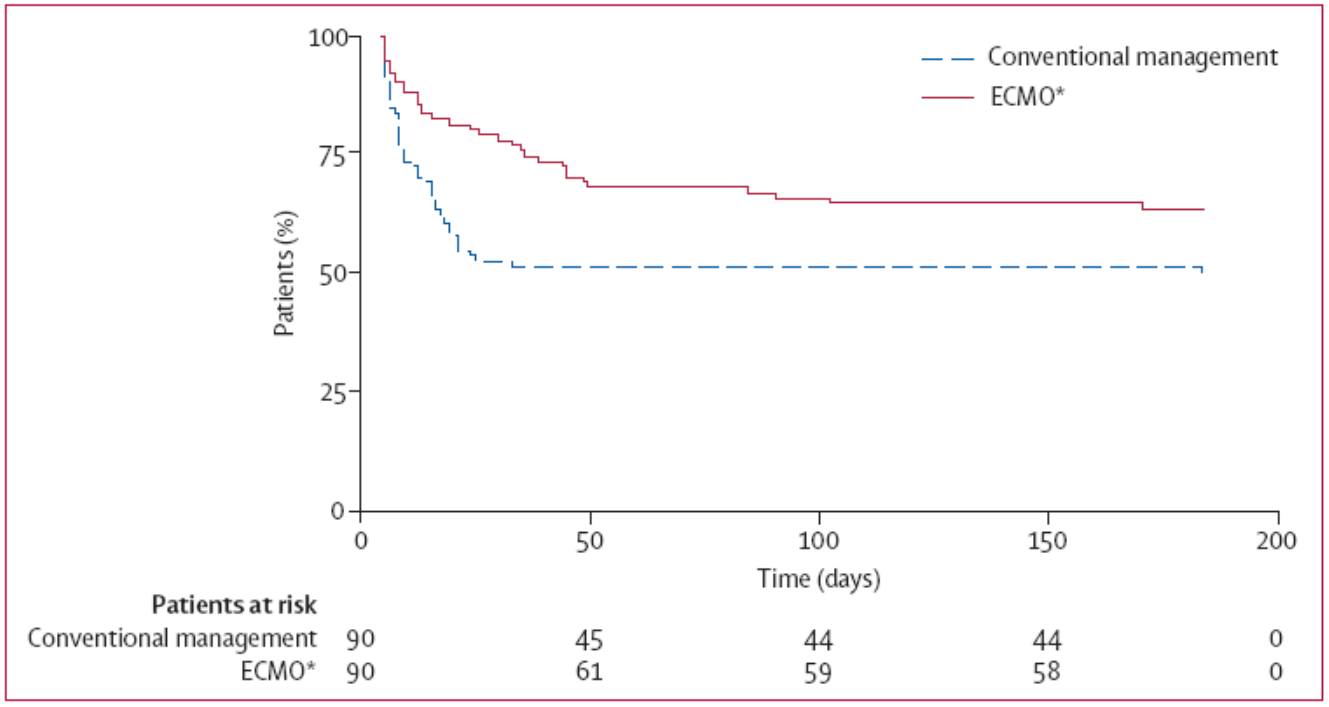

Figure 2: **Kaplan-Meier survival estimates**
ECMO=extracorporeal membrane oxygenation. *Patients were randomly allocated to consideration for treatment by ECMO, but did not necessarily receive this treatment.

Limitation

- if they had been on high pressure or high FiO2 ventilation for more than 7 days
- not treated with ECMO, are excluded from the analysis.

However, CESAR did demonstrate that protocolized care including ECMO in an expert ARDS center yielded higher survival than the best standard care in tertiary ICUs in the UK.

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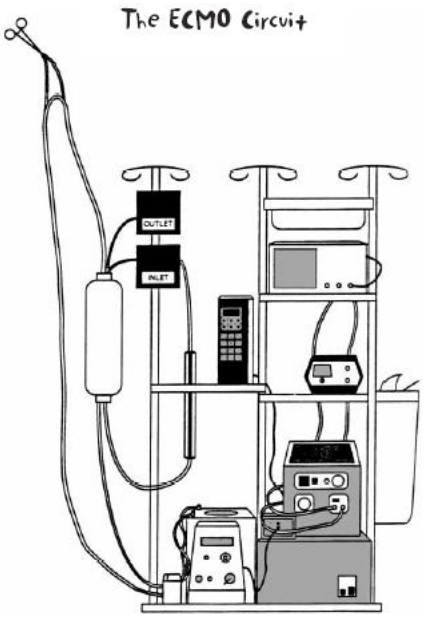
ECPR



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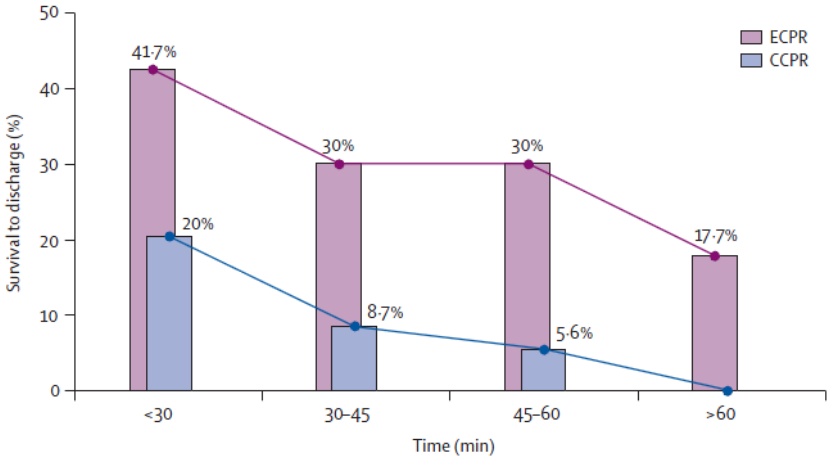
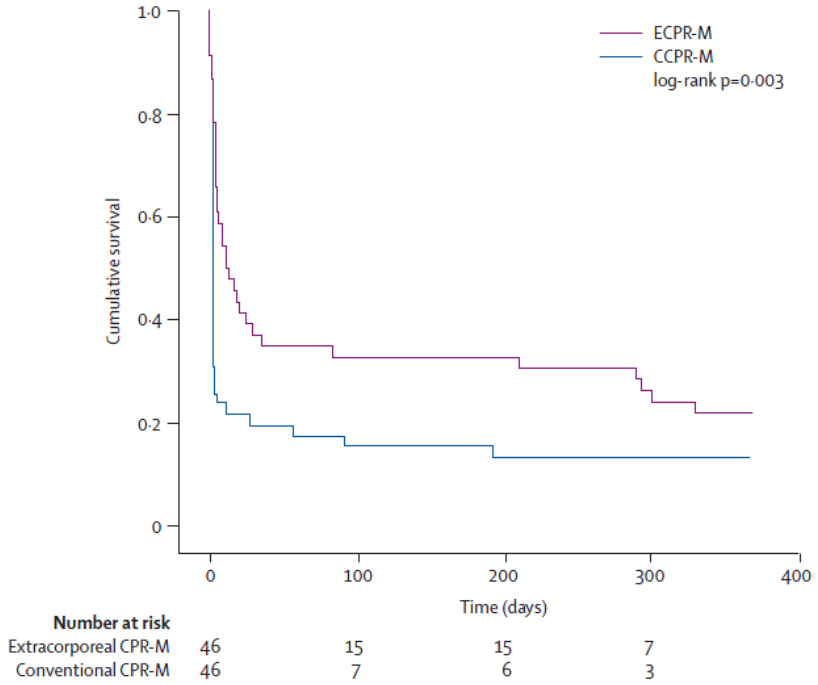
Cardiopulmonary resuscitation with assisted extracorporeal life-support versus conventional cardiopulmonary resuscitation in adults with in-hospital cardiac arrest: an observational study and propensity analysis

- 3 yrs, Taiwan, 2004-2006, age 18-75, in hospital arrest
- Compared 10 min arrest with ECPR vs conventional CPR by propensity analysis
- Oral permission immediate, written later
- 113 were enrolled in the conventional CPR group and 59 were enrolled in the extracorporeal CPR group





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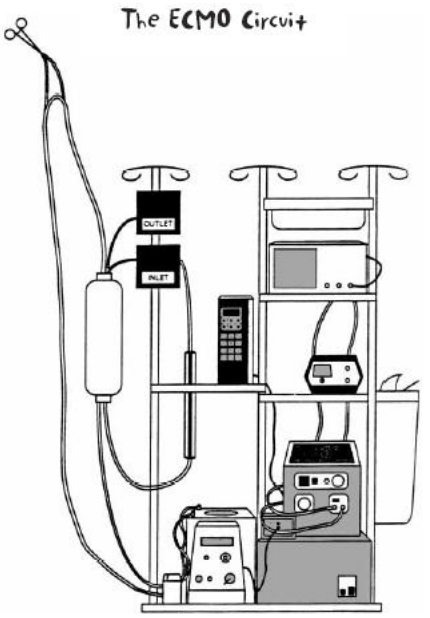
Lancet 2008 Aug 16;372(9638):554-61

Sepsis



전남대학교병원 흉부외과 정

Intensive Care Med
DOI 10.1007/s00134-012-2769-8

GUIDELINES

Surviving Sepsis Campaign: International Guidelines for Management of Severe Sepsis and Septic Shock, 2012

R. P. Dellinger
Mitchell M. Levy
Andrew Rhodes
Djillali Annane
Herwig Gerlach
Steven M. Opal
Jonathan E. Sevransky
Charles L. Sprung
Ivor S. Douglas
Roman Jaeschke
Tiffany M. Osborn
Mark E. Nunnally
Sean R. Townsend
Konrad Reinhart
Ruth M. Kleinpell
Derek C. Angus
Clifford S. Deutschman
Flavia R. Machado
Gordon D. Rubenfeld
Steven Webb
Richard J. Beale
Jean-Louis Vincent
Rui Moreno
The Surviving Sepsis Campaign Guidelines Committee
including The Pediatric Subgroup*

E. Extracorporeal Membrane Oxygenation

1. We suggest ECMO in children with refractory septic shock or with refractory respiratory failure associated with sepsis (grade 2C).

전남대학교병원 흉부외과 정인석

Clinical practice parameters for hemodynamic support of p and neonatal septic shock: 2007 update from the Americar of Critical Care Medicine*

Joe Brierley, MD; Joseph A. Carcillo, MD; Karen Choong, MD; Tim Cornell, MD; Allan DeCaen, MD Andreas Deymann, MD; Allan Doctor, MD; Alan Davis, MD; John Duff, MD; Marc-Andre Dugas, MI Alan Duncan, MD; Barry Evans, MD; Jonathan Feldman, MD; Kathryn Felmet, MD; Gene Fisher, M Lorry Frankel, MD; Howard Jeffries, MD; Bruce Greenwald, MD; Juan Gutierrez, MD; Mark Hall, MD; Yong Y. Han, MD; James Hanson, MD; Jan Hazelzet, MD; Lynn Hernan, MD; Jane Niranjan Kissoon, MD; Alexander Kon, MD; Jose Irazusta, MD; John Lin, MD; Angie Lorts, MD; Michelle Mariscalco, MD; Renuka Mehta, MD; Simon Nadel, MD; Trung Nguyen, MD; Carol Nichol Mark Peters, MD; Regina Okhuysen-Cawley, MD; Tom Poulton, MD; Monica Relves, MD; Agustin R Ranna Rozenfeld, MD; Eduardo Schnitzler, MD; Tom Shanley, MD; Sara Skache, MD; Peter Skippe Adalberto Torres, MD; Bettina von Dessauer, MD; Jacki Weingarten, MD; Timothy Yeh, MD; Arno Z Bonnie Stojadinovic, MD; Jerry Zimmerman, MD; Aaron Zuckerberg, MD

Background: **The Institute of Medicine calls for the use of clinical guidelines and practice parameters to promote "best practices" and to improve patient outcomes.**

Objective: **2007 update of the 2002 American College of Critical Care Medicine Clinical Guidelines for Hemodynamic Support of Neonates and Children with Septic Shock.**

Participants: **Society of Critical Care Medicine members with special interest in neonatal and pediatric septic shock were identified from general solicitation at the Society of Critical Care Medicine Educational and Scientific Symposia (2001–2006).**

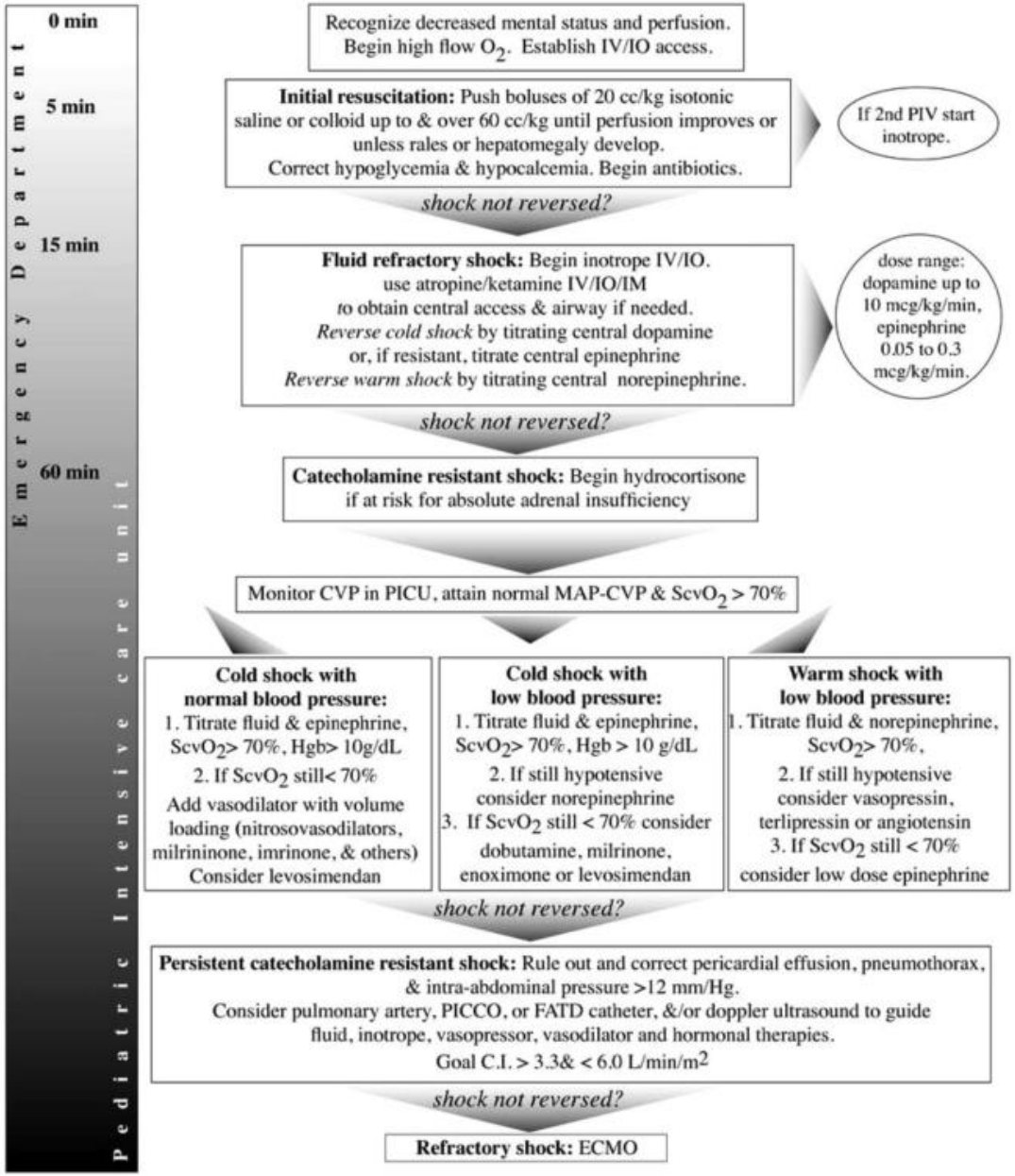
Methods: **The Pubmed/MEDLINE literature database (1966–2006) was searched using the keywords and phrases: sepsis, septicemia, septic shock, endotoxemia, persistent pulmonary hypertension, nitric oxide, extracorporeal membrane oxygenation (ECMO), and American College of Critical Care Medicine guidelines. Best practice centers that reported best outcomes were identified and their practices examined as models of care. Using a modified Delphi method, 30 experts graded new literature. Over 30 additional experts then reviewed the updated recommendations. The document was subsequently modified until there was greater than 90% expert consensus.**

Results: **The 2002 guidelines were widely disseminated, translated into Spanish and Portuguese, and incorporated into Society of Critical Care Medicine and AHA sanctioned recommendations. Centers that implemented the 2002 guidelines repo outcomes (hospital mortality 1%–3% in previously 10% in chronically ill children). Early use of 20 associated with improved outcome in the commu gency department (number needed to treat = pediatric intensive care setting (number needed to hour that went by without guideline adherence w a 1.4-fold increased mortality risk. The update continue to recognize an increased likelihood septic shock, compared with adults, require 1) pr quantities of fluid, 2) inotrope and vasodilator th cortisone for absolute adrenal insufficiency, and 4 tory shock. The major new recommendation in t earlier use of inotrope support through peripheral a access is attained.**

Conclusion: **The 2007 update continues to emp age-specific therapies to attain time-sensitive recommending 1) first hour fluid resuscitation an directed to goals of threshold heart rates, normal b capillary refill ≤2 secs, and 2) subsequent inten modynamic support directed to goals of centr saturation >70% and cardiac index 3.3–6.0 L/min/**

2009; 37:666–688)

KEY WORDS: guidelines; sepsis; severe sepsis



*See also p. 785.

The American College of Critical Care Medicine (ACCM), which honors individuals for their achievements and contributions to multidisciplinary critical care medicine, is the consultative body of the Society of Critical Care Medicine (SCCM) that possesses recognized expertise in the practice of critical care. The College has developed administrative guidelines and clinical practice parameters for the critical care practitioner. New guidelines and practice parameters are continually developed, and current ones are systematically reviewed and revised.

Dr. Brierley received meeting travel expenses from USCOM Ltd. Dr. Nadel has consulted, received honoraria, and study funding from Eli Lilly. Dr. Shanley has received a research grant from the National Institutes of Health. The remaining auth any potential conflicts of intere

For information regarding carcilloja@ccm.upmc.edu

DOI: 10.1097/CCM.0b013e

ECMO in Refractory Septic Shock

Adults, France

Objectives: Profound myocardial depression can occur during severe septic shock. Although good outcomes of venoarterial extracorporeal membrane oxygenation–treated children with refractory septic shock have been reported, little is known about adults' outcomes. This study was designed to assess the outcomes and long-term health-related quality-of-life of patients supported by venoarterial extracorporeal membrane oxygenation for refractory cardiac and hemodynamic failure during severe septic shock.

Design: A retrospective, single-center, observational study and a cross-sectional survey to assess health-related quality of life by the Short Form-36 questionnaire and frequencies of anxiety, depression and posttraumatic stress disorder symptoms by the Hospital Anxiety and Depression Scale and the Impact of Event Scale, respectively.

Setting: A 26-bed tertiary intensive care unit in a university hospital.

Patients: We evaluated the outcomes of patients who received venoarterial extracorporeal membrane oxygenation rescue therapy for refractory cardiovascular failure during bacterial septic shock. Results are expressed as medians (range).

Measurements and Main Results: From January 2008 to September 2011, 14 patients, 45 years old (28–66), seven males, none with a history of left ventricular dysfunction, received venoarterial extracorporeal membrane oxygenation for septic shock refractory to conventional treatment, 24 hours (3–108) after shock onset. All exhibited severe myocardial dysfunction at extracorporeal membrane oxygenation implantation. Left ventricular ejection fraction was 16% (10% to 30%), cardiac index was 1.3 L/min/m² (0.7–2.2) and systemic resistance vascular index was 3162 (2047–7685). All were receiving high-dose catecholamines and had signs of multiple organ failure: pH 7.16 (6.68–7.39), blood lactate 9 (2–17) mmol/L, Pao_2/Fio_2 87 (28–364), Simplified Acute Physiology Score III 84 (75–106) and Sepsis-Related Organ Failure Assessment score 18 (8–21). Twelve patients (86%) could be weaned off venoarterial extracorporeal membrane oxygenation after 5.5 days (2–12) days of support and 10 patients (71%) were discharged to home and were alive after a median follow-up of 13 months (3–43). All 10 survivors had normal left ventricular ejection fraction and reported good health-related quality of life at long-term follow-up.

Conclusions: Venoarterial extracorporeal membrane oxygenation rescued more than 70% of the patients who developed refractory cardiovascular dysfunction during severe bacterial septic shock. Survivors reported good long-term quality of life. Venoarterial extracorporeal membrane oxygenation might represent a valuable therapeutic option for adults in severe septic shock with refractory cardiac and hemodynamic failure. (*Crit Care Med* 2013; 41:1616–1626)

Key Words: cardiogenic; extracorporeal membrane oxygenation; quality-of-life assessment; salvage therapy; septic; shock; treatment outcome

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Venoarterial Extracorporeal Membrane Oxygenation Support for Refractory Cardiovascular Dysfunction During Severe Bacterial Septic Shock*

Nicolas Bréchot, MD, PhD[1]; Charles-Edouard Lu
Pascal Leprince, MD, PhD[2]; Jean-Louis Trouillet,
Jean Chastre, MD[1]; Alain Combes, MD, PhD[1]

Objectives: Profound myocardial depression can occur during severe septic shock. Although good outcomes of venoarterial extracorporeal membrane oxygenation–treated children with refractory septic shock have been reported, little is known about adults' outcomes. This study was designed to assess the outcomes and long-term health-related quality-of-life of patients supported by venoarterial extracorporeal membrane oxygenation for refractory cardiac and hemodynamic failure during severe septic shock.
Design: A retrospective, single-center, observational study and a cross-sectional survey to assess health-related quality of life by the Short Form-36 questionnaire and frequencies of anxiety, depression and posttraumatic stress disorder symptoms by the Hospital Anxiety and Depression Scale and the Impact of Event Scale, respectively.
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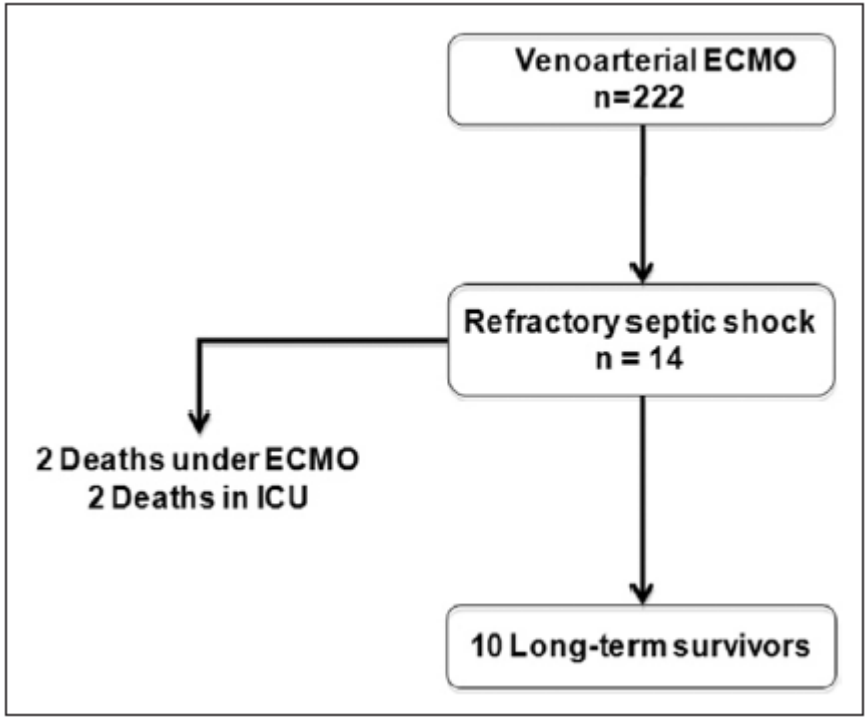

treatment outcome

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대한흉부심장혈관외과학회
제7차 전공의2,3,4년차 학술세미나

Trouble shooting

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Complications of Extracorporeal Membrane Oxygenation for Treatment of Cardiogenic Shock and Cardiac Arrest: A Meta-Analysis of 1,866 Adult Patients

Richard Cheng, MD, Rory Hachamovitch, MD, Michelle Kittleson, MD, PhD, Jignesh Patel, MD, PhD, Francisco Arabia, MD, Jaime Moriguchi, MD, Fardad Esmailian, MD, and Babak Azarbal, MD

Cedars-Sinai Heart Institute, Los Angeles, California, and Department of Cardiovascular Medicine, Heart and Vascular Institute, Cleveland Clinic, Cleveland, Ohio

Background. Venoarterial extracorporeal membrane oxygenation (ECMO) has been used successfully for treatment of cardiogenic shock or cardiac arrest. The exact complication rate is not well understood, in part because of small study sizes. In the absence of large clinical trials, performance of pooled analysis represents the best method for ascertaining complication rates for ECMO.

Methods. A systematic PubMed search was conducted on ECMO for treatment of cardiogenic shock or cardiac arrest in adult patients only, updated to November 2012. Studies with more than 10 patients published in the year 2000 or later that reported complication rates for ECMO were included. Specific complications analyzed included lower extremity ischemia, fasciotomy or compartment syndrome, amputation, stroke, neurologic complications, acute kidney injury, renal replacement therapy, major or significant bleeding, rethoracotomy for bleeding or tamponade, and significant infection. For studies that included overlapping patients, the largest study was included and the others excluded. Cochran's Q and I-squared were calculated. A more conservative random-effects model was chosen for all analyses.

Results. Twenty studies were included in the analyses encompassing 1,866 patients. Seventeen studies reported survival to hospital discharge, with a cumulative survival rate of 534 of 1,529, and a range of 20.8% to 65.4%. Analyses encompassed 192 to 1,452 patients depending on the specific complication analyzed. The pooled estimate rates of complications with 95% confidence intervals were as follows: lower extremity ischemia, 16.9% (12.5% to 22.6%); fasciotomy (7.3% to 14.5%); lowe to 9.3%); stroke, 5.9% cations, 13.3% (9.9% t (35.5% to 74.0%); rena to 55.5%); major or s 56.6%); rethoracoton postcardiotomy pati significant infection,

Conclusions. Altho patients with advanc associated morbidity tion. These finding risk–benefit analysis cardiogenic shock is

ATS 2014

PubMed search
Updated to Nov 2012
CS/CA c ECMO

Analysis of Cx.

Complications	Number of Studies	Reported Rate Minimum, Maximum (%)
LEI	13	3.7, 37.5
LEF	5	5.4, 20.7
LEA	5	0, 8.1
Stroke	3	3.9, 9.7
Neurologic	9	5.9, 22.1
AKI	6	29.9, 86.7
Requiring RRT	15	7.84, 86.7
Bleeding	5	14.8, 63.6
Re-Thx for bleed	6	16.1, 86.7
Significant infection	10	13.7, 64.5

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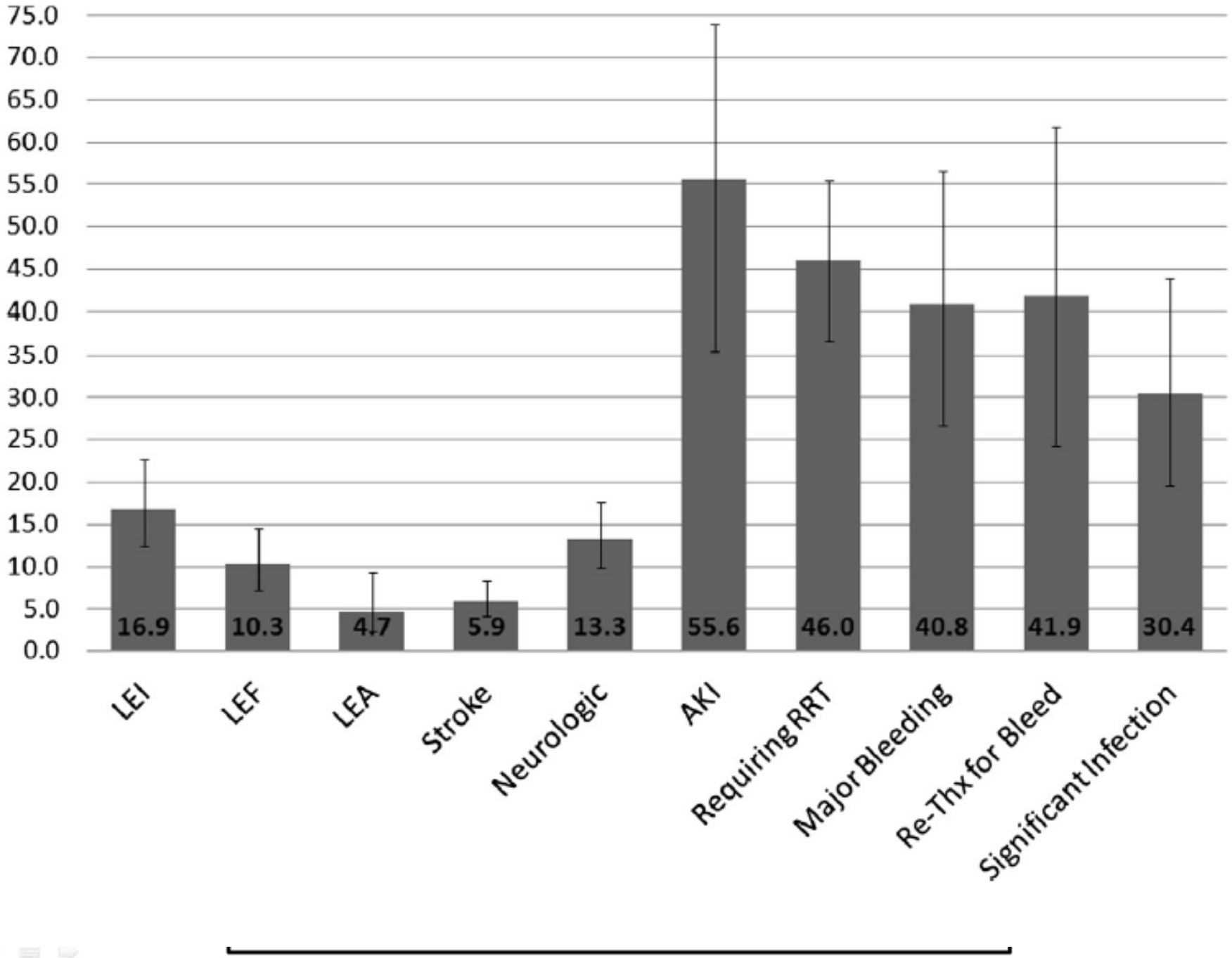
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46.0
40.8
41.9
30.4
LEI
LEF
LEA
Stroke
Neurologic
AKI
Requiring RRT
Major Bleeding
Re-Thx for Bleed
Significant Infection

low SaO2

- patient factor
  1. native lung function ↓ (pneumonia, PNX…)
  2. ↑oxygen consumption esp. in VV (sepsis)
  3. upper body hypoxia in VA
- mechanical factor
  1. inadequate flow
  2. oxygenator failure
  3. disconnection of sweep gas line
  4. recirculation in VV

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oxygenator failure

- Sign: color, sweating
- Check ABGA and Pr. in oxygenator
- determination of oxygenator change

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loss of circuit flow

- cause
  - hypovolemia (m.c.)
  - cardiac tamponade, tension pneumothorax, cannula malposition.

- in centrifugal pumps
  - impending loss of circuit flow is indicated by the inlet pressure becoming more negative (120 mmHg)
  - “chatter” of the drainage tubing

- This can progress to “suck down” of the vein or RA around the drainage cannula, which results in a sudden decrease in inlet pressure (150 mmHg) and an abrupt loss of circuit flow.

- action
  - transient reduction of ECMP flow (to release the suction effect.)

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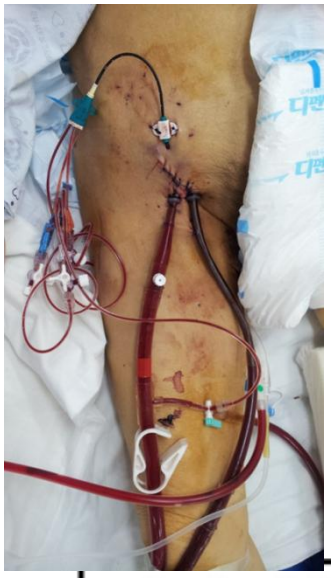
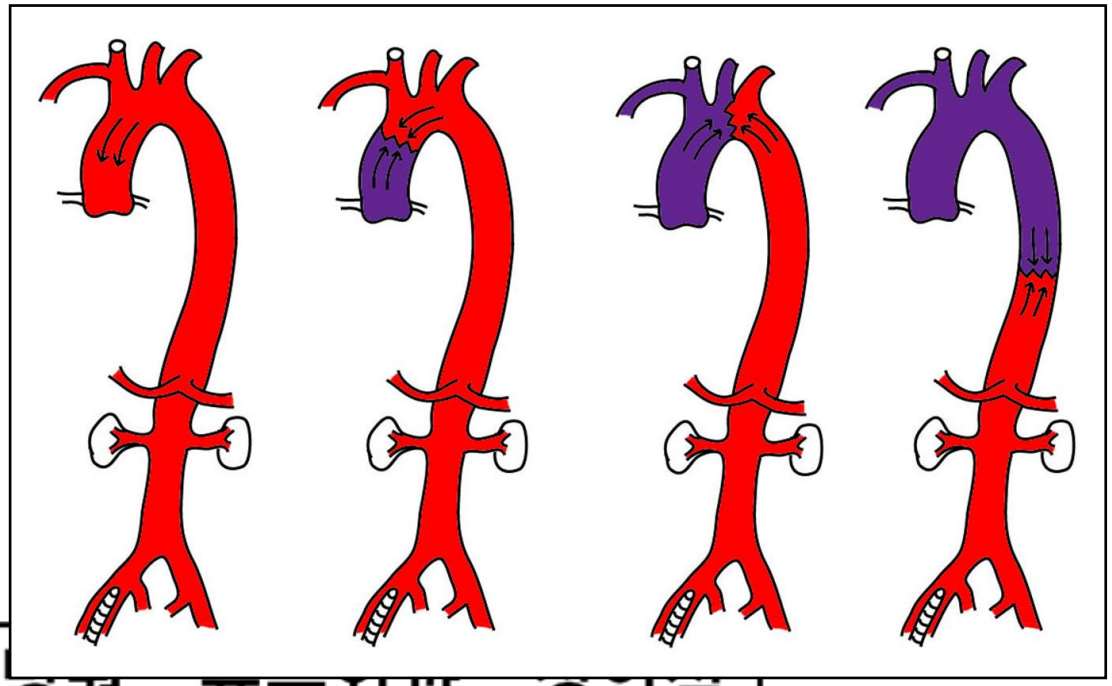
Upper body hypoxemia in VA ECMO

Differential cyanosis, 2-Pump circulation

- ↑ SaO2 in upper body / ↓ SaO2 in lower body
- marginal myocardial function and respiratory failure in VA





Potential solutions

- increasing ECMO flows to reduce LV ejection
- changing to VV / VAV ECMO (IJV)
- central cannulation (axillary artery)

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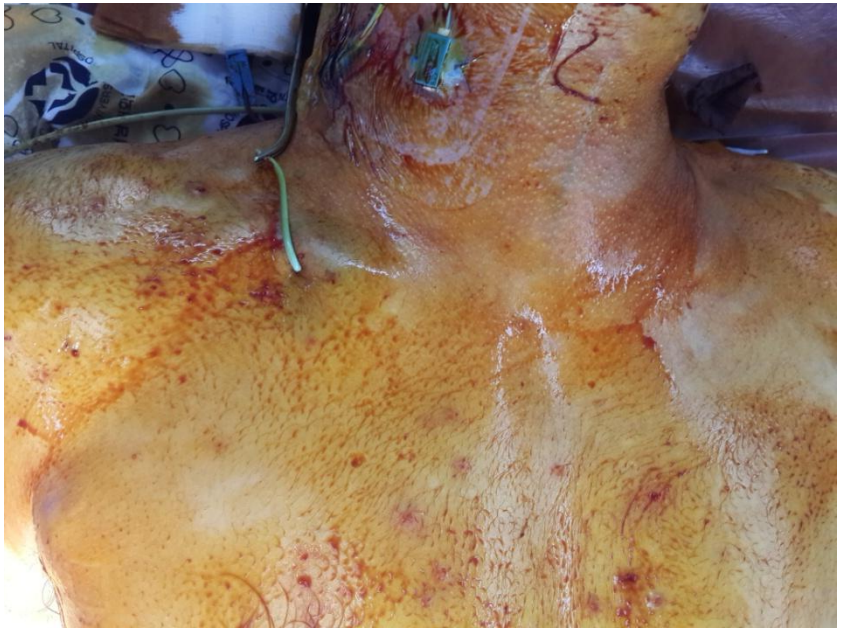

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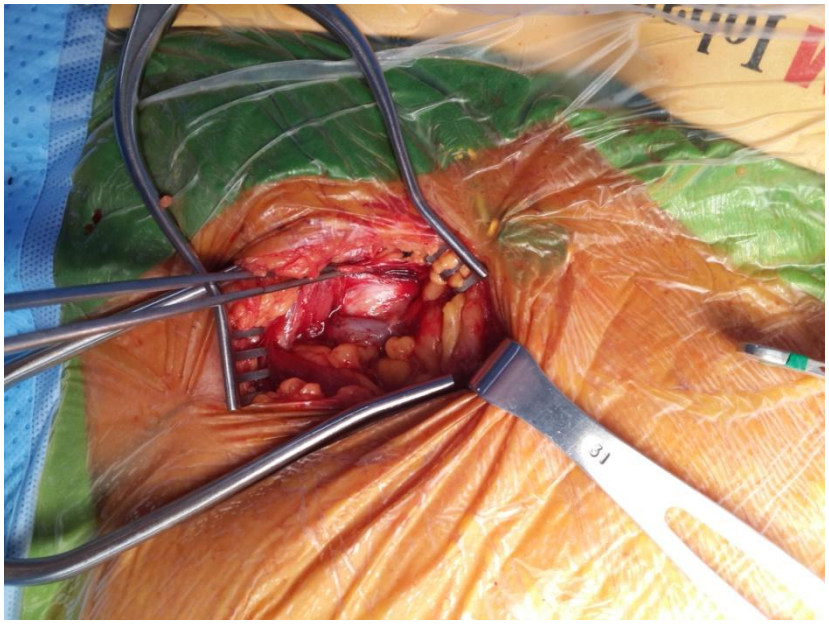

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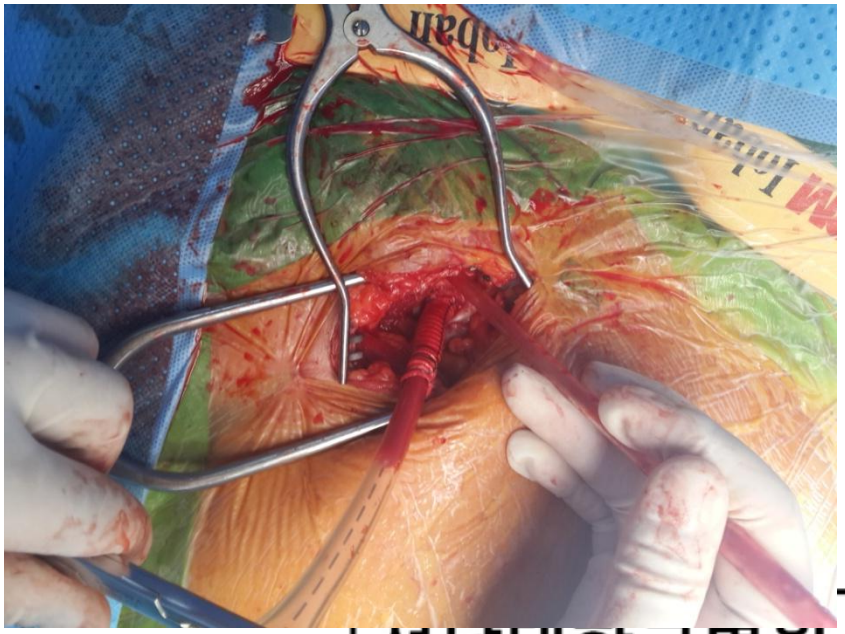

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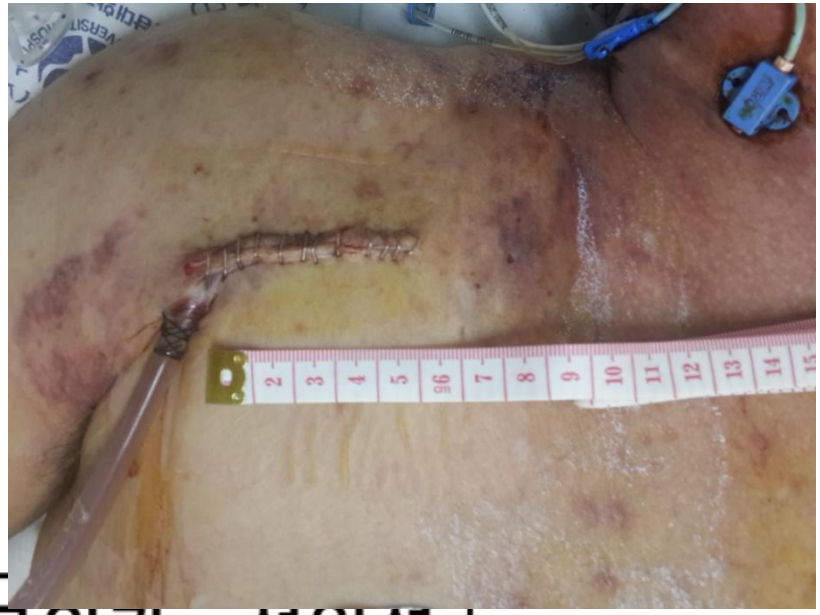

4

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hypoxemia with VV ECMO (SaO2 85%)

- inadequate ECMO flow (m.c.)
- other cause despite adequate circuit flows
  - significant recirculation
    - a low SaO2 and high SDO2 (typically 75%),
  - inadequate sedation, sepsis, iatrogenic overheating, overfeeding and seizures.
    - increased oxygen consumption and pathologically increased CO
    - a low SaO2 low SDO2.

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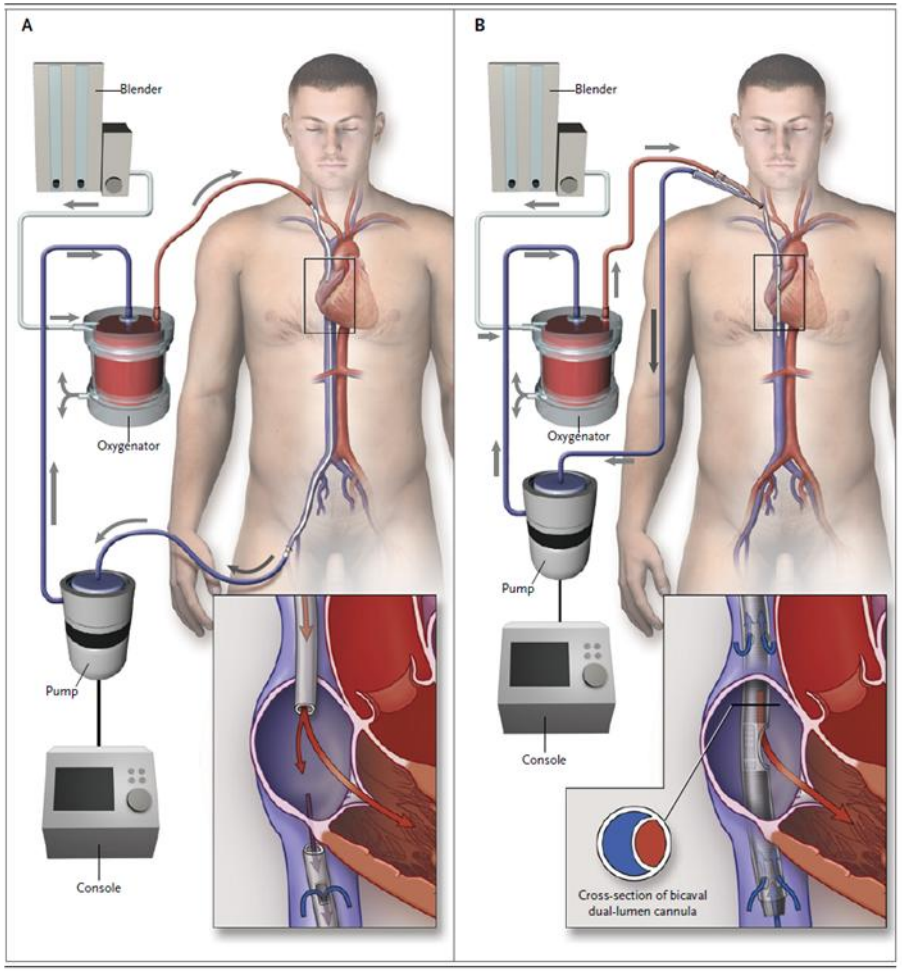
high SvO2 or SdO2 (>80%)

- recirculation in VV



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Early Goal Direct Therapy in early sepsis

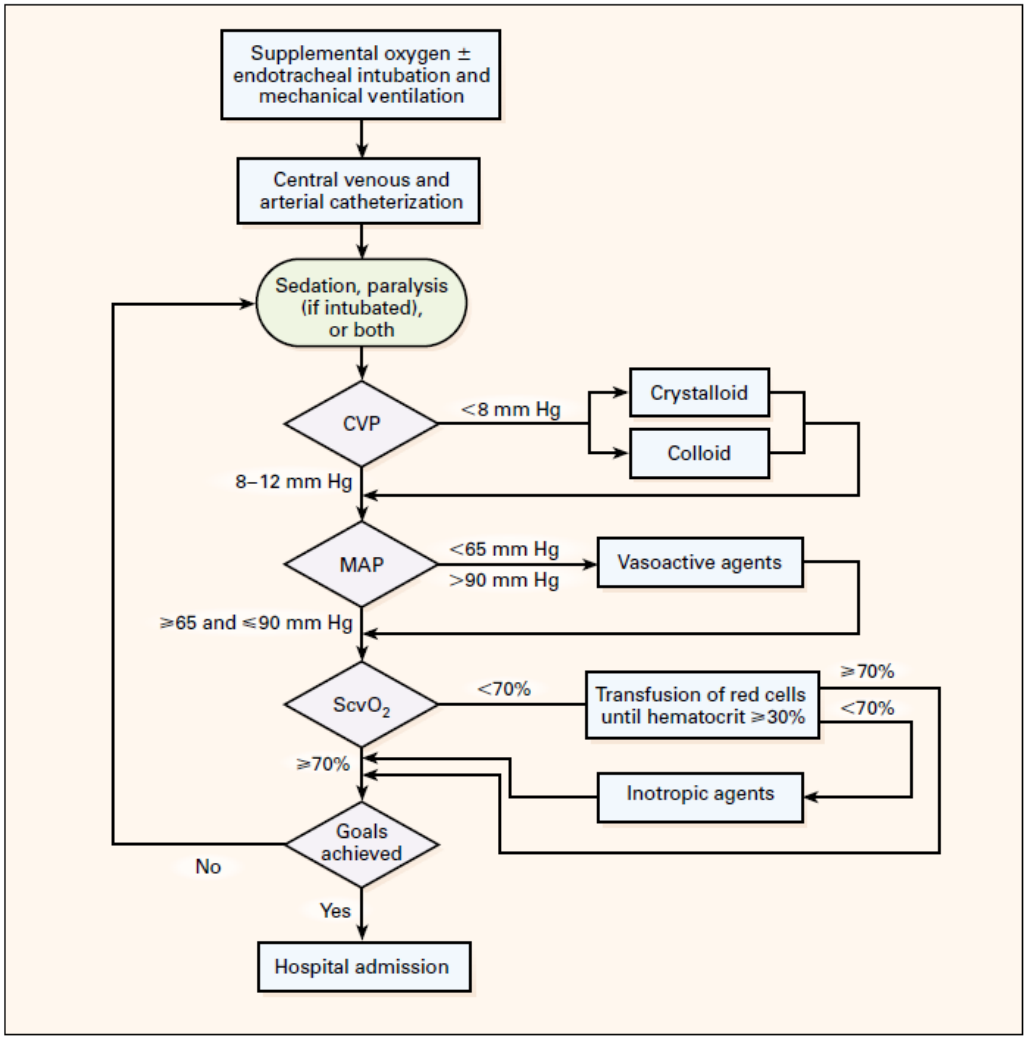

Figure 2. Protocol for Early Goal-Directed Therapy.
CVP denotes central venous pressure, MAP mean arterial pressure, and $ScvO_2$ central venous oxygen saturation.

Action for increased oxygen consumption

- correction of the underlying cause
- sedation +/- NMB
- boosting transfusion (Hgb: 11-12 g/dL),
- active cooling (down to 35°C)
- circuit flows(additional or central cannulation)

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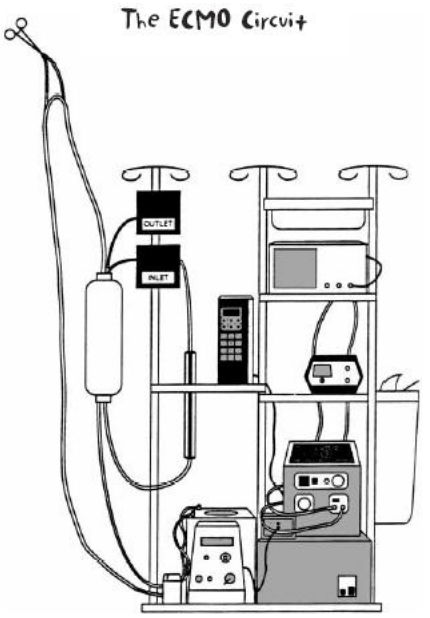
Left heart decompression



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Hemodynamic Instability in VA

- reduced vascular tone
- reduced preload
- cardiac dysfunction.

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- **Cardiac dysfunction with LV distension in VA ECMO**
  - risk: MR / AR (+)
  - CXR: alveolar edema (+)
  - edema secretion frothing up the ET tube
  - Echo: confirmed LV dysfunction and distension
  - action:
    - ↑ECMO flows (↓reduces PFB)
    - Failing this, the left heart must be vented

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- In general, LV dilatation (+) in pph VA ECMO
- Need for LV unloading
  - More rapid recovery of exhausted LV
- Management
  - Left heart decompression
  - Conversion to LVAD

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LH decompression (LHD)

- Atrial septostomy
  - US guided balloon or blade septostomy
  - via pph approach(ex. UV, FV)
- Additional drainage catheter insertion
  - Sternotomy (full or partial) : RPV / LA roof /LV apex
  - Anterior mini-thoracotomy: RPV
  - Subxiphoid approach : LV apex
  - Percutaneous transseptal approach
- Axial flow pump (Impella) with pph. ECMO

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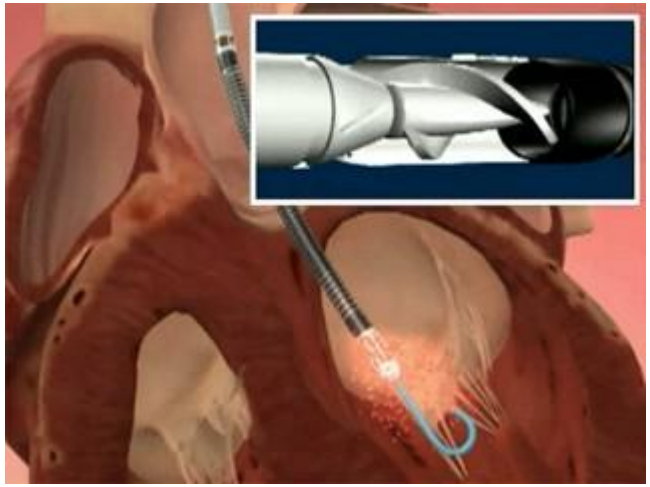
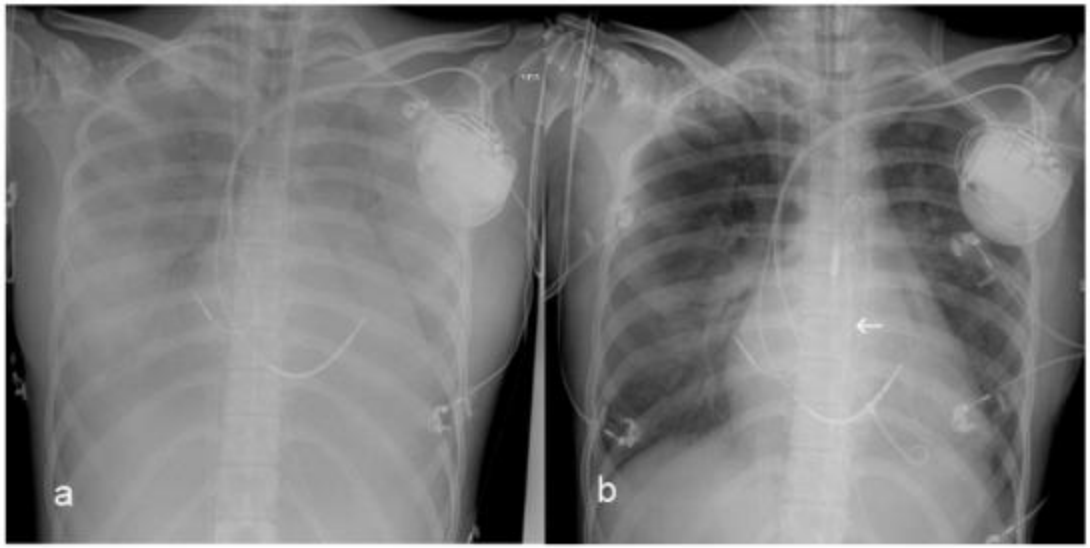
Successful left ventricular decompression following peripheral extracorporeal membrane oxygenation by percutaneous placement of a micro-axial flow pump



To the Editor:

We report the case of a patient in whom left ventricular decompression under extracorporeal membrane oxygenation (ECMO) was achieved using an intracardiac micropump (Impella Recovery LP 2.5).

A 25-year-old woman recently diagnosed with idiopathic non-obstructive cardiomyopathy was referred to our institution for her third episode of severe acute pulmonary edema within the last 12 months. Elevated serum creatinine (164 mmol/liter) and decreased activated partial thromboplastin time (aPTT; 29%) confirmed renal and hepatic dysfunction. Left ventricle end-diastolic diameter (LVEDD) was 51 mm/m^2 with functional mitral regurgitation (regurgitant orifice area [ROA] = 0.23 cm^2), and ejectio
(EF) was 25%. Systolic pulmonary artery pressure
35 mm Hg) was elevated with regard to the low out



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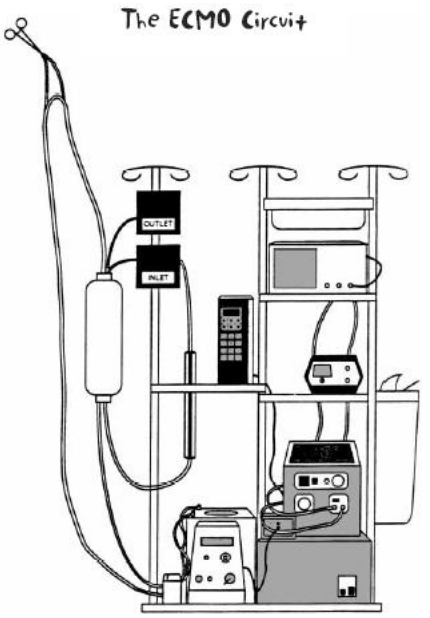
lower extremity ischemia



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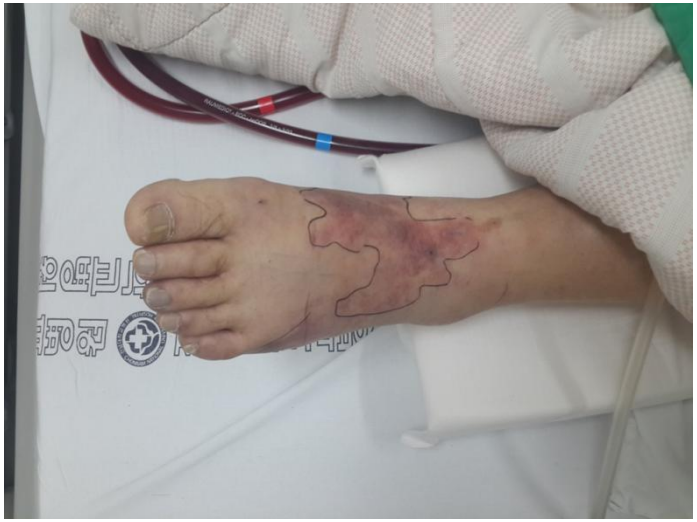
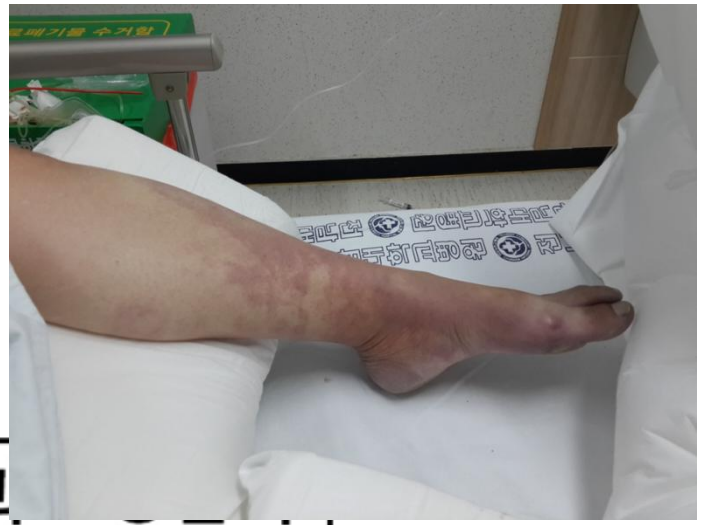
pph. VA ECMO

- early sign: cool, pale
- in progress: color change
- late phase:
  - compartment syndrome
  - rhabdomyolysis





action

- smaller bore cannula
- additional cannulation for distal perfusion
  - if, possible. US guided puncture
  - retrograde perfusion through DPA (micropuncture needle)
- Axillary artery cannulation

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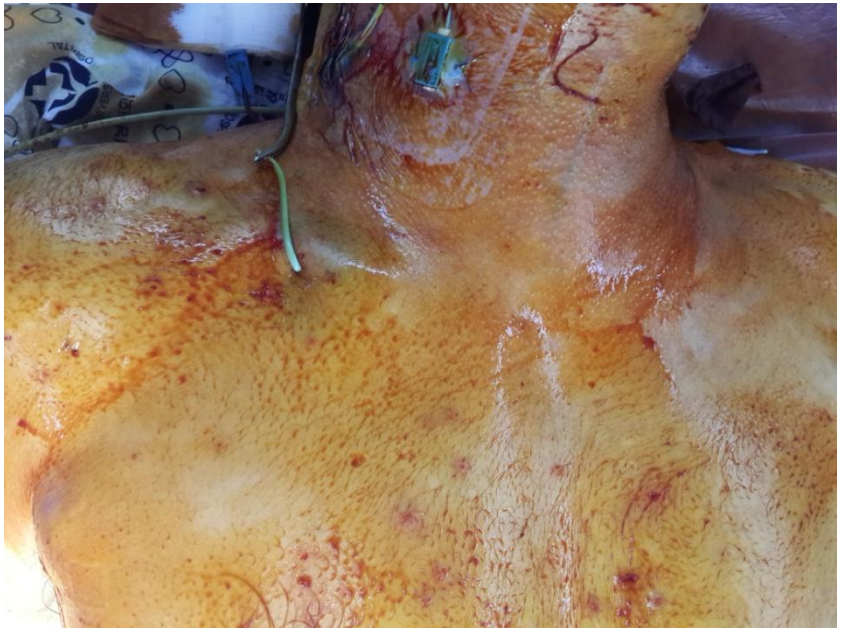
전남대학교병원 흉부외과 정인석



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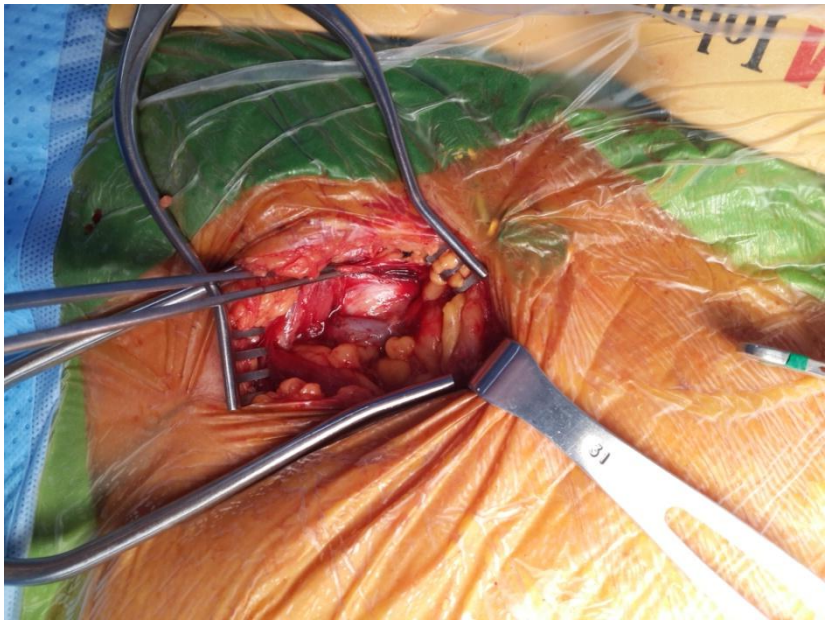

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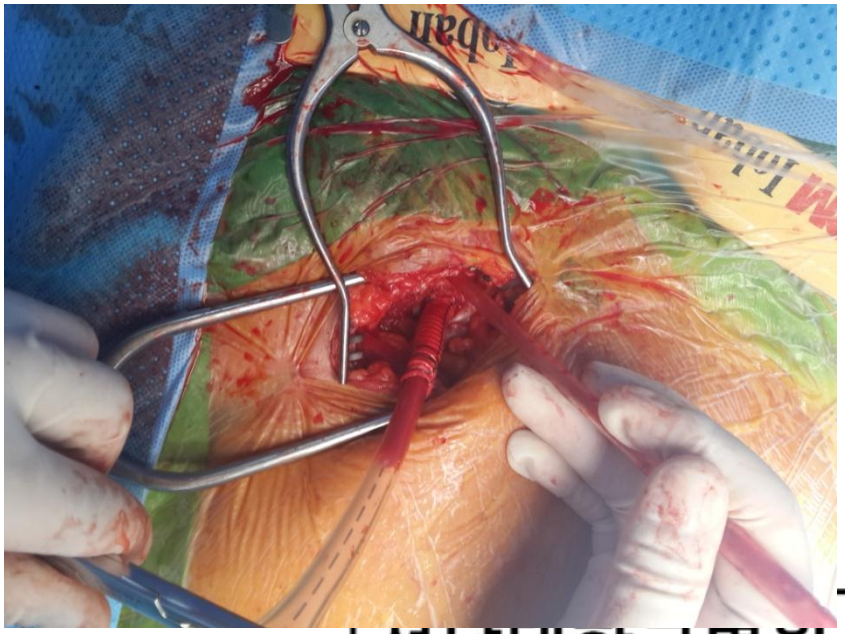

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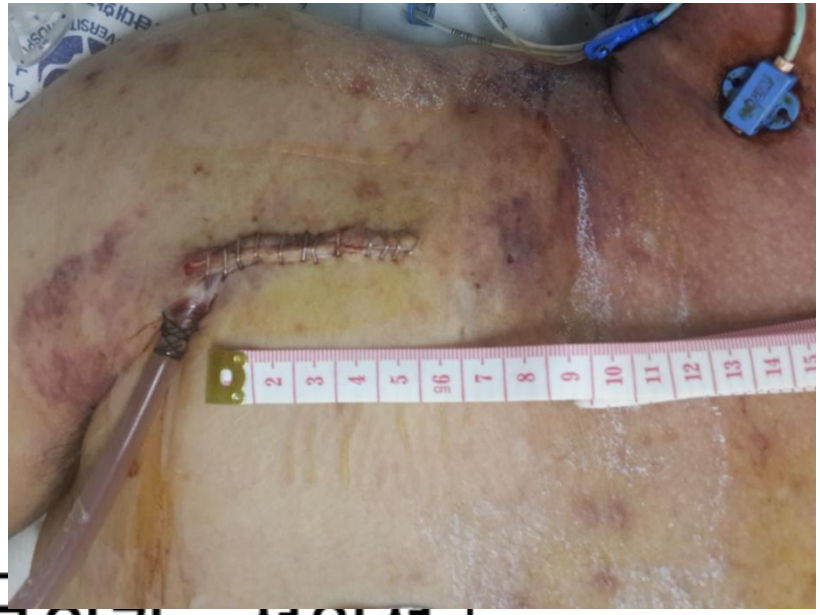

4

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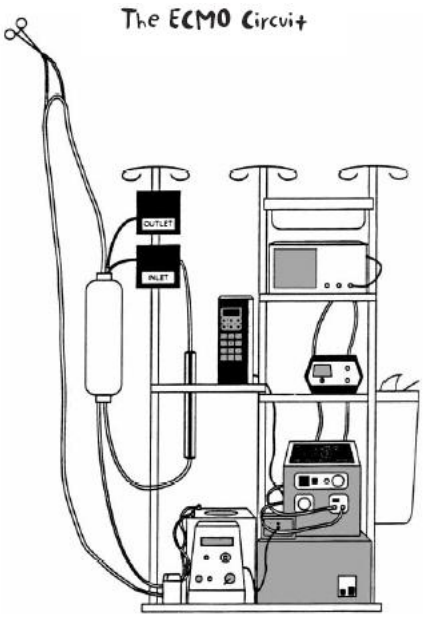
Massive air embolism



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massive air embolism

- mechanism
  1. large negative pressure(up to -100mmHg)
  2. cavitation
  3. loosening of 3-way and luer lock port
- intervention
  1. clamping immediately / stop ECMO
  2. full ventilation / inotropics ↑
  3. VA: trendelburg position
  4. flushing or change circuit/oxygenator

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3-way and luer lock port

- loosening or accidental opening
- in inlet portion: massive air embolism
- in outlet portion: massive blood loss

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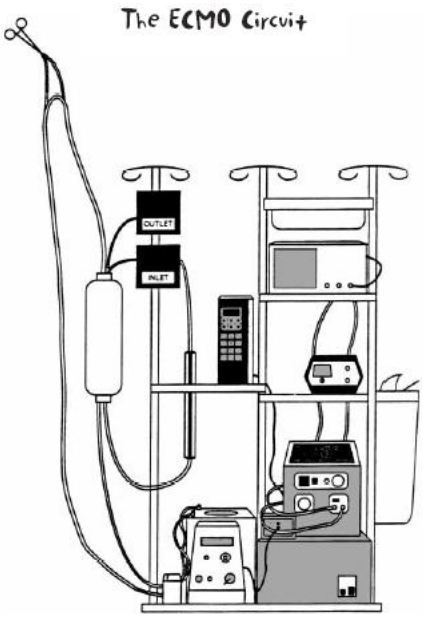
Infection and Sepsis



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Infection and Sepsis

- Infections in patients receiving ECMO are common
- sites of infection (most commonly bloodstream, lower respiratory tract, urinary tract, and wound)
- causative microorganisms (typically gram-negative bacilli and staphylococci)
- similar to other intensive care unit patients.

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- Signs of sepsis: ambiguous in patients on EMCO
- fever may be absent
  - because of the servo control of body temperature by the heat exchanger.
- even subtle signs of infection warrant an aggressive search for a septic cause.
  - (ex, deteriorating hemodynamics or leukocytosis)
- Broad spectrum empiric antimicrobial therapy
  - (ex. carbapenem, vancomycin)

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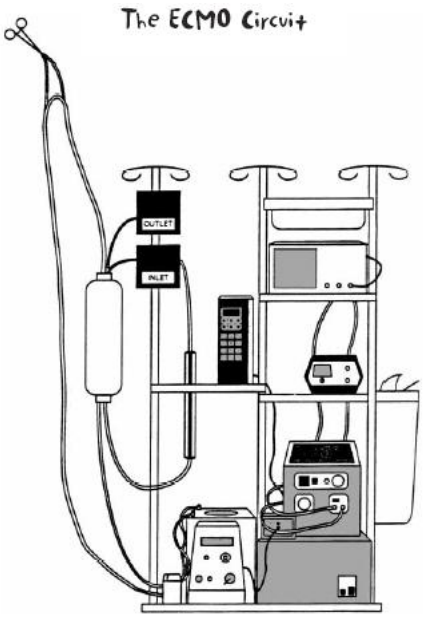
CRRT



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Laboratory Investigation (2010) 90, 128–139

Plasma concentrations of inflammatory cytokines rise rapidly during ECMO-related SIRS due to the release of preformed stores in the intestine

R Britt McILwain[1,2], Joseph G Timpa[1], Ashish R Kurundkar[3], David W Holt[2], David R Kelly[4], Yolanda E Hartman[3], Mary Lauren Neel[3], Rajendra K Karnatak[3], Robert L Schelonka[5], GM Anantharamaiah[6], Cheryl R Killingsworth[6] and Akhil Maheshwari[3,4,7]

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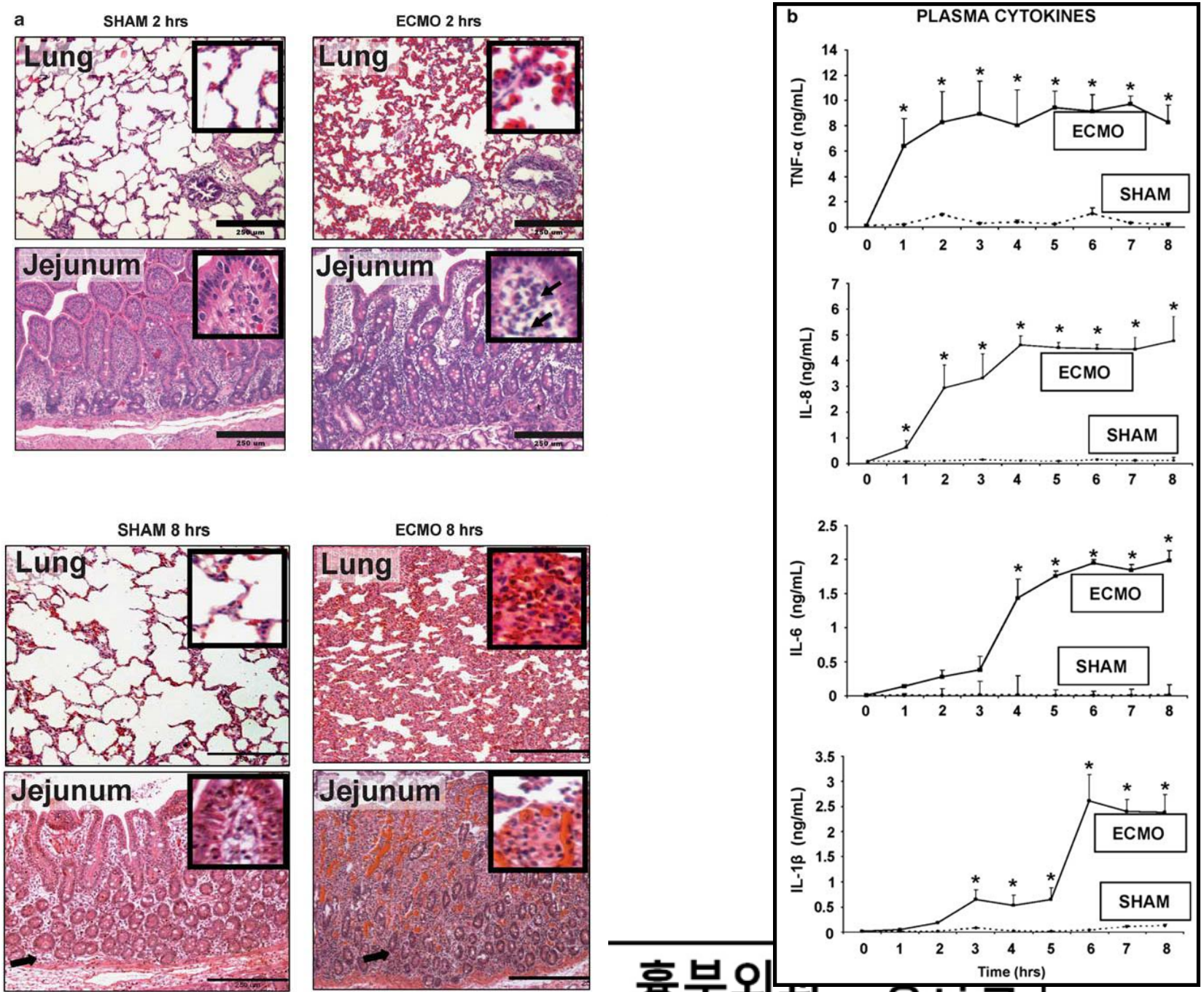
a
SHAM 2 hrs
ECMO 2 hrs
Lung
Jejunum
250 um
SHAM 8 hrs
ECMO 8 hrs
b
PLASMA CYTOKINES
TNF-α (ng/mL)
IL-8 (ng/mL)
IL-6 (ng/mL)
IL-1β (ng/mL)
ECMO
SHAM
Time (hrs)

흉부외과

Yimin *et al. Journal of Cardiothoracic Surgery* 2013, **8**:113
http://www.cardiothoracicsurgery.org/content/8/1/113

JOURNAL OF CARDIOTHORACIC SURGERY

RESEARCH ARTICLE Open Access

Effects of continuous renal replacement therapy on renal inflammatory cytokines during extracorporeal membrane oxygenation in a porcine model

Hu Yimin[1,2], Yu Wenkui[1], Shi Jialiang[1], Chen Qiyi[1], Shen Juanhong[1], Lin Zhiliang[1], He Changsheng[1], Li Ning[1*] and Li Jieshou[1]

전남대학교병원 흉부외과 정인석

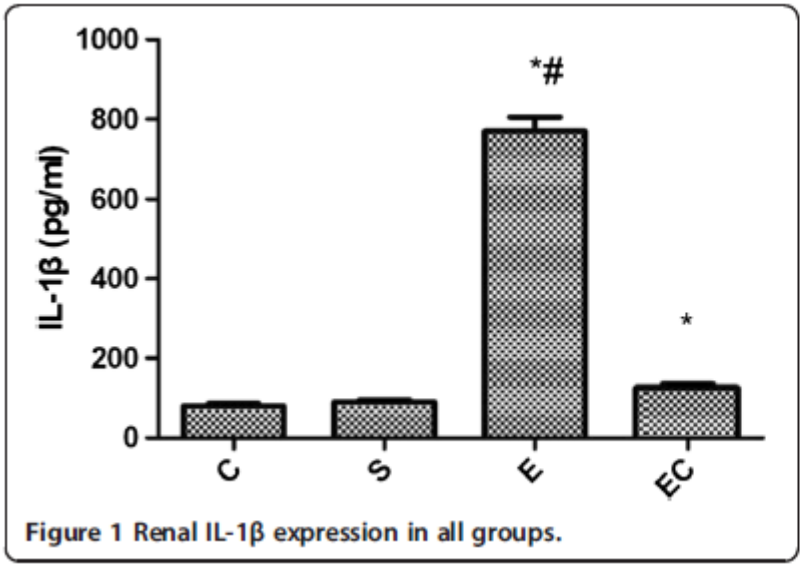

Figure 1 Renal IL-1β expression in all groups.

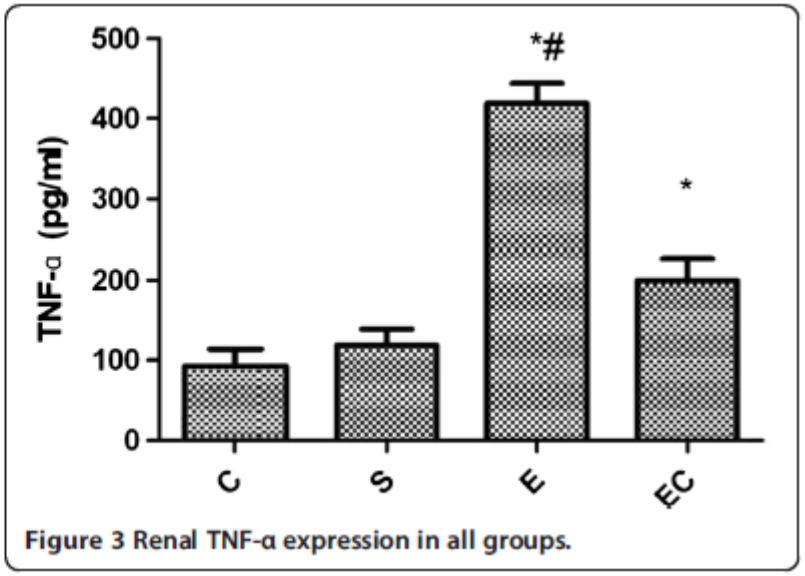

Figure 3 Renal TNF-α expression in all groups.

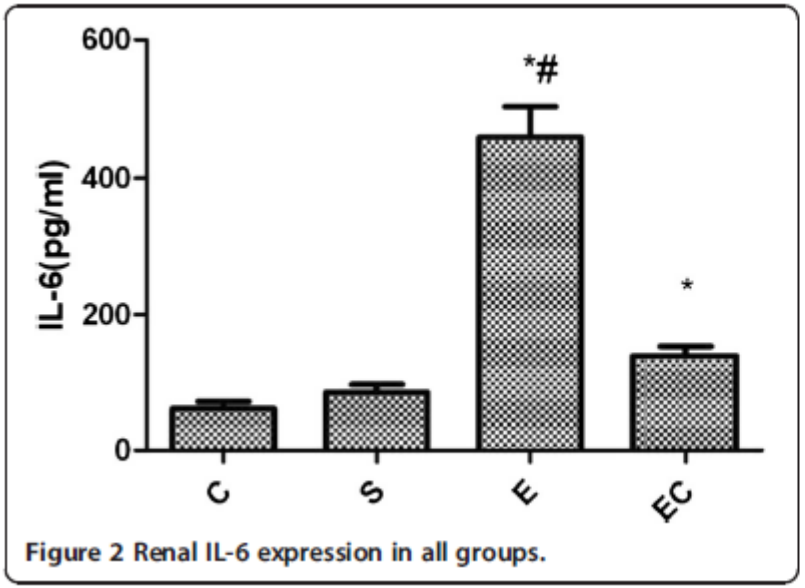

Figure 2 Renal IL-6 expression in all groups.

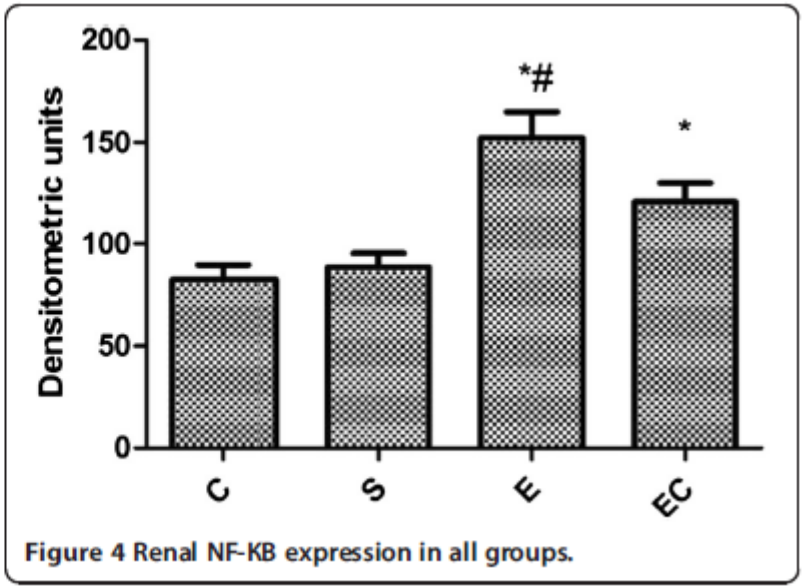

Figure 4 Renal NF-KB expression in all groups.

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CRRT on ECMO: Potential Benefits

- Management of **fluid balance**
- Control of **electrolyte abnormalities**
- Removal of **inflammatory mediators**
- Enhanced **nutritional support**

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Guideline for ECMO & CRRT

Question	Evidence based conclusions
Optimal population ?	unknown (esp. neonate)
What indication ?	Survey results about what people are doing
Timing of initiation ?	Experts opinion, ELSO guideline
Optimal mode ?	unknown
Optimal connection ?	unknown
Optimal dose ?	unknown
Effectiveness ?	unknown
Outcomes ?	Single center reports, registry data

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ELSO Guidelines 1.

• Despite the literature surrounding *fluid overload (>10%) as a risk factor for death*, review of the ELSO registry also finds use of *RRT is also a risk factor for poor outcome*.

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ELSO Guidelines 2.

- RRT use to enhance fluid removal *allowing adequate nutritional support* is often performed.

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ELSO Guidelines 3.

- The hourly fluid balance goal should be set and maintained until *normal ECF volume is reached.*
  - no systemic edema
  - within 5% of dry weight

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ELSO Guidelines 4.

• Even if ARF occurs with ECLS, resolution in survivors occurs in *> 90%* of patients *without need for long-term dialysis*.

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Recommendations

- Early (5-10 % FO)
- CVVHDF
- Fluid removal
  - Once hemodynamically stable
  - 1 ~ 3% blood volume/hr as tolerated

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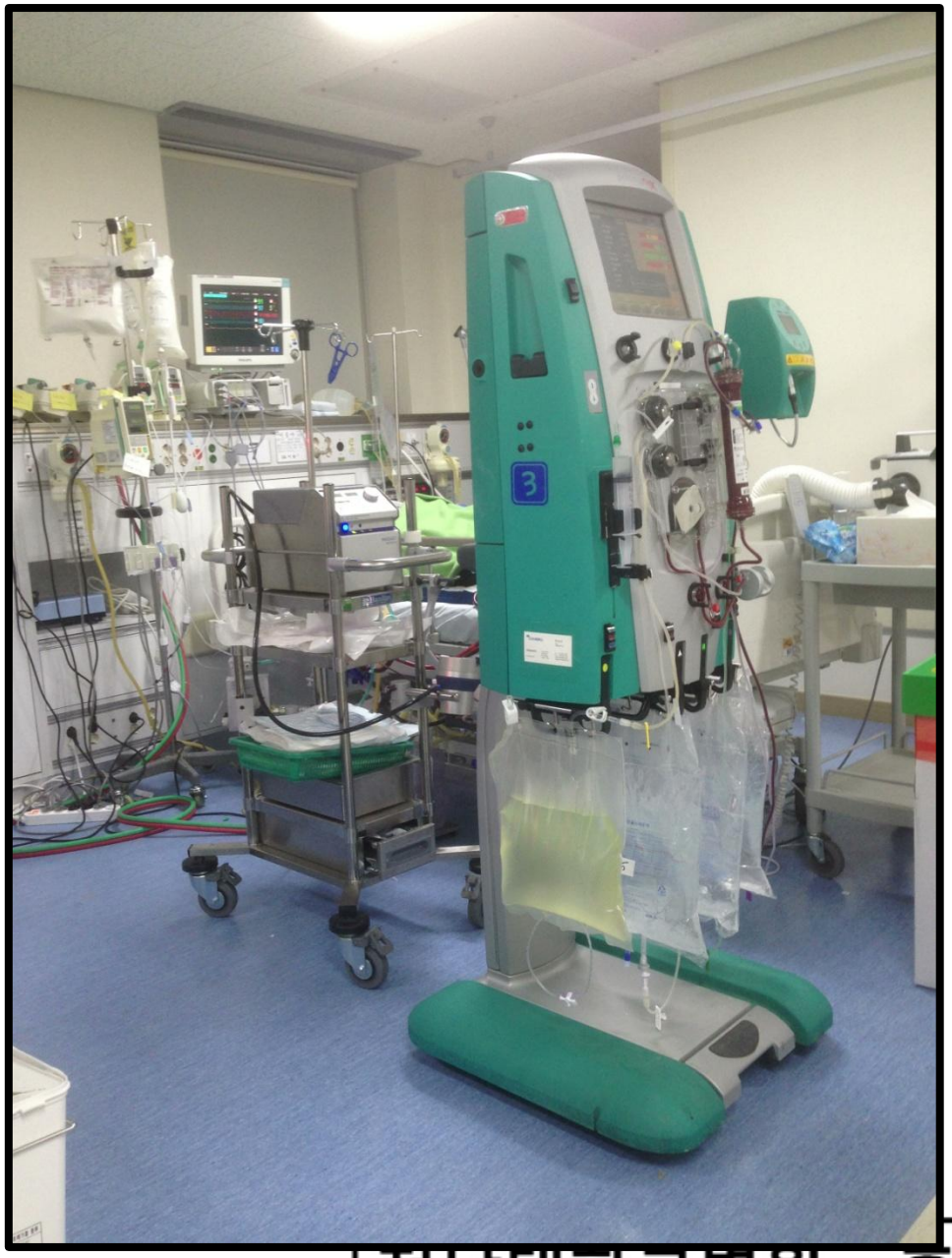

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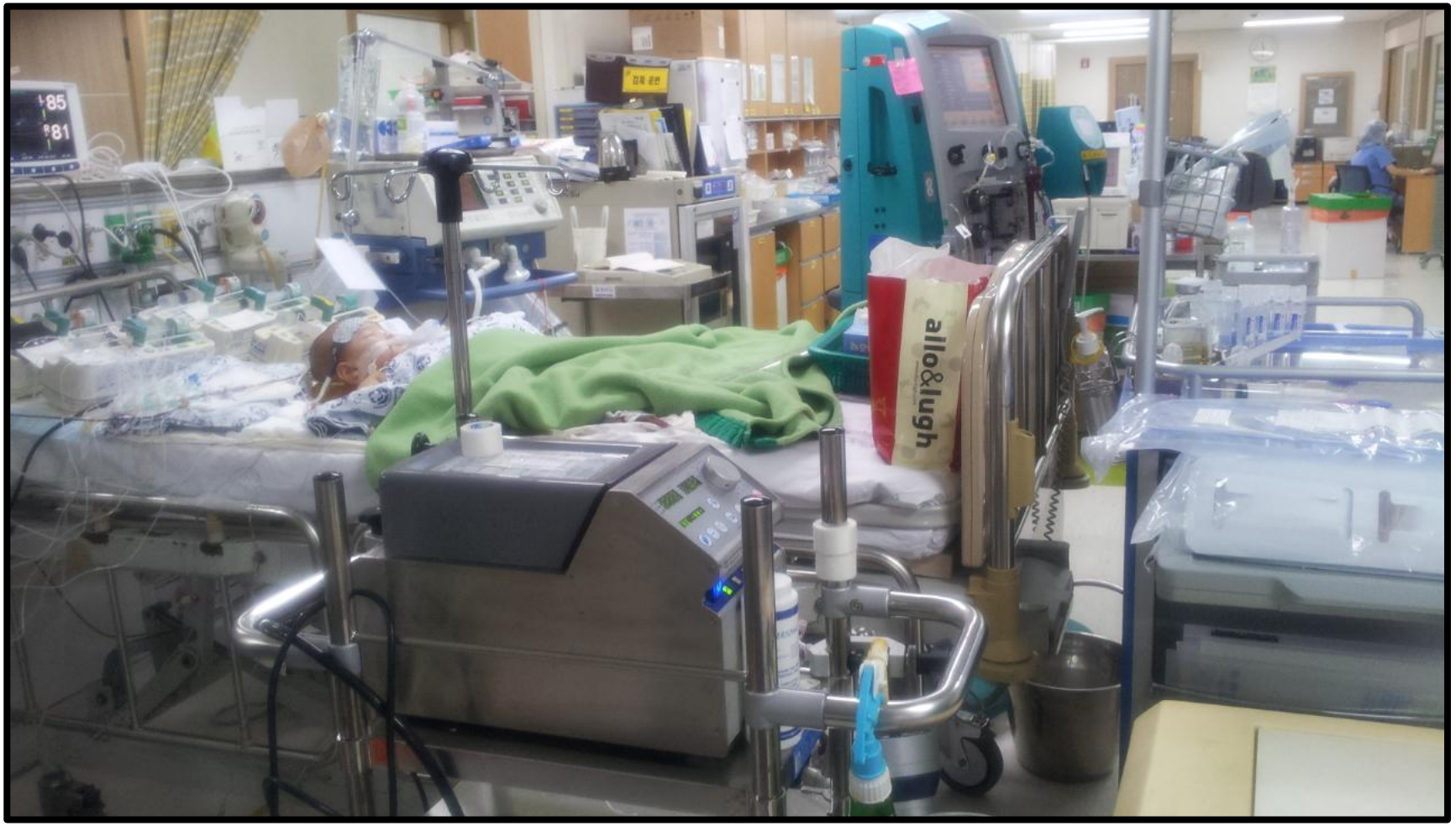

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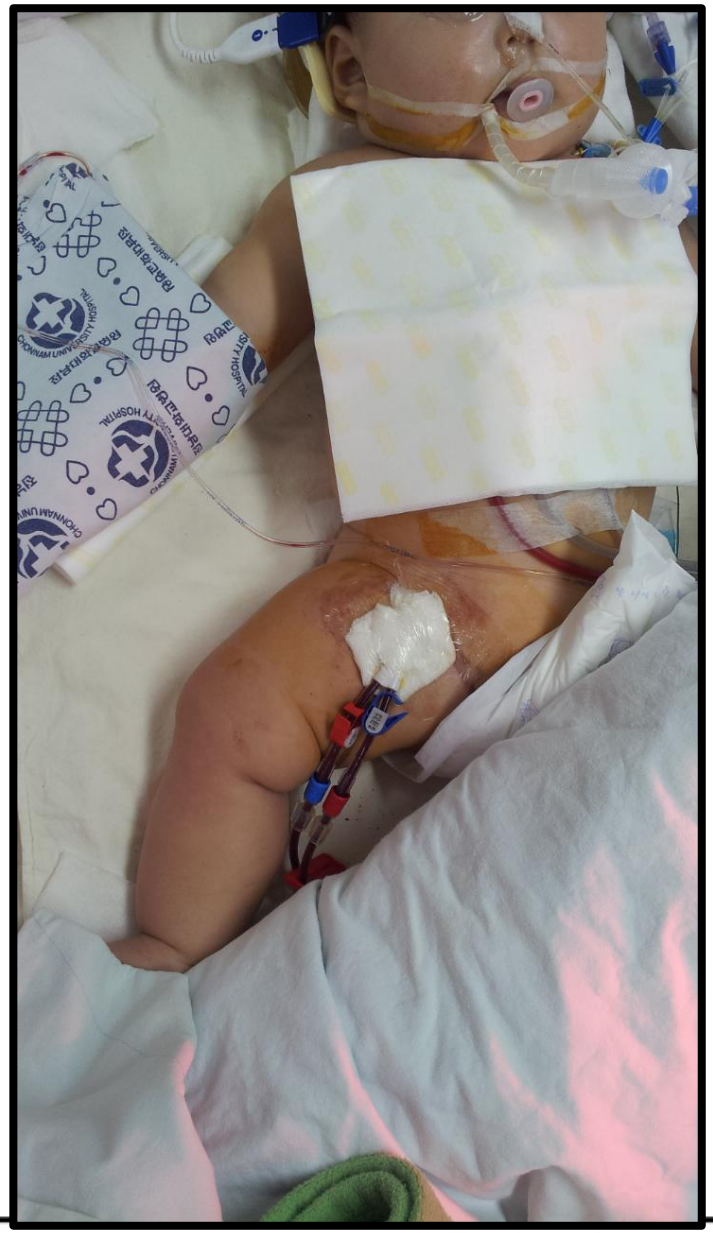

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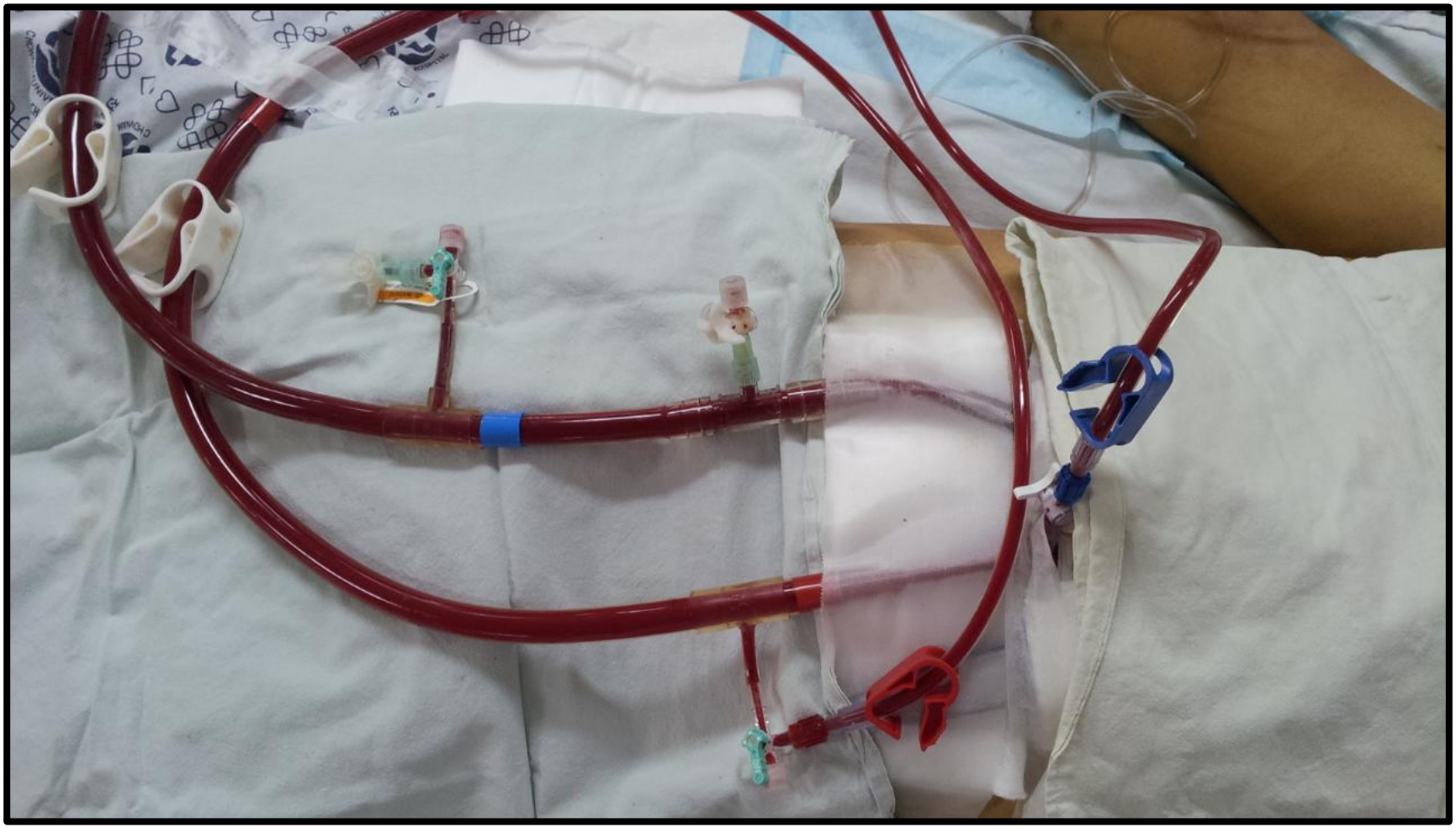

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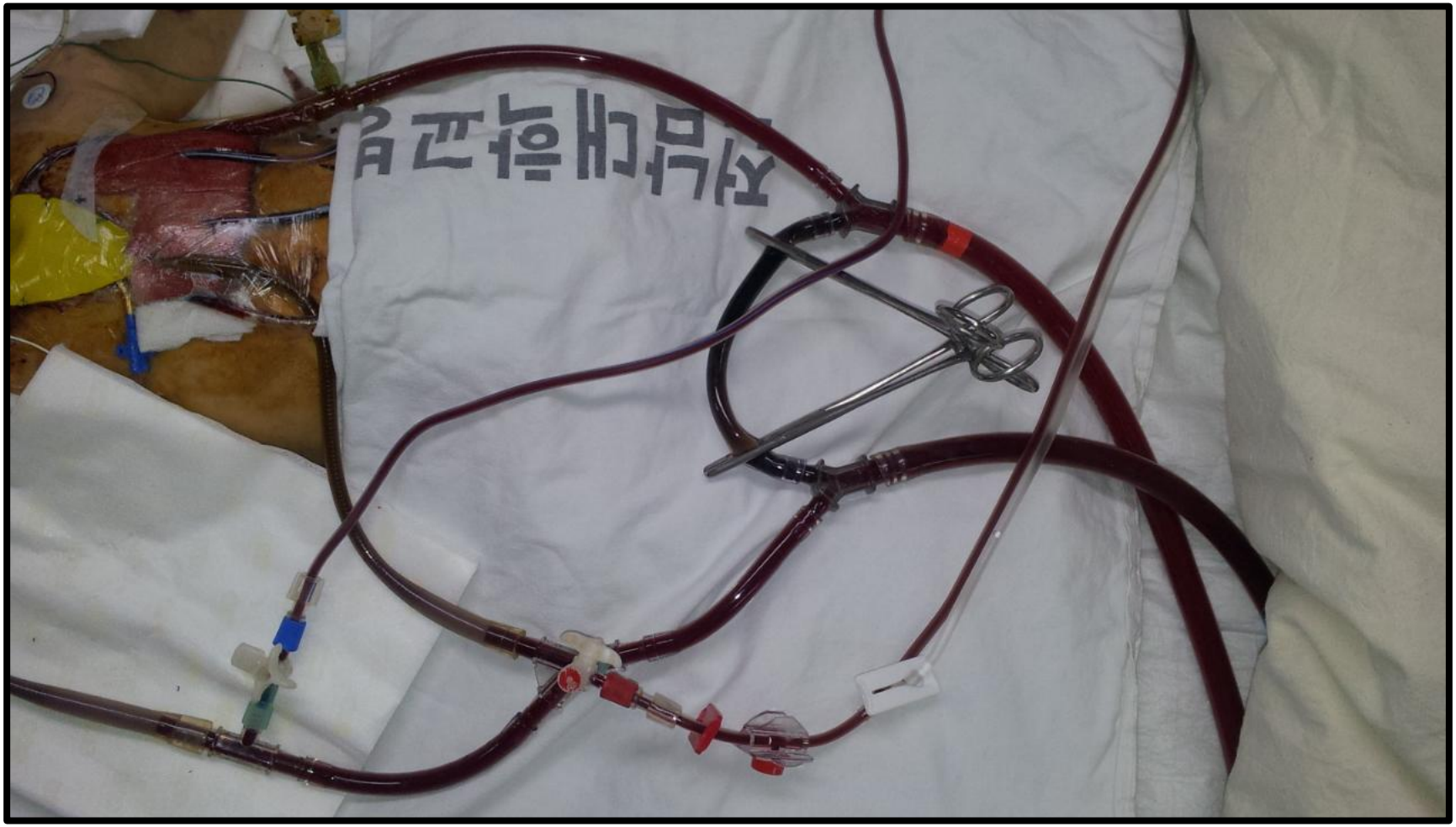

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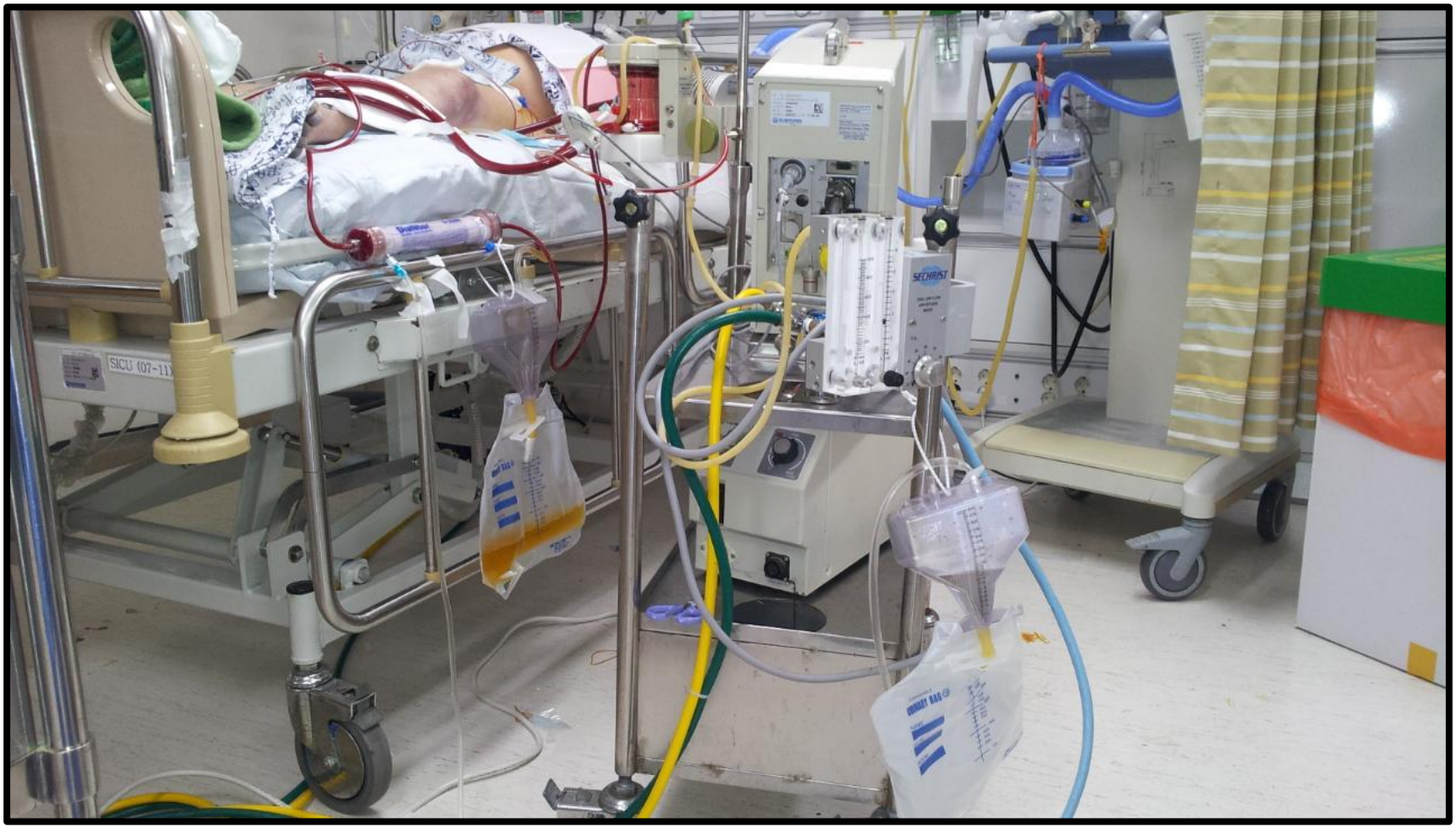

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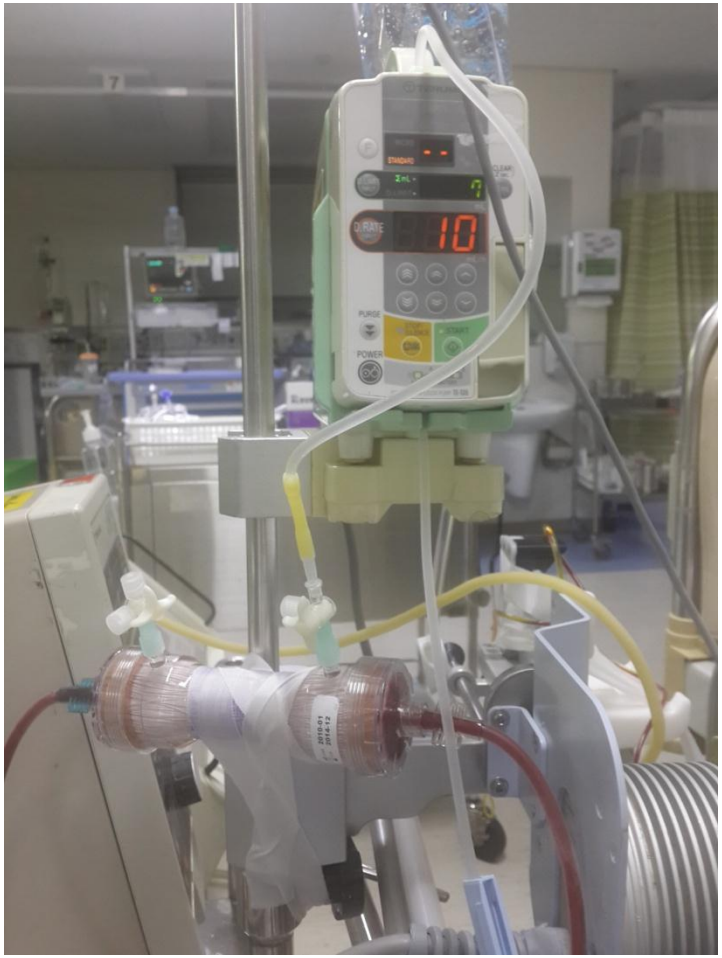

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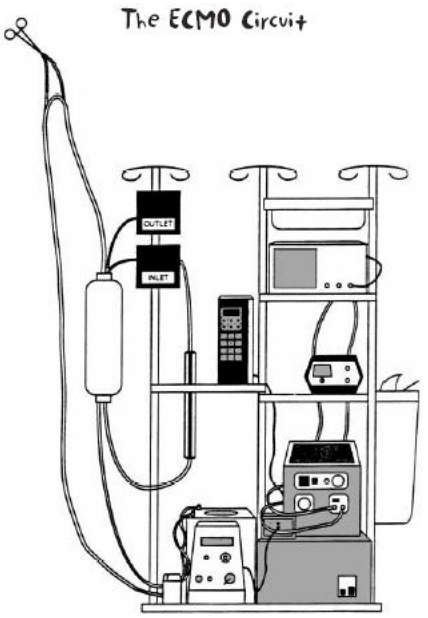
Neurologic comlication



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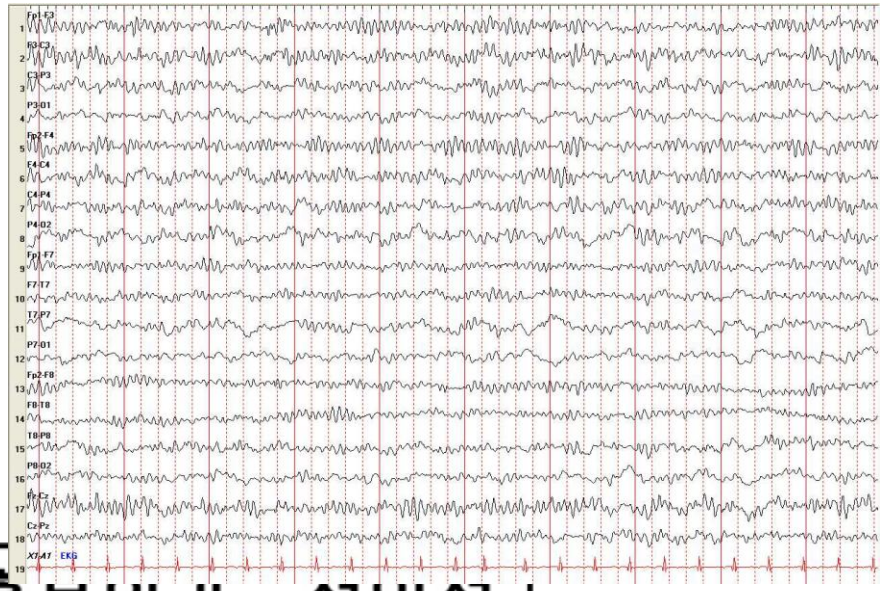
How about the EEG?

- Continuous bed-side monitoring
- Skill required for recording and interpreting
- Difficult long term recording (over 2-4 days)



Editorials

Brain Monitoring During Extracorporeal Membrane Oxygenation: Will it Alter Care?*

Kimberly Statler Bennett, MD, MPH
Division of Pediatric Critical Care
University of
Salt Lake Cit

ECMO patients may be much more common than reported or clinically suspected.

reported seizures are more common with VA than venovenous (VV) cannulation. Reported prevalences for seizures are 13% for VA and 6% for VV in neonates and 8.7% for VA and 4% for VV in children (7, 8). These studies also confirm that EEG monitoring is rare. Clinical seizures are reported in 8.4% of children but EEG-confirmed seizures are reported in only 2.1% (9).

The detection of seizures during ECMO is likely akin to ascertainment of cerebral infarction or hemorrhage. Rates reported in the ELSO registry are 3.8% for infarction and

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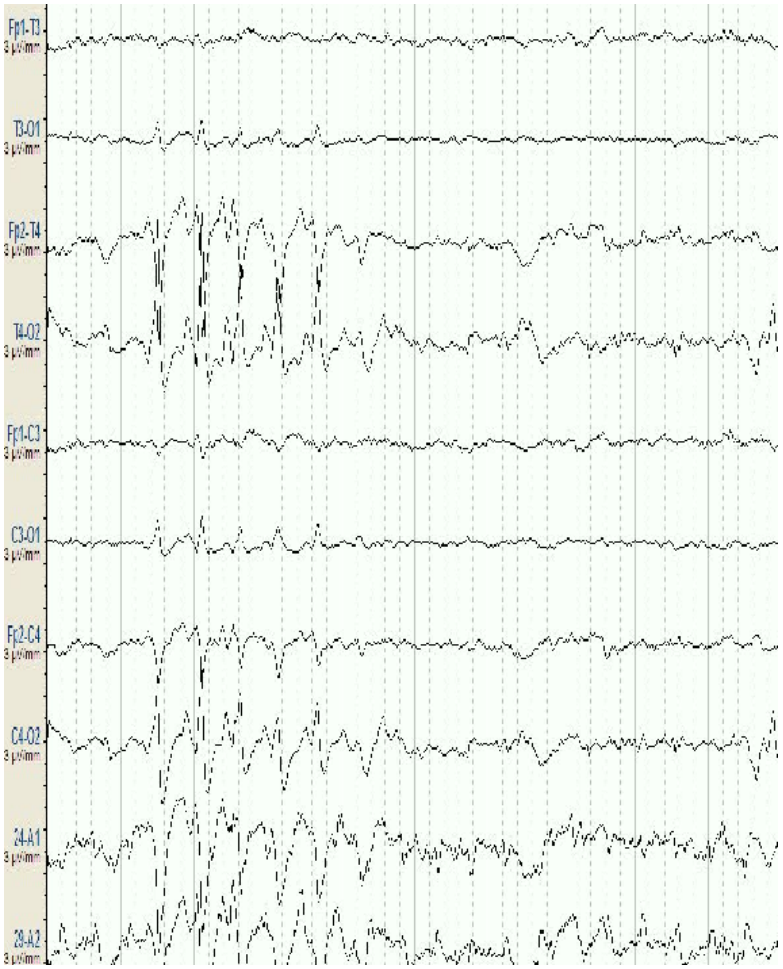
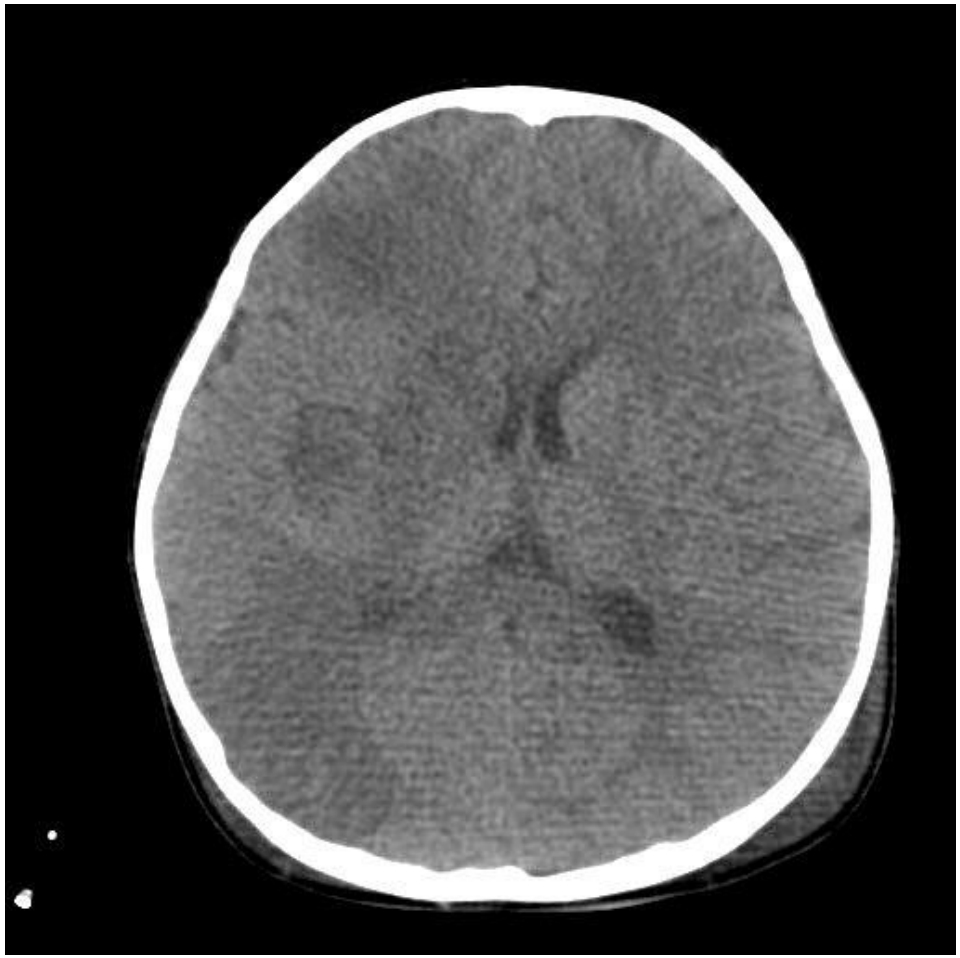
RCCM 2013;14:648

22m / Myocarditis





focal sharp activity in right occipital area

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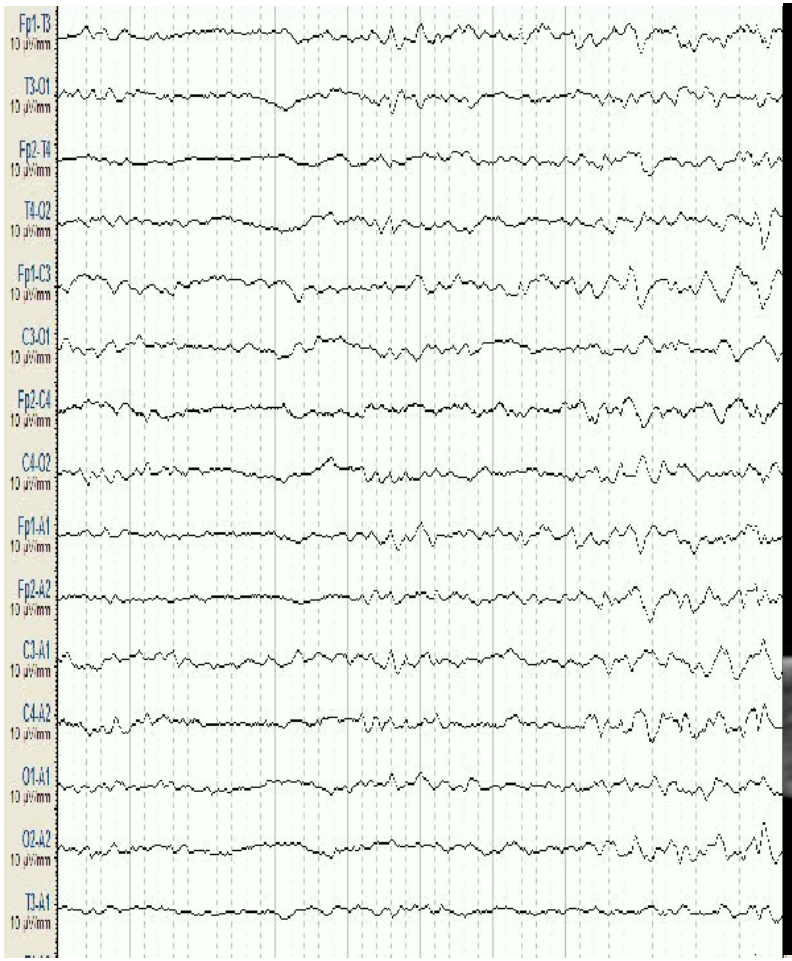
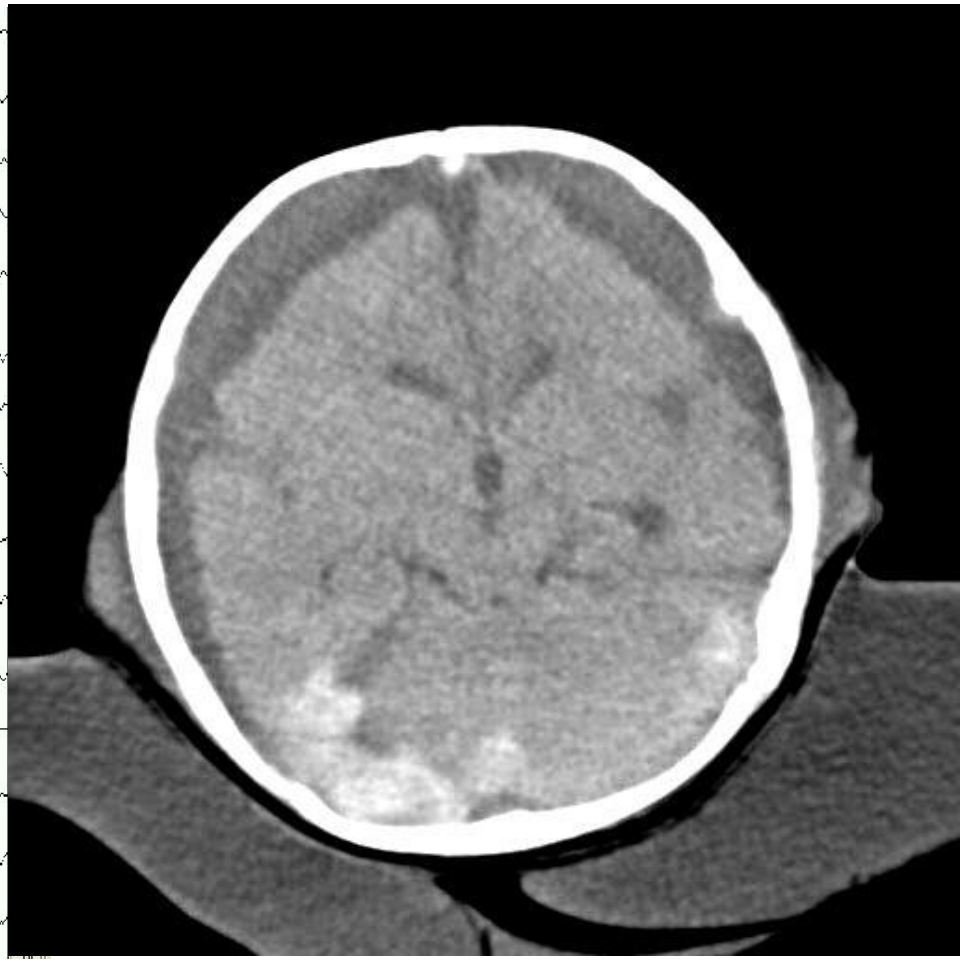
4m / post-OHS





diffuse irregular low amplitude activity

전남대학교병원 흉부외과 정인석

Korean J Crit Care Med
2014 May 29(2):?-? / http://dx.doi.org/10.4266/kjccm.2014.29.2.?
pISSN: 1229-4802 · eISSN: 2234-3261

■ Original Article ■

Efficacy of Electroencephalographic Monitoring for the Evaluation of Intracranial Injury during Extracorporeal Membrane Oxygenation Support in Neonates and Infants

In Seok Jeong, M.D., Young Jong Woo, M.D., Do Wan Kim, M.D., Nan Yeol Kim, M.D., Hwa Jin Cho, M.D., and Jae Sook Ma, M.D.

Department of Pediatrics, Chonnam National University Hospital, Chonnam National University Medical School, Gwangju, Korea

Background: Neurological complications are a serious concern during extracorporeal membrane oxygenation (ECMO) support in neonates and infants. However, evaluating brain injury during ECMO has limitations. Herein, we report our experience with bedside electroencephalographic monitoring during ECMO support and compared this to post-ECMO brain imaging studies and immediate neurologic outcomes.

Methods: We retrospectively reviewed the data for 18 children who underwent ECMO. From these subjects, we reviewed the medical records of 10 subjects who underwent bedside EEG monitoring during ECMO support. We collected data on patient demographics, clinical details of the ECMO course, electroencephalographic monitoring, brain imaging results, and neurologic outcomes.

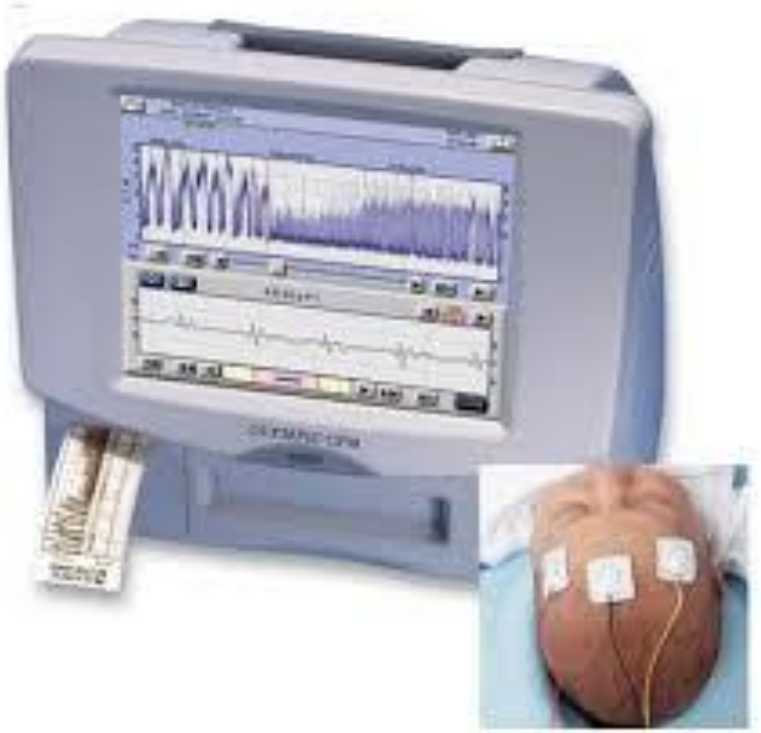
Results: The median age was 4 months (range: 7 days-22 months), the median weight was 5 (3.6-12) kg, and the median length of ECMO therapy was 86 (27-206) h. Eight patients (80%) were weaned successfully, and seven (70%) survived to discharge. Those with normal to mildly abnormal electroencephalographic findings had non-specific to mildly abnormal brain computed tomography findings and no neurologic impairment. Those patients with a moderately to severely abnormal electroencephalograph had markedly abnormal brain computed tomography findings and remained neurologically impaired.

Conclusions: Normal electroencephalographic findings are closely related to normal or mild neurologic impairment. Our results indicate that electroencephalographic monitoring during ECMO support can be a feasible tool for evaluating brain injury although further prospective studies are needed.

Key Words: brain imaging studies; electroencephalography; extracorporeal membrane oxygenation; infant; neonate.

Fundamentals of amplitude integrated EEG (aEEG)

- 1 or 2 channel electrodes
- special filtering and processing
- simple bedside monitoring of global or bilateral cerebral cortical activity



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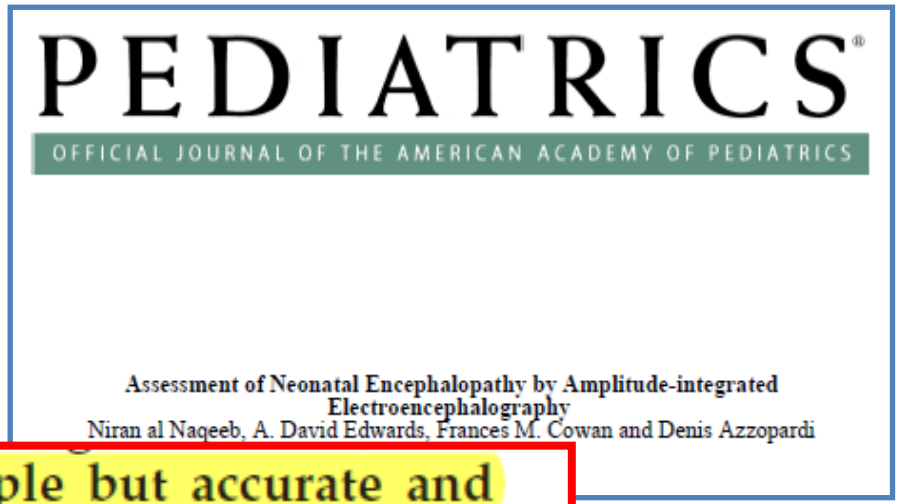
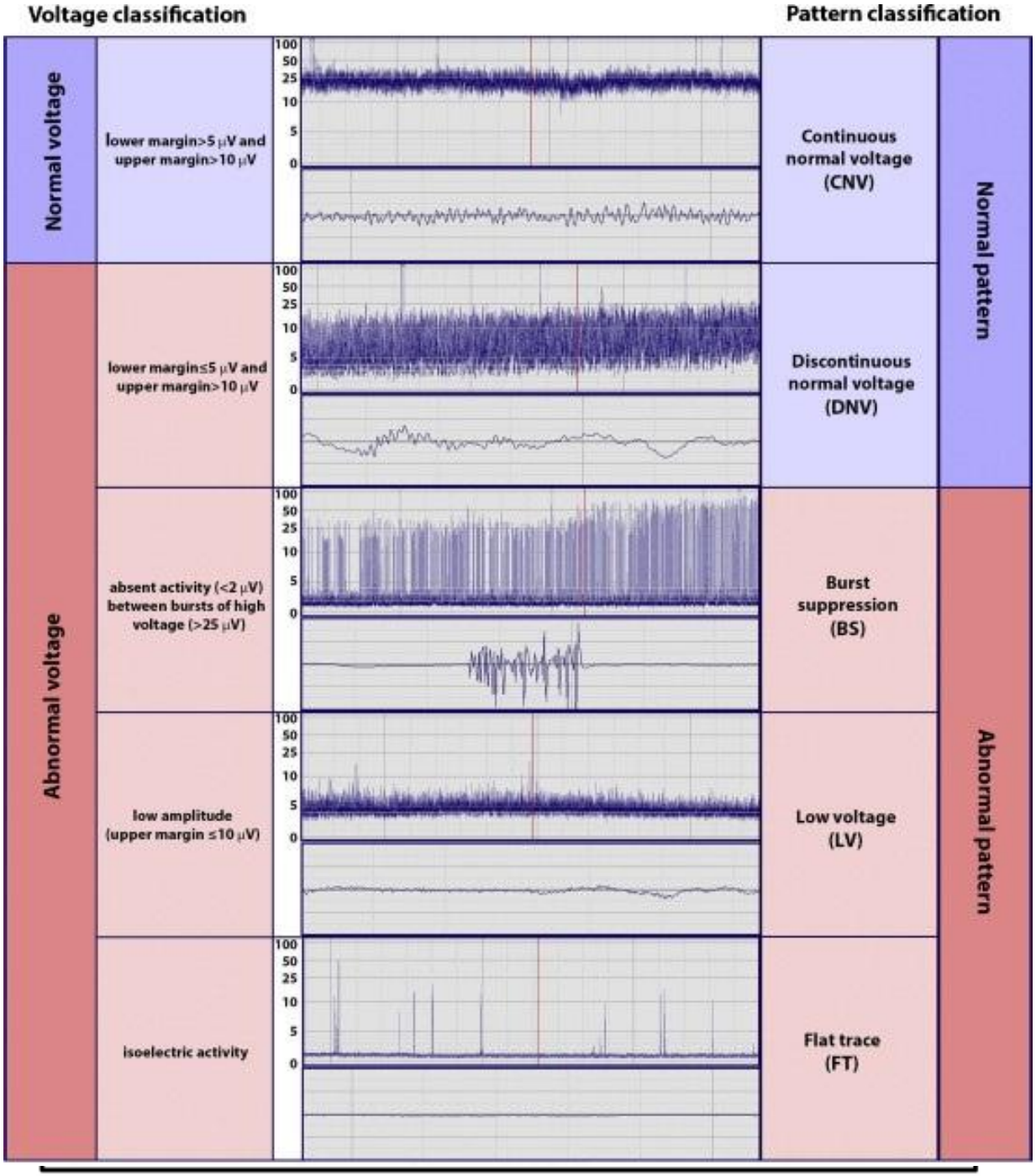
aEEG monitoring

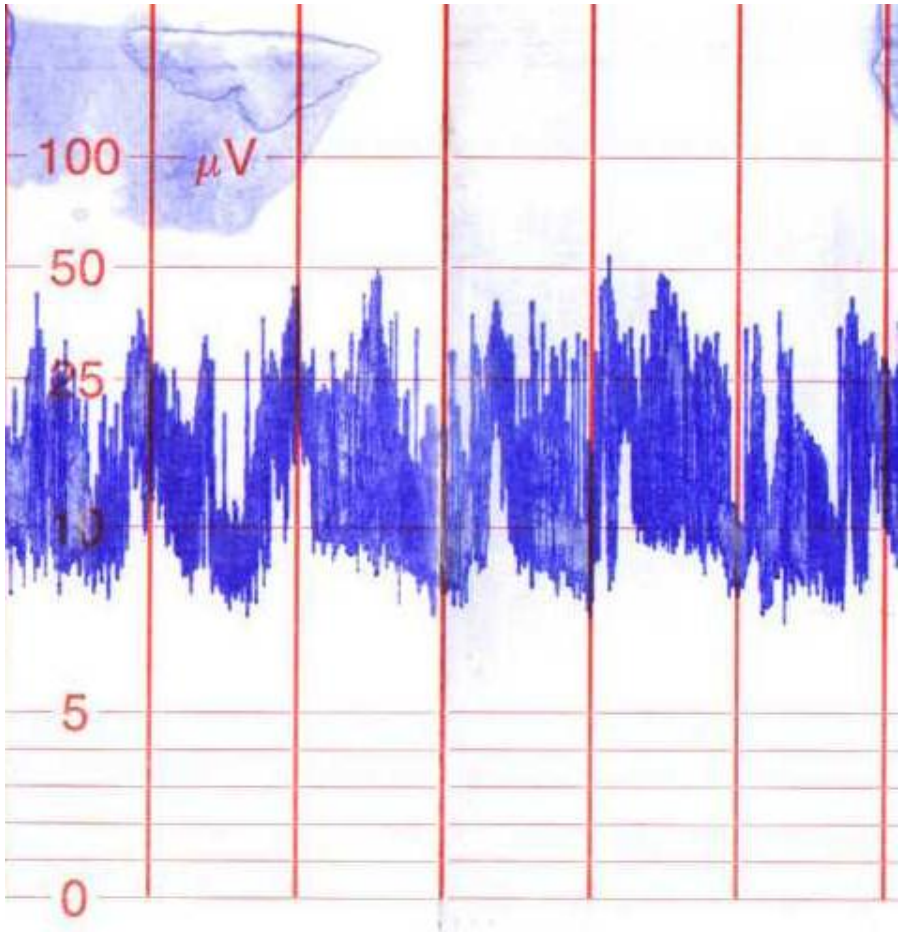
It is well known that the aEEG provides the useful information for neonatal encephalopathy.



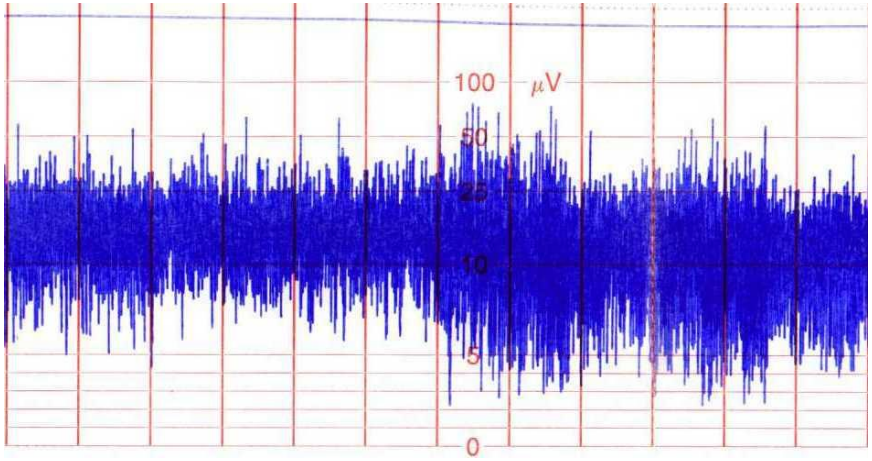
Conclusion. The aEEG is a simple but accurate and reproducible clinical tool that could be useful in the assessment of infants with encephalopathy. *Pediatrics* 1999;103:1263–1271; *cerebral function monitor, neonatal encephalopathy, outcome.*


Voltage classification
Pattern classification
Normal voltage
Abnormal voltage
lower margin>5 μV and upper margin>10 μV
lower margin≤5 μV and upper margin>10 μV
absent activity (<2 μV) between bursts of high voltage (>25 μV)
low amplitude (upper margin ≤10 μV)
isoelectric activity
100
50
25
10
5
0
Continuous normal voltage (CNV)
Discontinuous normal voltage (DNV)
Burst suppression (BS)
Low voltage (LV)
Flat trace (FT)
Normal pattern
Abnormal pattern

Seizure in aEEG



Normal finding



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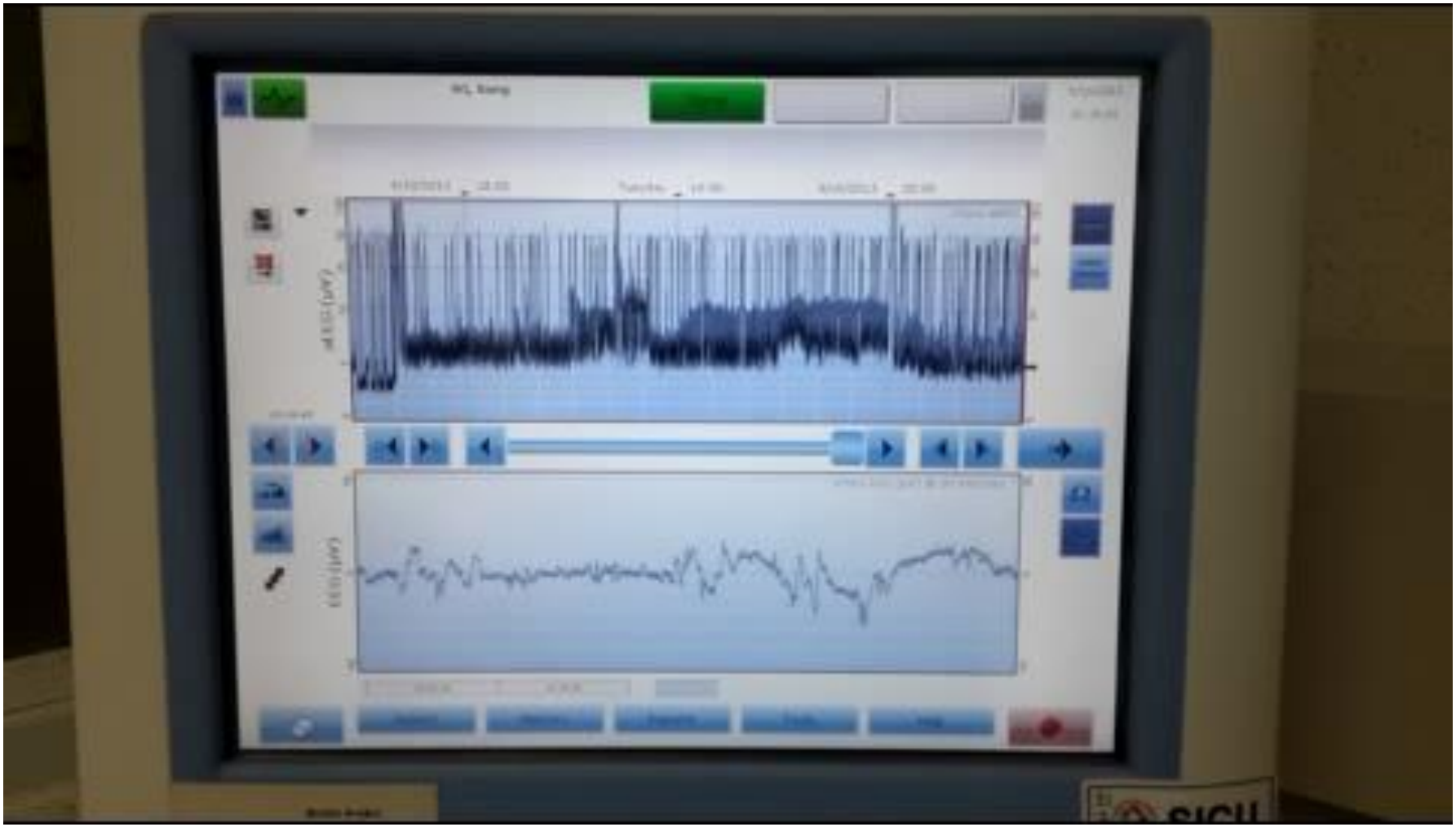

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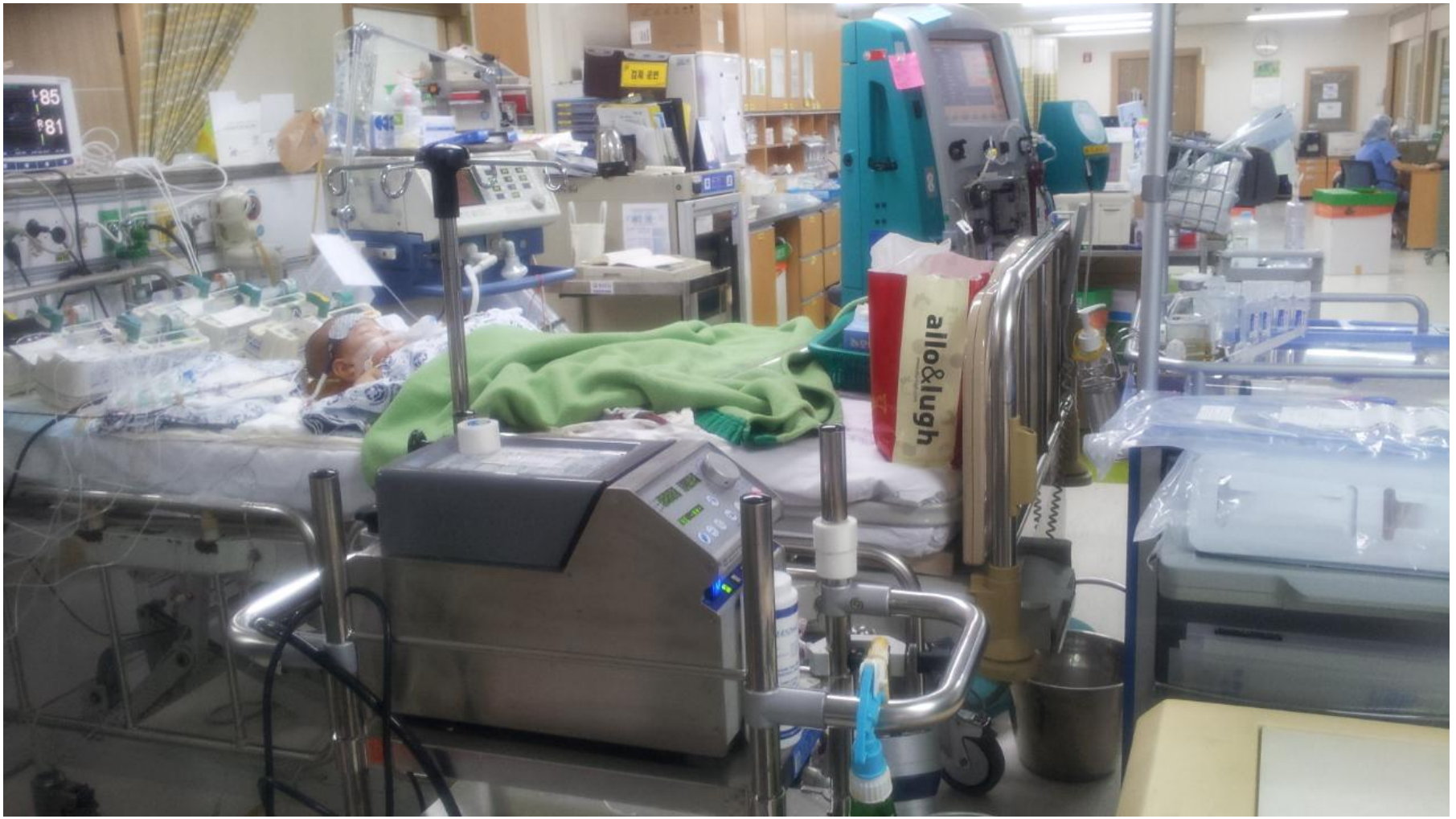

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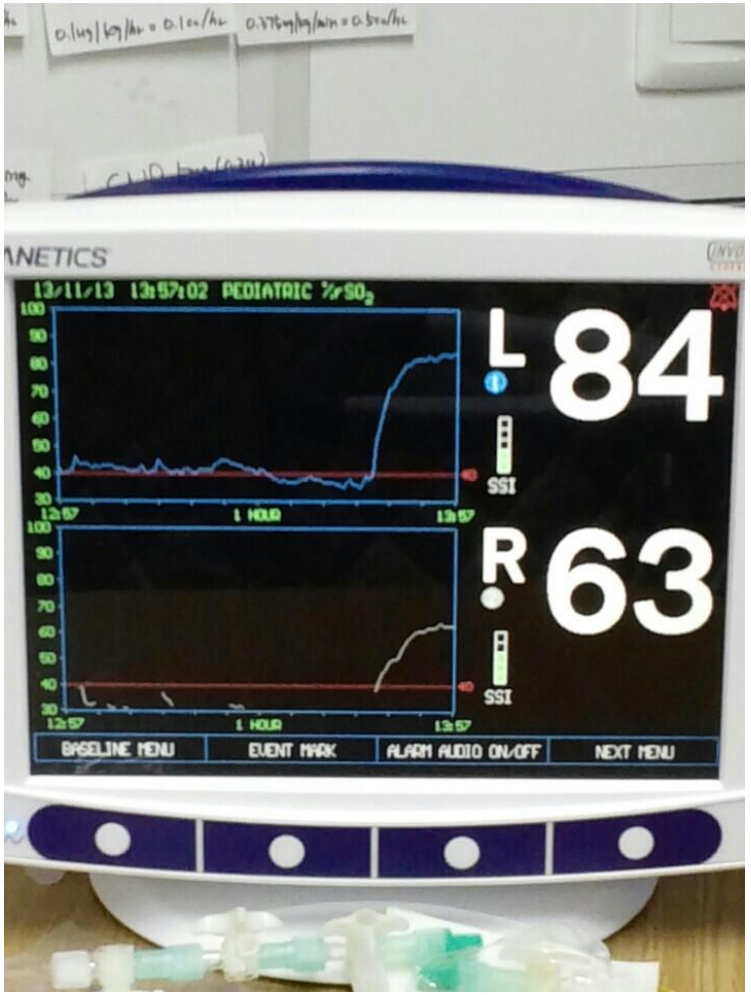

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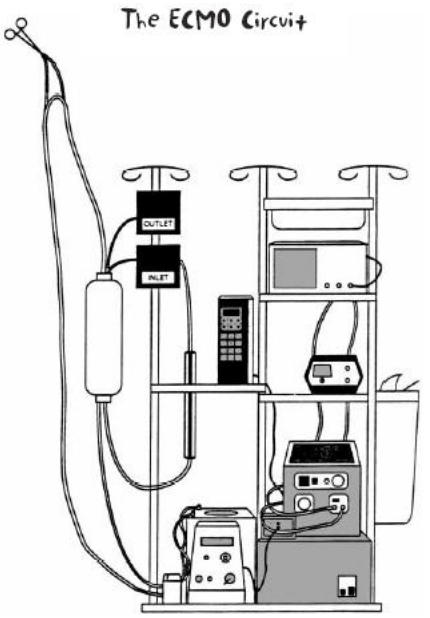
Conclusion



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