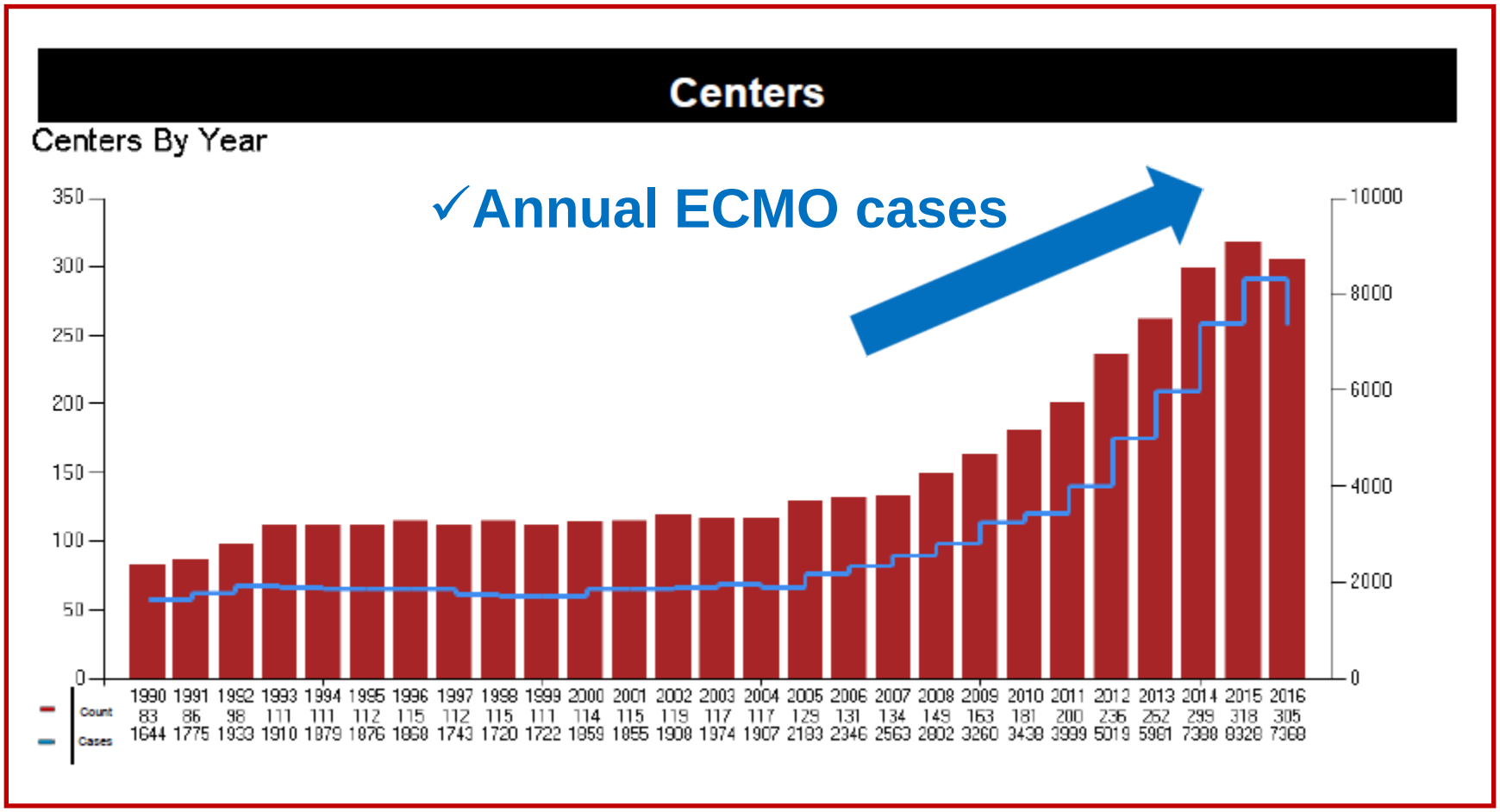
How to Manage Major Complications of ECMO

Chonnam National University Hospital

Department of Thoracic and Cardiovascular Surgery

Team Director, CNUH ECMO Team

In Seok Jeong. MD. PhD.



The extracorporeal membrane oxygenation(ECMO) has been used in various conditions from neonates to old ages.

ECLS Registry Report

International Summary

January, 2017

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

Overall Outcomes

	Total Runs	*Survived ECLS*		*Survived to DC or Transfer*	
Neonatal					
Pulmonary	29,942	25,205	84%	21,948	73%
Cardiac	7,169	4,643	64%	2,938	40%
ECPR	1,532	1,028	67%	627	40%
Pediatric					
Pulmonary	8,070	5,424	67%	4,632	57%
Cardiac	9,362	6,404	68%	4,758	50%
ECPR	3,399	1,958	57%	1,414	41%
Adult					
Pulmonary	12,346	8,242	66%	7,157	57%
Cardiac	10,982	6,251	56%	4,466	40%
ECPR	3,485	1,382	39%	993	28%

And the clinical results also improved.

However,
ECMO has still a high potential for complications.

Extracorporeal Life Support Organization

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Click here for details

ECLS Complications (Requiring Intervention)

Mechanical	Date/Time	Mechanical	Date/Time
Oxygenator failure		Raceway rupture	
Pump malfunction		Other tubing rupture	
Clots: bridge		Cracks: pigtail connectors	
Clots: other		Air in circuit	
Clots: hemofilter		Cannula problems	
Clots: bladder		Heat exch. Malfunction	
Clots: oxygenator			

Hemorrhage	Date/Time	Neurological	Date/Time
GI hemorrhage		Brain death clinically determined	
Cannulation site bleeding		Seizures clinically determined	
Surgical site bleeding		Seizures EEG determined	
Hemolysis (plasma hgb > 50 mg/dl)		CNS Infarction (US or CT)	
DIC		CNS Hemorrhage (US or CT)	
Renal	**Date/Time**	**Cardiovascular**	**Date/Time**
Creatinine 1.5-3.0 mg/dL		Inotropes on ECLS	
Creatinine > 3.0 mg/dL		CPR required	
Hemodialysis		Myocardial stun by echo	
Hemofiltration required		Cardiac arrhythmia	
CAVHD Required		Hypertension requiring vasodilator treatment	
Tamponade: Blood		PDA: R→L	
Tamponade: Serous		PDA: L→R	
Tamponade: Air		PDA: Bidirectional	
		PDA: Unknown	
Pulmonary	**Date/Time**	**Pulmonary**	**Date/Time**
Pneumothorax		Pulmonary hemorrhage	
Infectious	**Date/Time**	**Infectious**	**Date/Time**
Culture proven new infection (specify under infections)		WBC < 1,500	
Metabolic	**Date/Time**	**Metabolic**	**Date/Time**
Glucose < 40 mg/dL		Glucose > 240 mg/dL	
pH < 7.20		pH > 7.60	
Hyperbilirubinemia (> 2 mg/dL direct, > 13 mg/dL indirect, or > 15 mg/dL total)			
Limb	**Date/Time**	**Limb**	**Date/Time**
Ischemia		Compartment Syndrome	
Fasciotomy		Amputation	

Unique ID: ___

Birth Date: ___
(include time for n

Sex: _____

n)

ECLS Registry Form

Extracorporeal Life Support Organization (ELSO)

Unique ID: _____ Run No: _____

Birth Date: _____
(include time for neonates)

Sex: _____(M, F) Race: _____(Asian, Black, Hispanic, White, Other, Unknown)

Classification of Complications

1. Mechanical
2. Hemorrhagic
3. Neurologic
4. Renal
5. Pulmonary
6. Cardiac
7. Metabolic
8. Limb

Adult Cardiac Complications - 1 (Incidence / Survival)

(1) Mechanical

1. Oxygenator failure (6% / 36%)
2. Raceway rupture (0.1% / 33%)
3. Other tubing rupture (0.1% / 31%)
4. Pump malfunction (0.7% / 31%)
5. Heat exchanger malfunction (0.1% / 63%)
6. Clots
   - oxygenator (8.2% / 40%)
   - bridge (0.5% / 54%)
   - bladder (0.2% / 47%)
   - hemofilter (1.1% / 24%)
   - other (5.6% / 41%)
7. Air in circuit (1.1% / 31%)
8. Cracks in pigtail connectors (0.3% / 24%)
9. Cannula problems (3.9% / 35%)

Adult Cardiac Complications - 2 (Incidence / Survival)

(2) Hemorrhagic

1. GI hemorrhage (4.4% / 25%)
2. Cannulation site bleeding (17.5% / 39%)
3. Surgical site bleeding (19.2% / 33%)
4. Hemolysis (hgb > 50 mg/dl) (5.5% / 31%)
5. Disseminated intravascular coagulation (DIC) (3.5% / 19%)

(3) Neurologic

1. Brain death clinically determined (3.8% / 0%)
2. Seizures: clinically determined (1.4% / 26%)
3. Seizures: EEG determined (0.6% / 22%)
4. CNS infarction by US/CT (3.8% / 23%)
5. CNS hemorrhage by US/CT (2.1% / 10%)

Adult Cardiac Complications - 3 (Incidence / Survival)

(4) Renal

1. Creatinine 1.5 - 3.0 (21.3% / 35%)
2. Creatinine > 3.0 (11.9% / 29%)
3. Dialysis required (9.9% / 26%)
4. Hemofiltration required (12.3% / 30%)
5. CVVHD required (13.9% / 29%)

(5) Pulmonary

1. Pneumothorax requiring treatment (1.6% / 33%)
2. Pulmonary: Pulmonary hemorrhage (2.8% / 23%)
3. Infectious: Culture proven infection (12.8% / 36%)
4. Infectious: WBC < 1,500 (1.4% / 30%)

Adult Cardiac Complications - 4 (Incidence / Survival)

(6) Metabolic

1. Glucose < 40 (2% / 5%)
2. Glucose > 240 (12.8% / 40%)
3. pH < 7.20 (9.8% / 19%)
4. pH > 7.60 (4% / 45%)
5. Hyperbilirubinemia (> 2 direct or > 15 total) (12% / 27%)

(7) Limb

1. Ischemia (3.6% / 28%)
2. Compartment Syndrome (1% / 30%)
3. Fasciotomy (1.5% / 28%)
4. Amputation (0.5% / 58%)

Adult Cardiac Complications - 5 (Incidence / Survival)

(8) Cardiovascular

1. Inotropes on ECLS (52.3% / 37%)
2. CPR required (3.8% / 16%)
3. Myocardial stun by echo (5.8% / 32%)
4. Cardiac arrhythmia (15.9% / 33%)
5. Hypertension requiring vasodilators (4% / 51%)
6. PDA: R->L (0% / 0%)
7. PDA: L->R (0% / 33%)
8. PDA: unknown 2 (0% / 0%)
9. Tamponade: blood (5% / 32%)
10. Tamponade: serous (0.3% / 34%)
11. Tamponade: air (0% / 0%)

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:
cardiopulmonary resuscitation; bridge-to-decision

BACKGROUND: Mortality for refractory cardiogenic shock (RCS) remains high. However, with

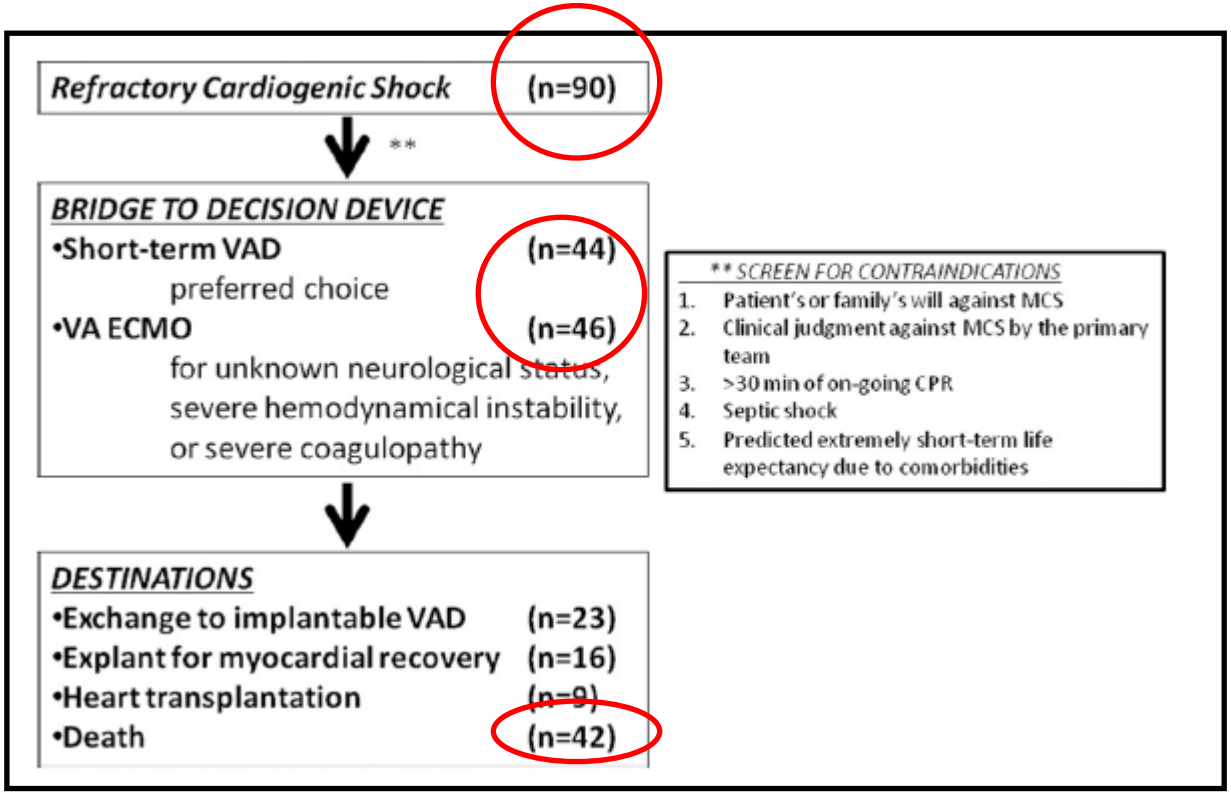
RESULTS: From January 2007 through January 2012, 90 patients received an MCSD for RCS, 21 (23%) of whom had active cardiopulmonary resuscitation (CPR). The etiology of RCS included acute myocardial infarction in 49% and acute decompensated heart failure in 27%. Mean age was 53 ± 14 years, 71% were male, and 60% had an intra-aortic balloon pump. The initial approach utilized was short-term VAD in 49% and VA ECMO in 51%. Median length of support was 8 days (IQR 4 to 18 days). Exchange to implantable VAD was performed in 26% of patients. Other destinations included myocardial recovery in 18% and heart transplantation in 11%. Survival to hospital discharge was 49%. Multivariate analysis showed ongoing CPR to be an independent risk factor for mortality (OR = 5.79, 95% CI 1.285 to 26.08, $p = 0.022$).

CONCLUSIONS: In the current era, roughly half of the patients who need an MCSD for RCS survive, and roughly half of these survivors require an implantable VAD. Ongoing CPR is predictive of in-hospital mortality.

J Heart Lung Transplant 2013;32:106–111

Key Study (1)
: Cause of Death in VA-ECMO/VAD d/t Cardiogenic shock

Takayama H. et al, JHLT. 2013 (NY CUMC)



Causes of Death

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.

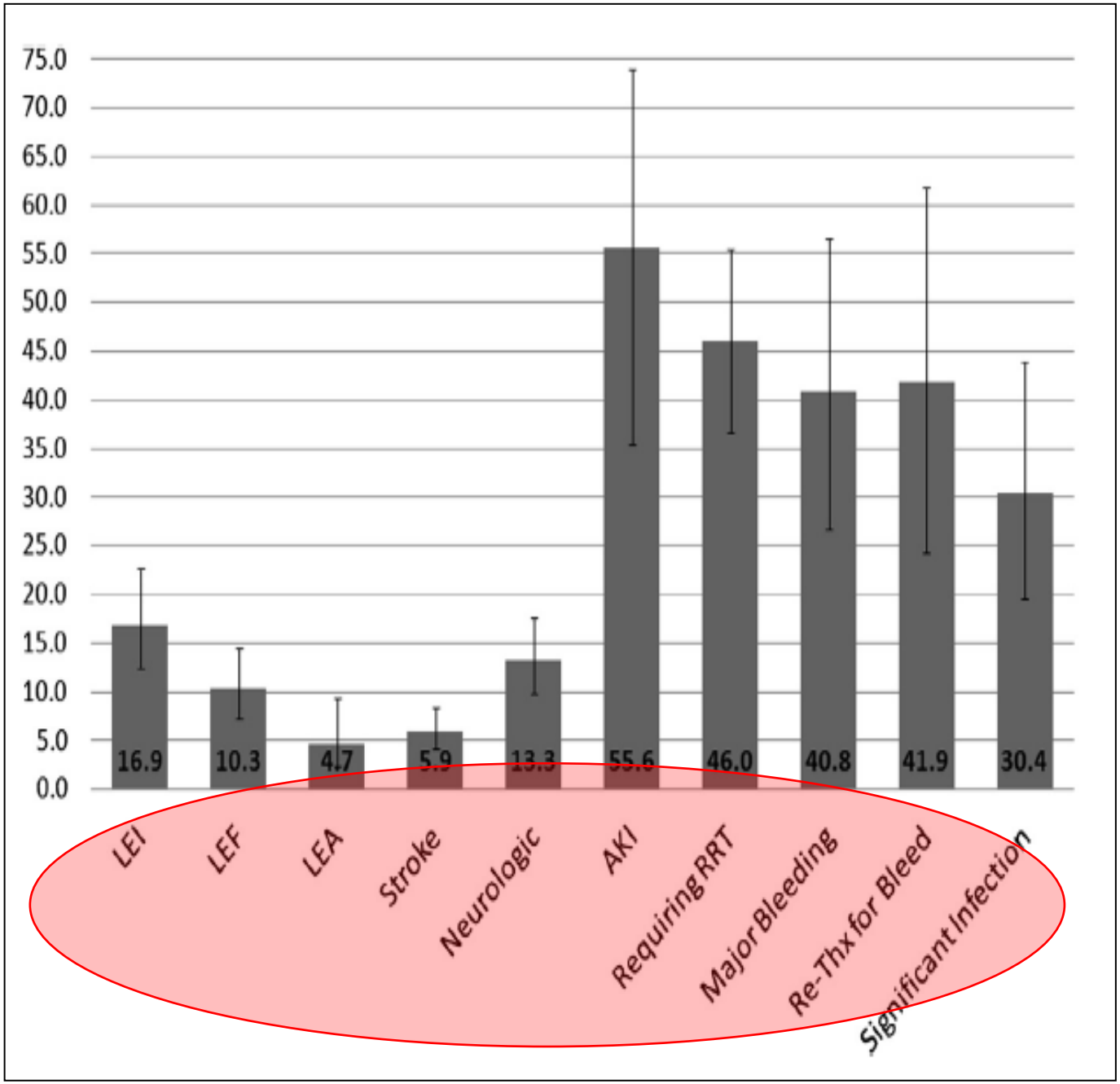
Complications of Extracorporeal Membrane Oxygenation for Treatment of Cardiogenic Shock and Cardiac Arrest: A Meta-Analysis of 1,866 Adult Patients

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

Key Study (2)
: Complications of VA-ECMO d/t Cardiogenic shock / arrest

Cheng R, et al. ATS 2014. 97, 610-6


75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
16.9
10.3
4.7
5.9
13.3
55.6
46.0
40.8
41.9
30.4
LEI
LEF
LEA
Stroke
Neurologic
AKI
Requiring RRT
Major Bleeding
Re-Thx for Bleed
Significant Infection

Major Complications and Causes of death by VA-ECMO

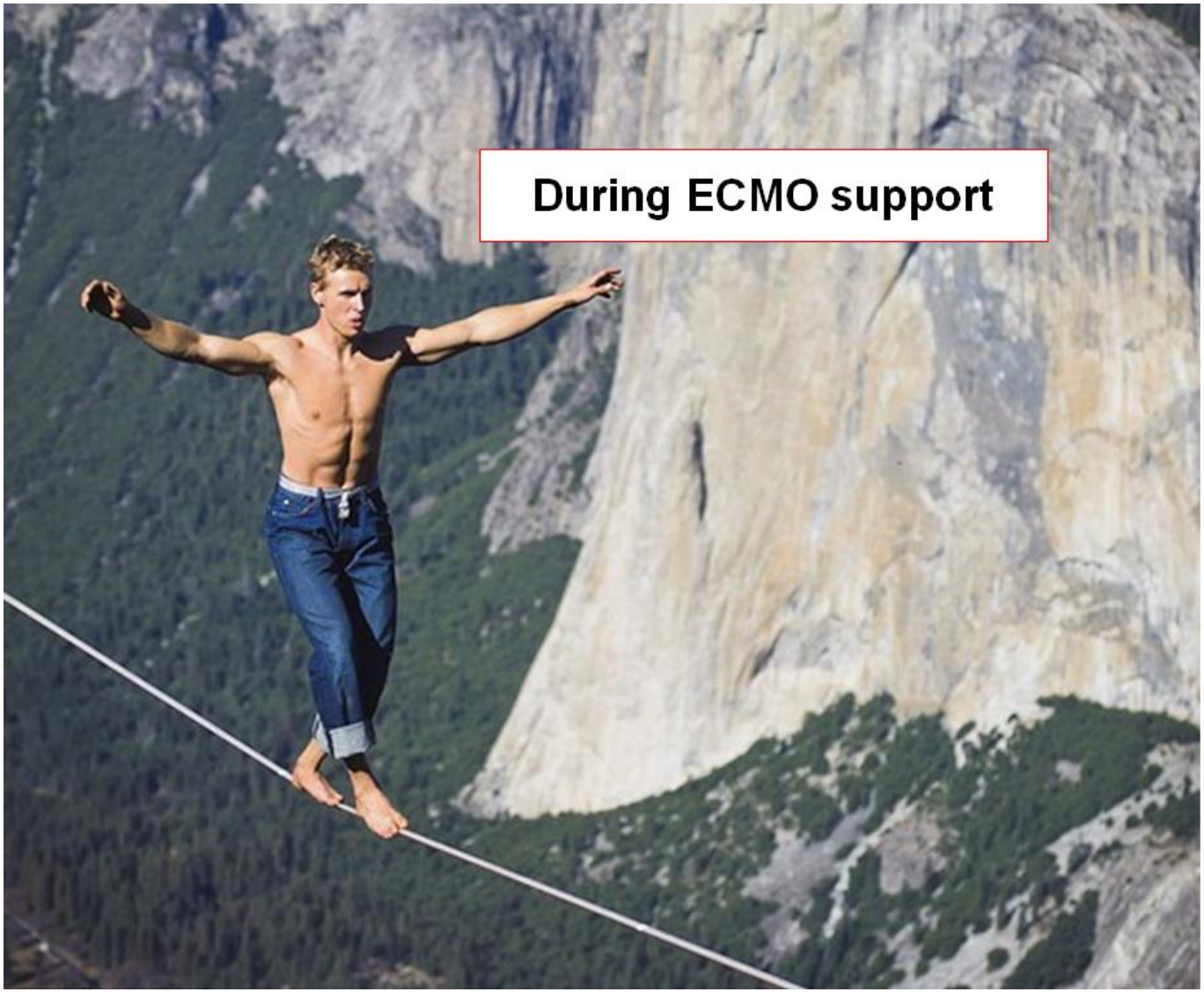
1. Bleeding and Thrombosis
2. ~~Brain Injury~~
3. Infection and Sepsis

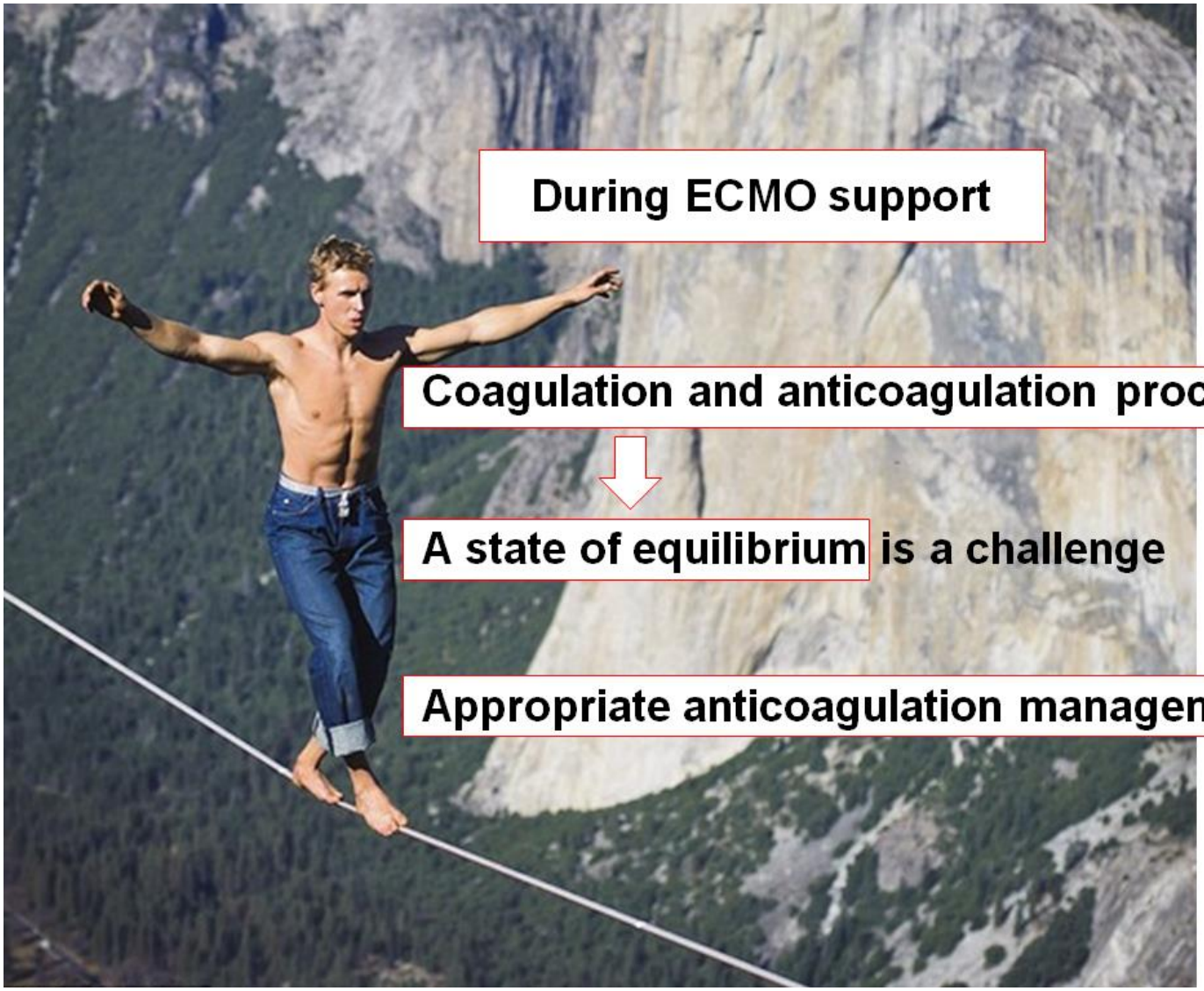
4. Limb Ischemia

Today's Topics

1. Bleeding and Thrombosis
2. Infection and Sepsis
3. Limb Ischemia

1. Bleeding and Thrombosis


During ECMO support



During ECMO support

Coagulation and anticoagulation process are activated

A state of equilibrium is a challenge

Appropriate anticoagulation management is essential

Anticoagulation Management

- Monitoring of anticoagulation
  - Target range
    - ACT (activated clotting time): 160 ~ 180 s
    - aPTT (activated partial thromboplastin time): 60 ~ 80 s
    - Anti-Xa assay: 0.3 ~ 0.7 U/mL
- Replacement of Antithrombin III
- Transfusion (FFP, PC, Cryoprecipitate. etc.)
- Meticulous Surgical Repair

Anticoagulation Management

- Monitoring of anticoagulation
  - Target range
    - ACT (activated clotting time): 160 ~ 180 s

Very High or Very Low aPTT / ACT

A slowly decrease or increase

To avoid a so-called **yo-yo effect**

Prevent big swings in coagulation levels

    - Anti-Xa assay: 0.3 ~ 0.7 U/mL
      - Confirm the reliability of the aPTT valve
      - Once a day

Bleeding Control in Various Sites

- Cannulation site
- Operative site
- GI tract
- Nose, mouth, respiratory tract

Bleeding Control in Various Sites

- Cannulation exit site
  - Purse-string suture, but can cause needle puncture bleeding
- Operative site (ex, in the case of thoracotomy)
  - bronchoscopy, gauze packing, flushes of saline mixed with 1% adrenaline

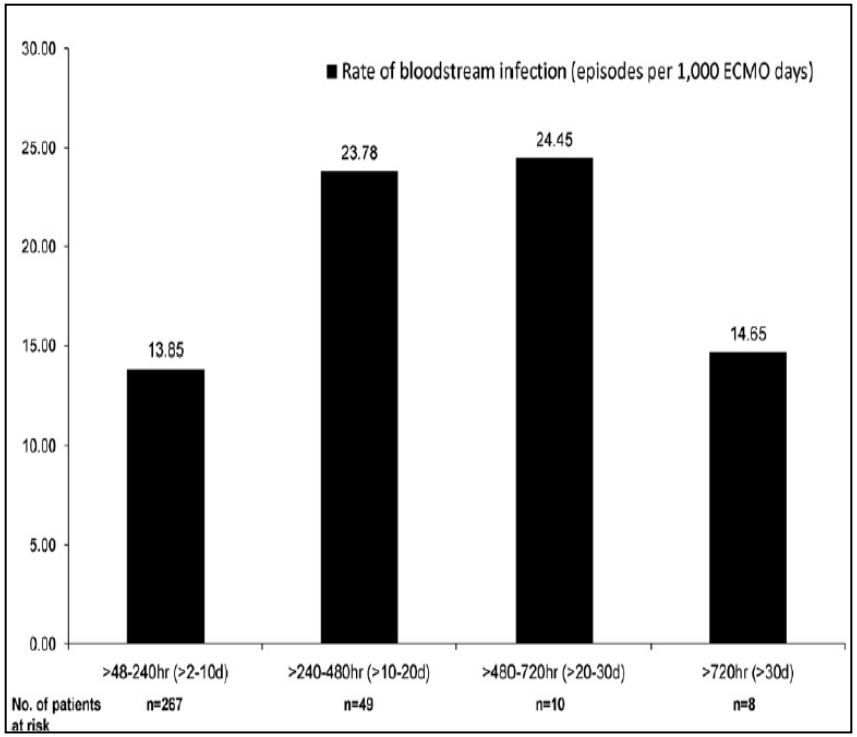
Appropriate anticoagulation management is essential in CASE-BY-CASE

2. Nosocomial Infection

ECMO itself is a Risk Factor of Infection.

Infections occurring during extracorporeal membrane oxygenation use in adult patients

Hsin-Yun Sun, MD,[a] Wen-Je Ko, MD,[b] Pi-Ru Tsai, RN,[b] Chun-Chuan Sun, RN,[c] Yin-Yin Chang, RN,[c] Ching-Wen Lee, MS,[d] and Yee-Chun Chen, MD, PhD[a,c]



2010 JTCS 2010;140:1125-32

ORIGINAL ARTICLE
Infectious Diseases, Microbiology & Parasitology

JKMS

https://doi.org/10.3346/jkms.2017.32.4.593 • J Korean Med Sci 2017; 32: 593-598

Nosocomial Infection in Adult Patients Undergoing Veno-Arterial Extracorporeal Membrane Oxygenation

Gwan Sic Kim,[1]* Kyo Seon Lee,[1]*
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Gwangju, Korea; [2]Dep
Cardiovascular Surger
of Medicine, Asan Me

*Gwan Sic Kim and Ky
equally to this work.

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E-mail: bhahn@chonnam.ac.kr

Data on the frequency of nosocomial infections during extracorporeal membrane
the risk factors
(VA-ECMO)
nderwent ECMO.
or less than 48
hock were
ents were female.
was 8.6 ± 2.2.
ccessful ECMO
There were 18
tract infections in
, independent
el (hazard ratio
the duration of
preoperative
rs for infection.
Therefore, to avoid the development of nosocomial infections, strategies to shorten the length of ECMO support should be applied whenever possible.

Keywords: Extracorporeal Membrane Oxygenation Support; Infection

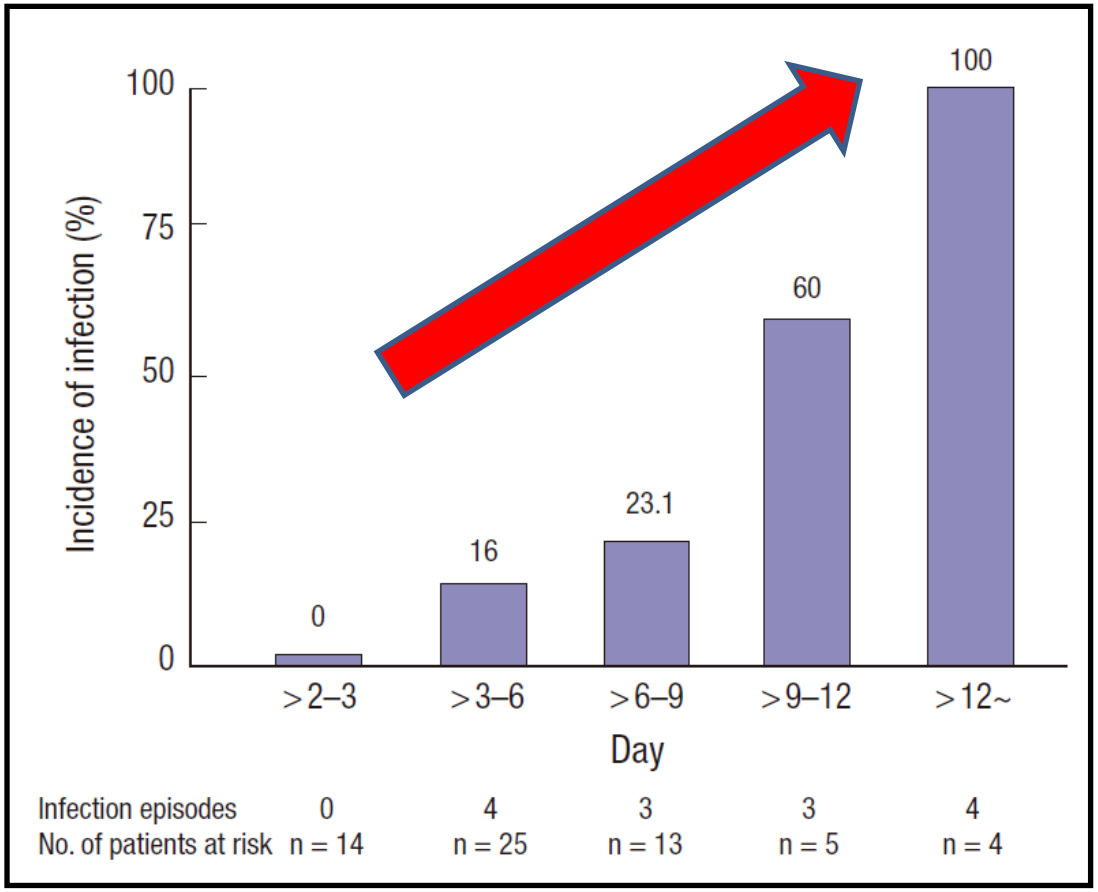
2011-2015
VA-ECMO d/t cardiogenic shock
61pts (mean age: 60.6±14.3 years)

Mean duration: 6.8±7.4 days
Weaning/Survival: 44.3% / 31.1%

Nosocomial Infection: 23%
Risk factors: ECMO duration (Odds Ratio: 1.40)

2017 JKMS (CNUH)

The INCIDENCE of nosocomial infection according to the duration of ECMO.



Strategies to Manage Infection

- Minimize ECMO exposure and associated environment
- Basic infection control
- Immune-modulation therapy

Strategies to Manage Infection

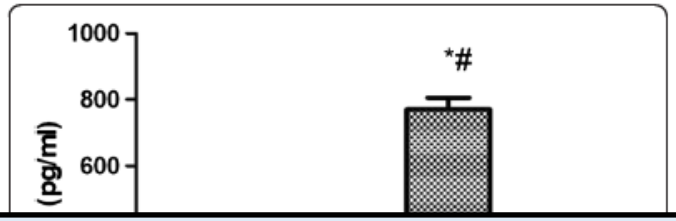
- Minimize ECMO exposure and associated environment
  - Adequate control of underlying disease
  - Prevent VILI / VAP
- Basic infection control
  - Basic guideline of systemic infection
    : Removal of unnecessary catheter
  - Culture based appropriate antibiotics
  - No consensus of frequent culture and prophylatic antiobiotics, yet!
- Immune-modulation therapy
  - CVVHD, Hemoperfusion with other hemofilter

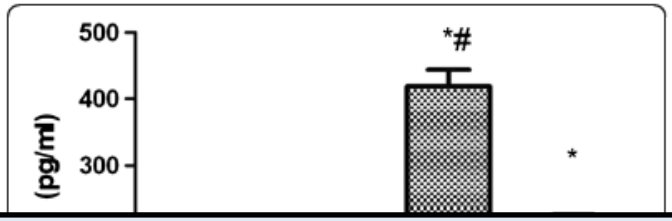
Yimin *et al. Journal of Cardiothoracic Surgery* 2013, **8**:113
http://www.cardiothoracicsurgery.org/content/8/1/113

JCTS JOURNAL OF CARDIOTHORACIC SURGERY

RESEARCH ARTICLE Open Access

Effects of continuous renal replacement therapy on r extr porc





ECMO combined with CRRT treatment

- alleviate levels of inflammatory cytokines
- maintain immune homeostasis balance

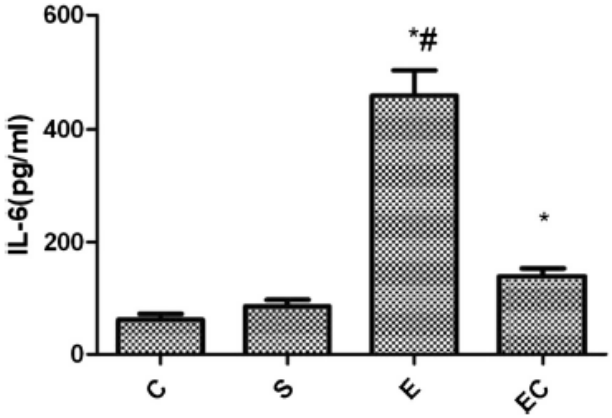


Figure 2 Renal IL-6 expression in all groups.

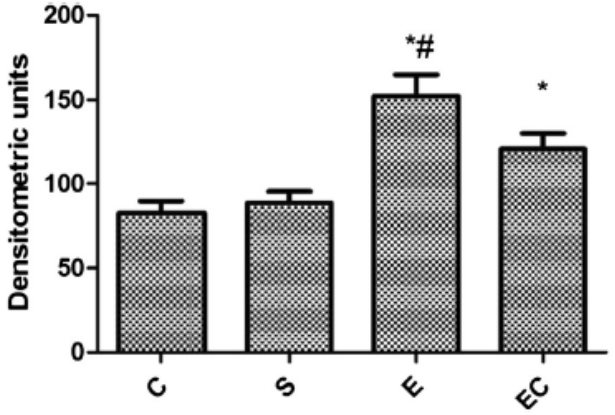


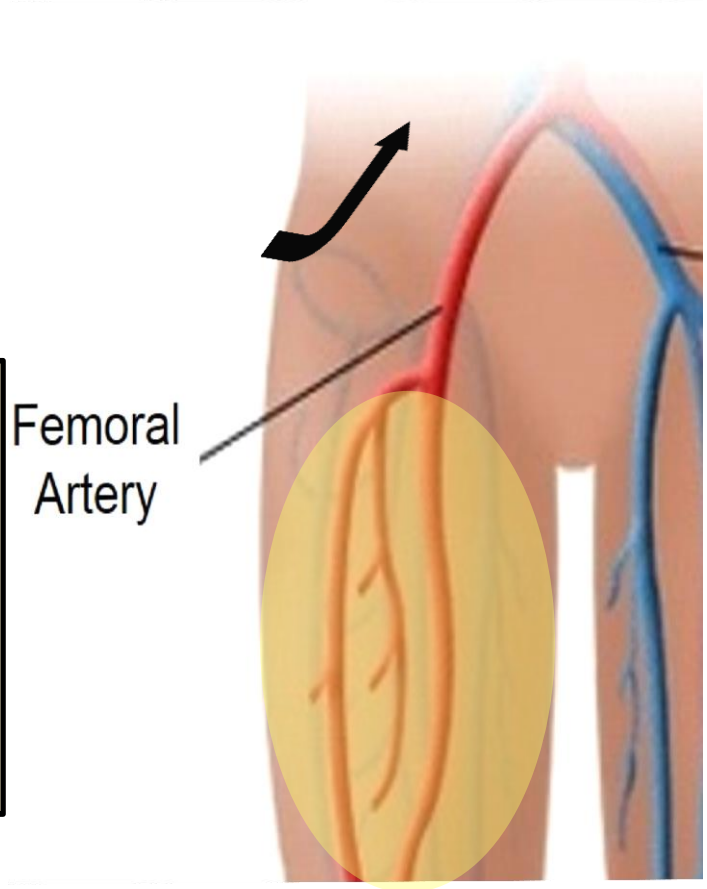
Figure 4 Renal NF-KB expression in all groups.

4. Lower Limb Ischemia and Vascular Injury

Distal limb Ischemia

Percutaneous VA ECMO

- Significant size cannulation (15fr, 17fr)
- Retrograde flow direction
- Vasoconstriction d/t inotropics effect
- Prothrombotic state d/t sepsis or low flow state



⬇

Distal limb hypo-perfusion / total occlusion

Distal limb Ischemia

- Incidence: 5 ~ 30%
  - 6.7 % (Yeo et al.)
  - 8 % (Ganslmeier et al.)
  - 10 % (Bisdas et al.)
  - 11.5 % (Hendrickson and Glower)
  - 16 % (Foley et al.)
  - 17 % (Zimpfer et al.)
  - 20 % (Ma et al.)
- A significant cause of morbidity and mortality
- Risk factors:
  - long-term ECMO (> 7day)
  - No distal perfusion cannulation at initial cannulation
  - Healthy, younger age (without collaterals)

Strategies to Manage Lower Limb Ischemia

- Early detection and Monitoring
- Prophylatic distal perfusion (PDP) cannulation
- Cannulation and Decannulation technique
- Fasciotomy

Strategies to Manage Lower Limb Ischemia

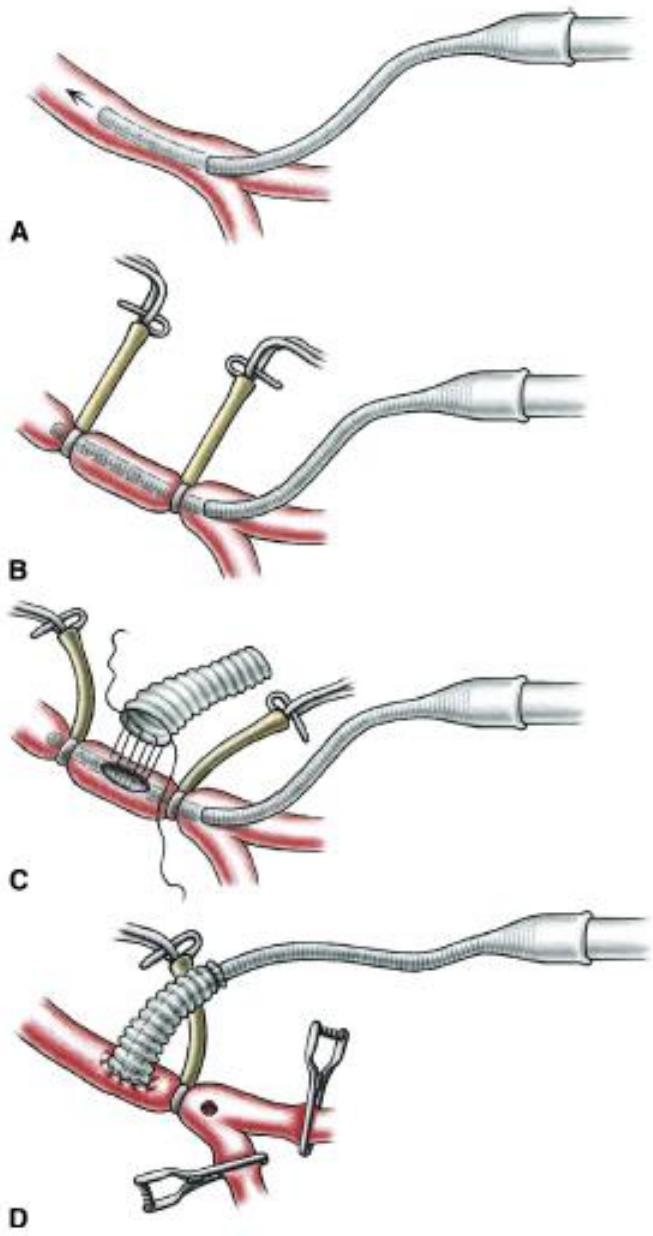
- Early detection of limb ischemia
  - P/E (Colar change etc..)
  - Doppler signal
  - NIRS monitoring
- Adequate perfusion
  - Prophylactic distal perfusion cannulation (DPC)

SURGICAL TECHNIQUES

Transformation of percutaneous venoarterial extracorporeal membrane oxygenation access to a safe peripheral arterial cannulation

Stefanos Demertzis, MD, PhD,[a] and Thierry Carrel, MD, PhD,[b] Lugano and Bern, Switzerland

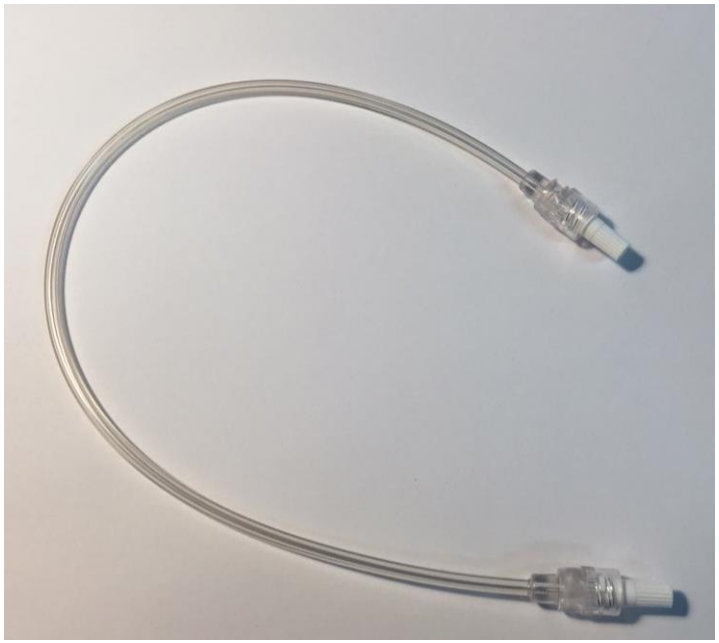
2013 JTCS;146:1293-4

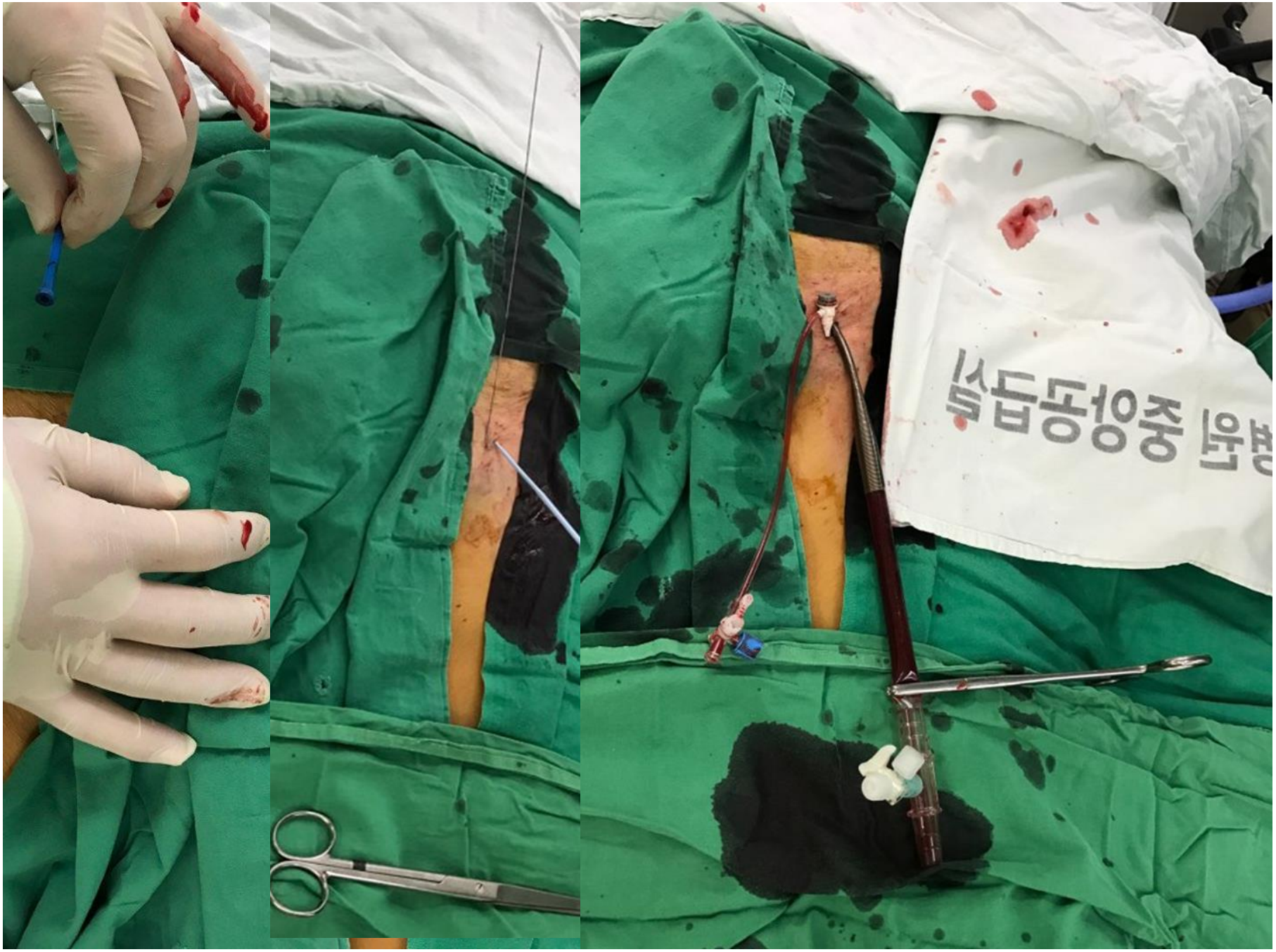


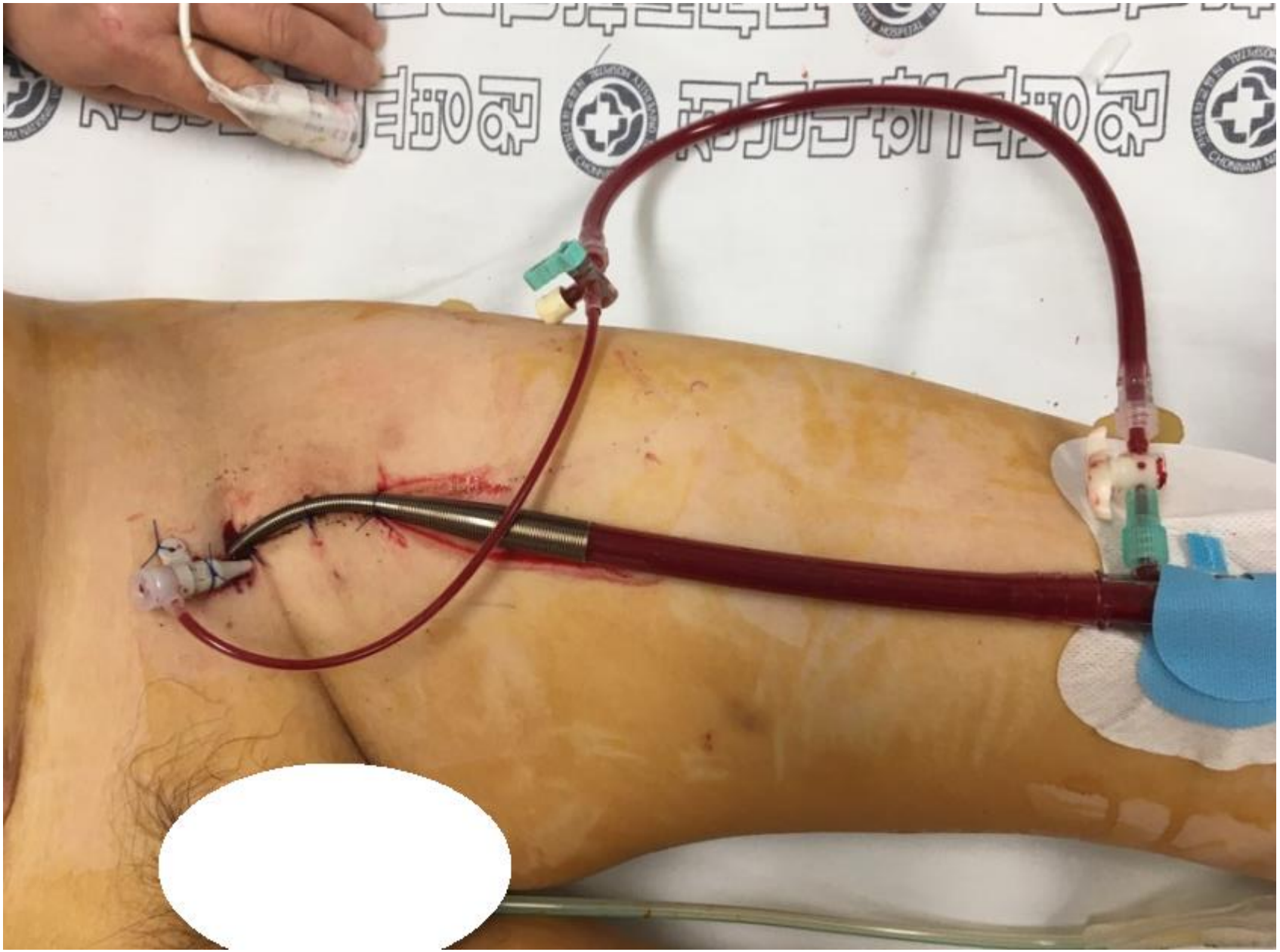
CNUH Distal Perfusion Technique

1. Separate Distal perfusion catheter
: 5 Fr Vascular sheath

2. Pressure line
- PVC (polyvinyl chloride)
- inner diameter 1.5 mm
- outer diameter 3.4 mm
- tube length 30 cm







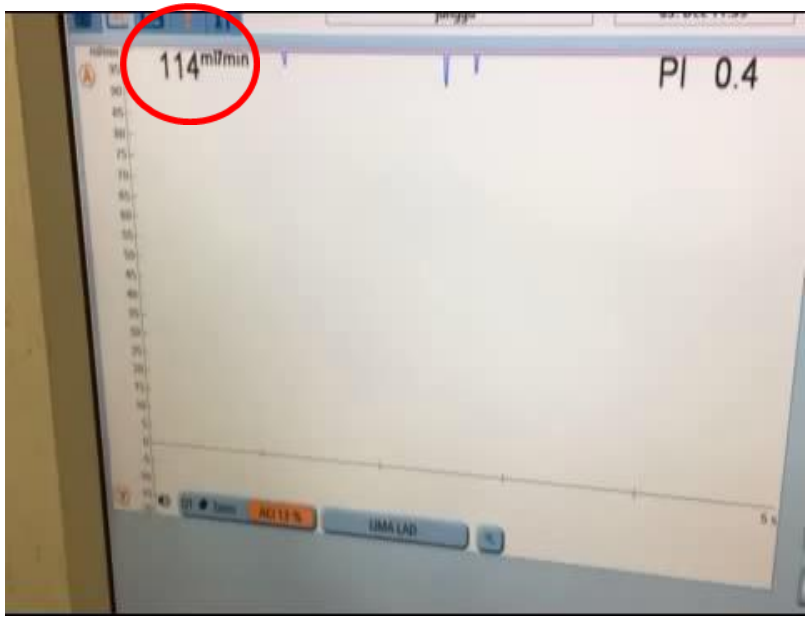
Outcomes of PDP

Yr.	Author	N	Incidence	Limb ischemia (+ PDP)	Limb ischemia (- PDP)	comment
2016	YEO et al	151	10 (6.6%)	0/44 (**0**%)	10/107 (**9.3**%)	**5~8Fr**
2016	MA et al	70	14 (20%)	6/33 (**18**%)	8/37 (**22**%)	**6~8.5Fr**
2016	Tanaka et al	84	10 (12%)	No data	No data	No data
2010	Foley et al	43	7 (16.3%)	0/10 (**0**%)	7/33 (**21**%)	No data
2006	Madershahian et al	3	0 (0%)	0/3 (**0**%)	No data	**6Fr**

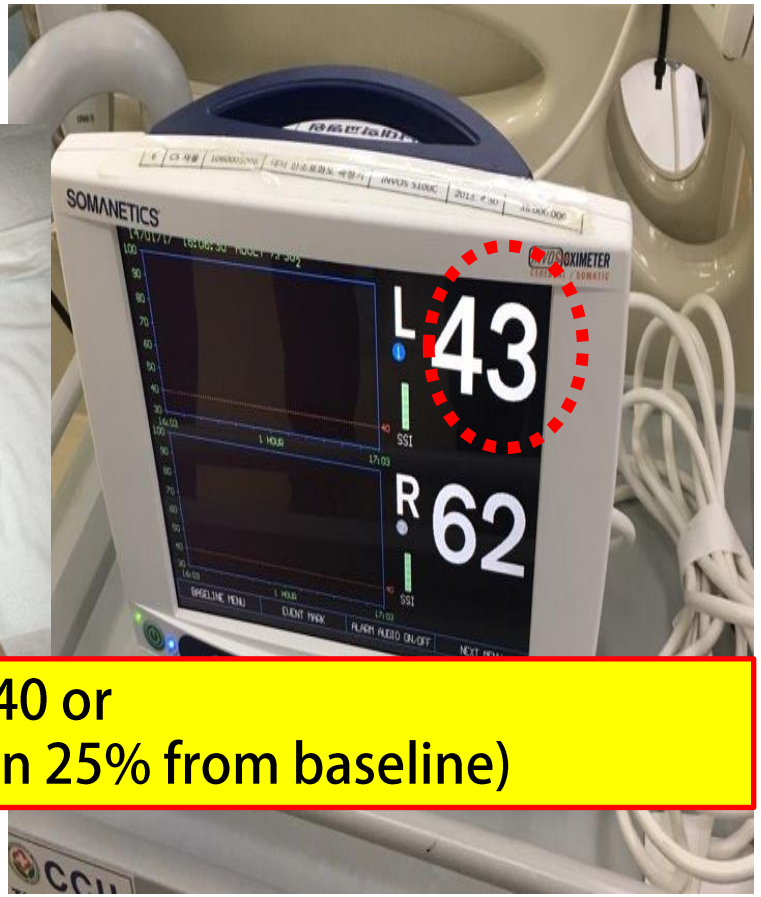
Distal Perfusion Blood Flow

Investigator	Study site			
	CFA	SFA	POP	DP
Lewis et al. 1986	350 ± 141	–	–	–
Field et al. 1989	371 ± 132	–	140 ± 54	–
Hussain et al. 1996	359 ± 114	196 ± 69	–	–
This study	284 ± 119	152 ± 66	72 ± 34	3 ± 4

Data presented as mean volumetric flow ± one standard deviation.



NIRS monitoring

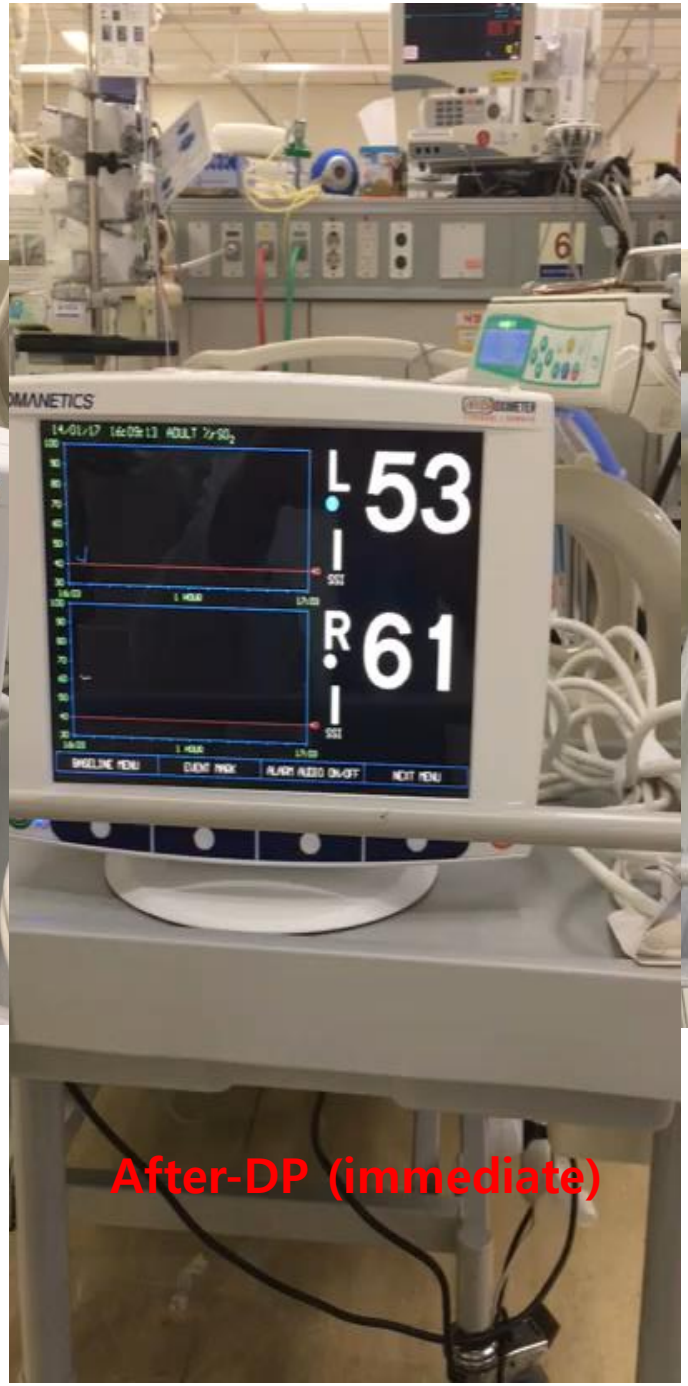


1. rSO2 below 40 or
2. drop in rSO2 values more than 25% from baseline)

Pallor, Color change

NIRS상 rSO2 감소

Before-DP



After-DP (immediate)

After-DP

NIRS monitoring

1. Near-Infrared Spectroscopy Monitoring for Early Detection of Limb Ischemia in Patients on Veno-Arterial Extracorporeal Membrane Oxygenation

Kim DJ, et al. ASAIO J. 2017 (Epub)

2. Using Near-Infrared Spectroscopy to Monitor Lower Extremities in Patients on Venoarterial Extracorporeal Membrane Oxygenation.

Steffen RJ, et al. Ann Thorac Surg 2014. 98(5), 1853-1854

3. Cerebral and lower limb near-infrared spectroscopy in adults on extracorporeal membrane oxygenation.

Wong JK, et al. Artificial organs 2012. 36(8), 659-67

4. Cerebral and peripheral tissue oxygenation in children supported on ECMO for cardio-respiratory failure.

Papademetriou MD, et al. Adv Exp Med Biol 2010. 662, 447-53

From the S

Arterial
catheter
undergo

Kathleen M.
Neil Moudgil
Nicholas C. C

ABSTRACT

Objective: Ver
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Thomas Jefferson UH and other 3 Hosp. in US

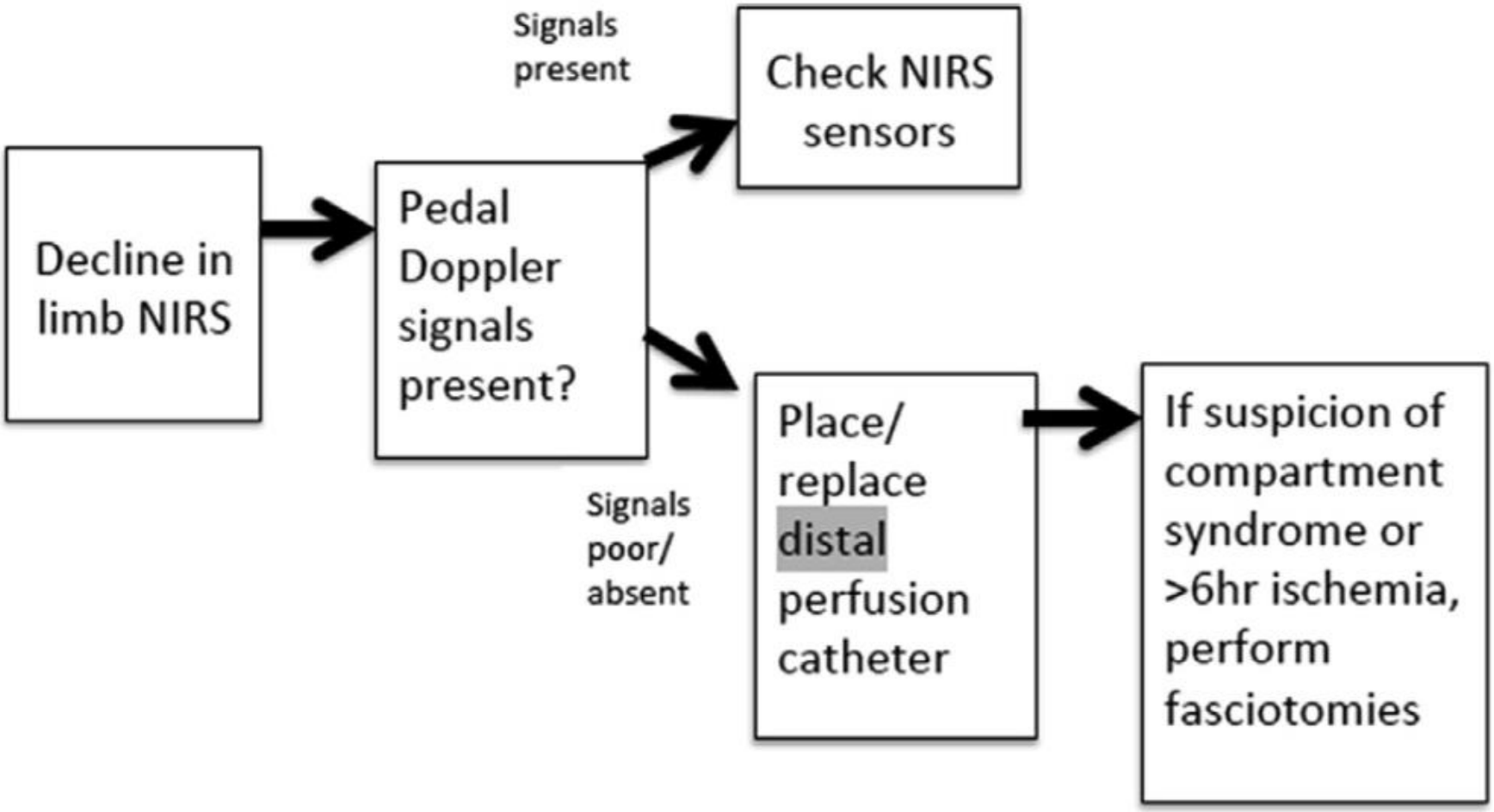
- 2010-2015
- 91pts. VA-ECMO

1. Prophylatic DPC (N=55)
   - no Limb ischemia
2. No prophylatic DPC (N=36)
   - Ischemia (N=12, 33%)
   - DPC ± Fasciotomy (N=7)
   - Fasciotomy (N=4)
   - Amputation (N=1)

- Risk Factor
  - DPC at the time cannulation, Larger cannula
  - Trend to younger age

- Recommendation
  - Prophylatic DPC
  - NIRS monitoring
  - Decannulation with open technique

Kathleen ML et al. J Vasc Surg 2017;65:1074-9



Kathleen ML et al. J Vasc Surg 2017;65:1074-9

「대뇌피질 산소포화도 감시용 Sensor」 급여기준 관련 전문가 자문회의

2015. 9. 10.

건강보험심사평가원
Health Insurance Review & Assessment Service
치료재료실 재료기준부

Vascular Injury after Cannulation

J Artif Organs
DOI 10.1007/s10047-010-0545-5

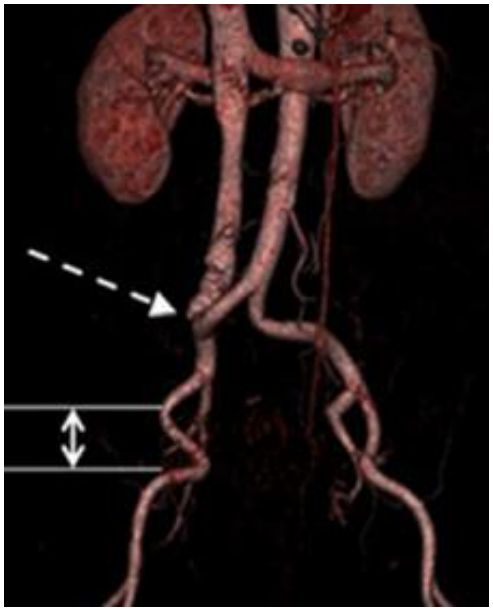
CASE REPORT

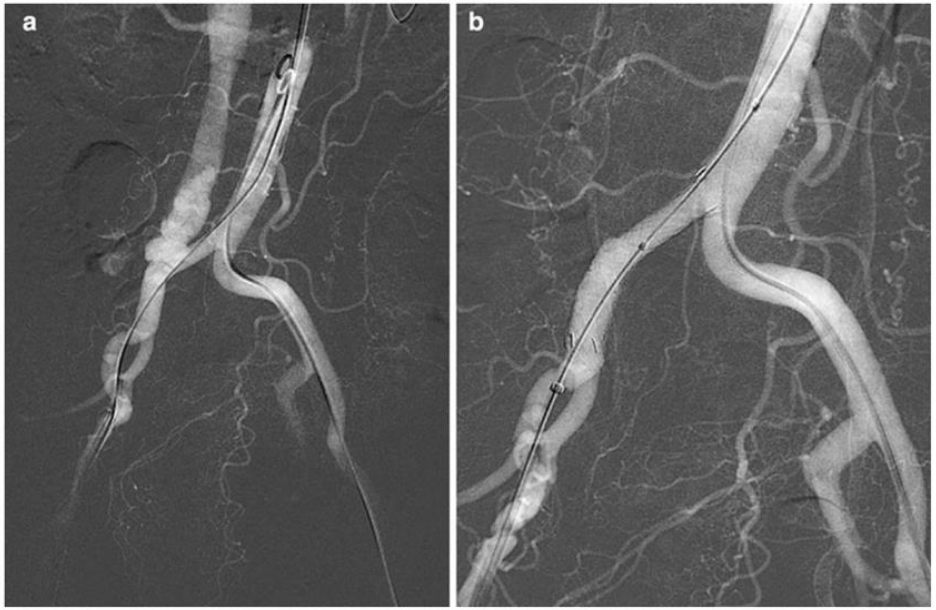
A case of iatrogenic ilio-iliac arteriovenous fistu after percutaneous cardiopulmonary support in a patient with a tortuous iliac artery

82 / F
Cardiogenic shock d/t AMI
VA-ECMO (D: 9days)

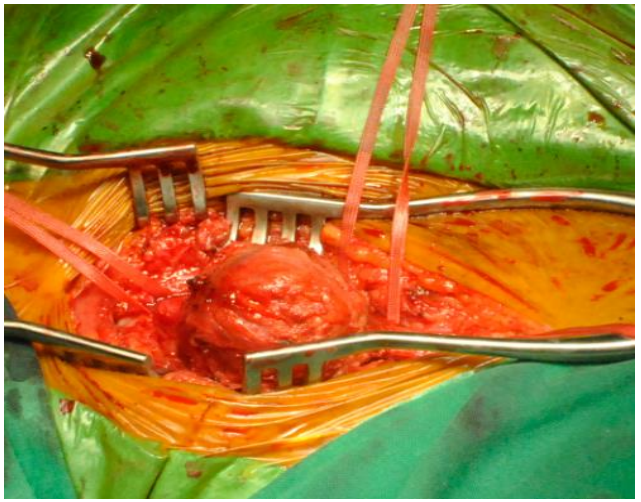
Rt. Ilio-iliac AVF
: Covered Stent graft deployment

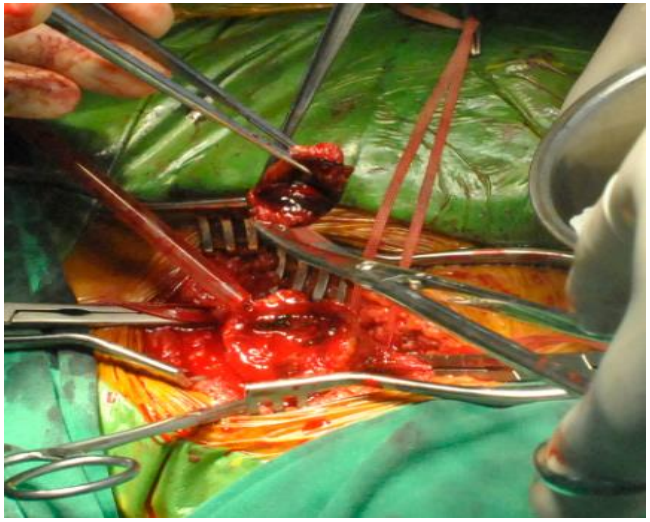
2012 Artificial Organs (CNUH)

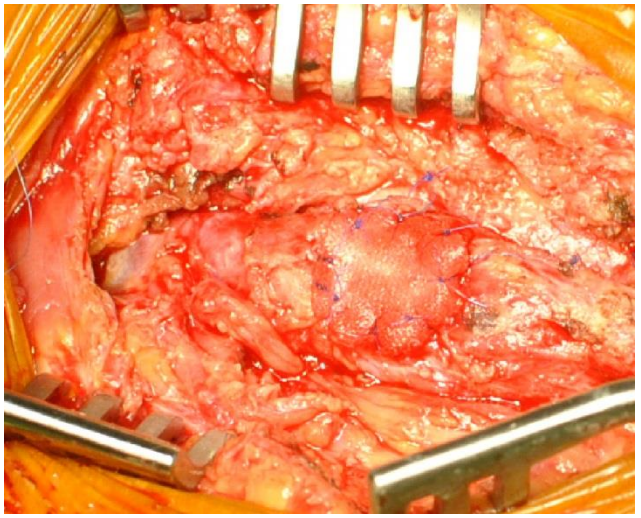




Pseudoaneurysm (34 / F)







How to manage the complication?

- Close monitoring and Prevention

- Early intervention

Take Home Message

1. Bleeding and Thrombosis
   - Appropriate anticoagulation management is essential
2. Nosocomial infection
   - Minimize ECMO exposure and associated environment
   - Basic infection control
   - Immune-modulation therapy
3. Lower limb ischemia
   - Prophylactic distal perfusion cannulation in appropriate timing.
   - NIRS monitoring

Thanks

Please send your feedback to:

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