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EXTREME ECMO: COMBAT, TRAUMA, TRANSPORT

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I have no disclosures

The views presented in this talk do not reflect those of the United States Military, Department of Defense or Inova Health System.

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Extracorporeal Support will define the future of critical care medicine

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Extracorporeal Support will direct the future care of severe heart and lung failure

- Consider early – as soon as optimal therapy failing
- Select patients carefully
- Can transport anywhere, anytime,anyplace with right team

Principles of patient selection

1. Reversible process
2. Good neurologic outcome possible
3. Ability to tolerate anticoagulation
4. Performance and functional status - age

Institutional Process:

ECMO team, Shock team

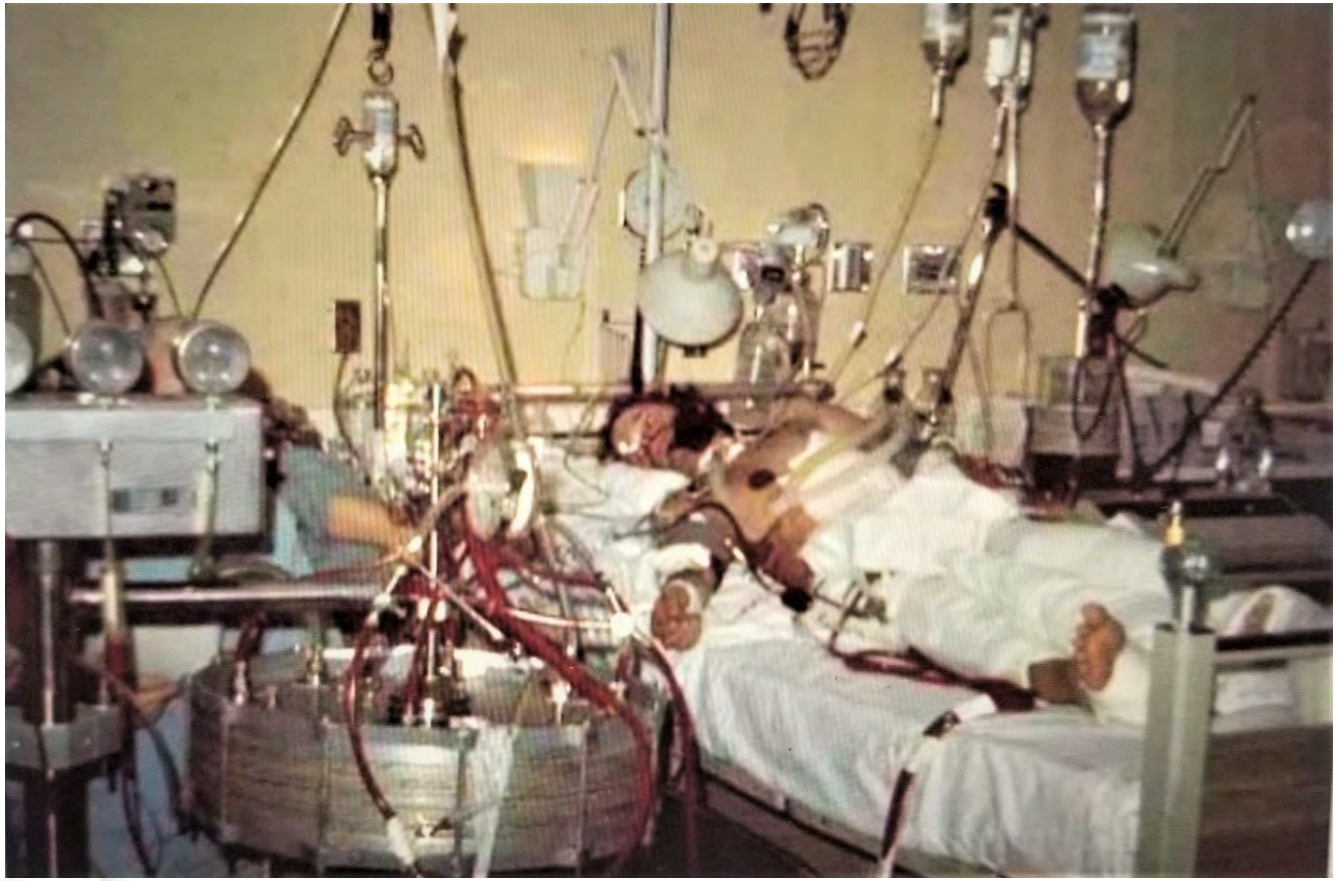
Multidisciplinary discussion

Pre-established guidelines and criteria

University Hospital Regensburg Germany – Landstuhl Collaboration

November 2007
Prototype of Small ECMO Device :
To pick up Patient on Pumpless AV Lung support

First ECMO adult patient that survived was a trauma patient



Technology advances….

10kg
High or low flow
PMP membrane
Built in monitoring
of flow pressure, temp,
SVO2, hemoglobin

The ELSO Registry - Survival

Adult pulmonary 59%

Adult cardiac 42%

eCPR 29%

ECLS Registry Report

International Summary

July, 2018

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

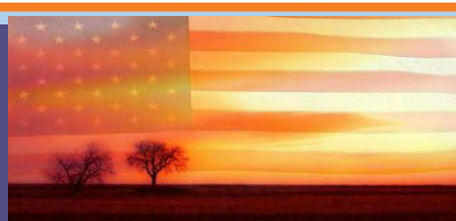
Overall Outcomes

	Total Runs	Survived ECLS		Survived to DC or Transfer	
Neonatal					
Pulmonary	30,934	25,990	84%	22,662	73%
Cardiac	7,794	5,063	64%	3,281	42%
ECPR	1,718	1,140	66%	708	41%
Pediatric					
Pulmonary	8,820	5,953	67%	5,131	58%
Cardiac	10,462	7,177	68%	5,447	52%
ECPR	3,946	2,262	57%	1,675	42%
Adult					
Pulmonary	16,337	10,857	66%	9,649	59%
Cardiac	15,942	8,865	55%	6,747	42%
ECPR	4,952	1,896	38%	1,443	29%
Total	100,905	69,203	68%	56,743	56%

Centers

Three groups of patients

- Severe lung failure – VV ECMO
- Severe cardiac or cardiopulmonary failure – VA ECMO
- Cardiac arrest - eCPR



ECMO use in trauma increasing…

- Number of ECMO trauma articles – pubmed search ECMO and trauma
  - 2013- present **423** Last 5 years
  - 2007-2012 157
  - 2001-2006 74
  - 1995-2000 72

Trauma Survival is better

TABLE 5. Comparison of Survival Rates in Trauma Patients Versus Other ELSO Registry Cohorts

Diagnosis	n	Average Run Duration, d	Survival to Hospital Discharge
Trauma—total cohort	279	8.8 ± 9.5	61%
Trauma—respiratory support	247	9.3 ± 9.3	63%
ARDS, not postoperative/trauma*	837	13.0	54%
Acute respiratory failure, non-ARDS*	1408	11.5	55%
Viral pneumonia*	926	13.5	65%
Bacterial pneumonia*	1362	10.9	61%
Trauma—cardiac support	20	4.1 ± 4.5	50%
Adult cardiac support*	9025	6.5	41%
Trauma—ECPR	12	6.5 ± 16.8	25%
Adult ECPR*	2885	Not available	29%

*Data from ELSO.[15]

Survival Rates

- Trauma Pulmonary 63%
- Adult Pulmonary 59%

- Trauma Cardiac 50%
- Adult Cardiac 41%

- The only group where trauma survival is less than non-trauma survival is eCPR
  - Trauma eCPR 25%
  - Adult eCPR 29%

Avoid ECMO in traumatic cardiac arrest

If severe shock or cardiac arrest is due to blood loss, ECMO will not work

Every guideline or rule has an exception..

Black

White

Colorful Grey

ECMO works well in Trauma

- Bleeding controlled
- Same principles for other patients
  - Can run ECMO without anticoagulation for 24-72 hours or longer…
- How do we know when a good neurologic outcome is possible in patients with brain injury?

Case: Charlie - 27 year old UK Army Officer

2 months before illness

Sleeping outside - Sandstorms

Admitted to ward:
Doxycycline
2L O2 NC
CXR R infiltrates
Mild transaminitis
Low platelets

2 days later:
Increased O2 needs
Levaquin started

ANAPHYLAXIS

ICU

Organs down:

LUNGS

HEART

LIVER

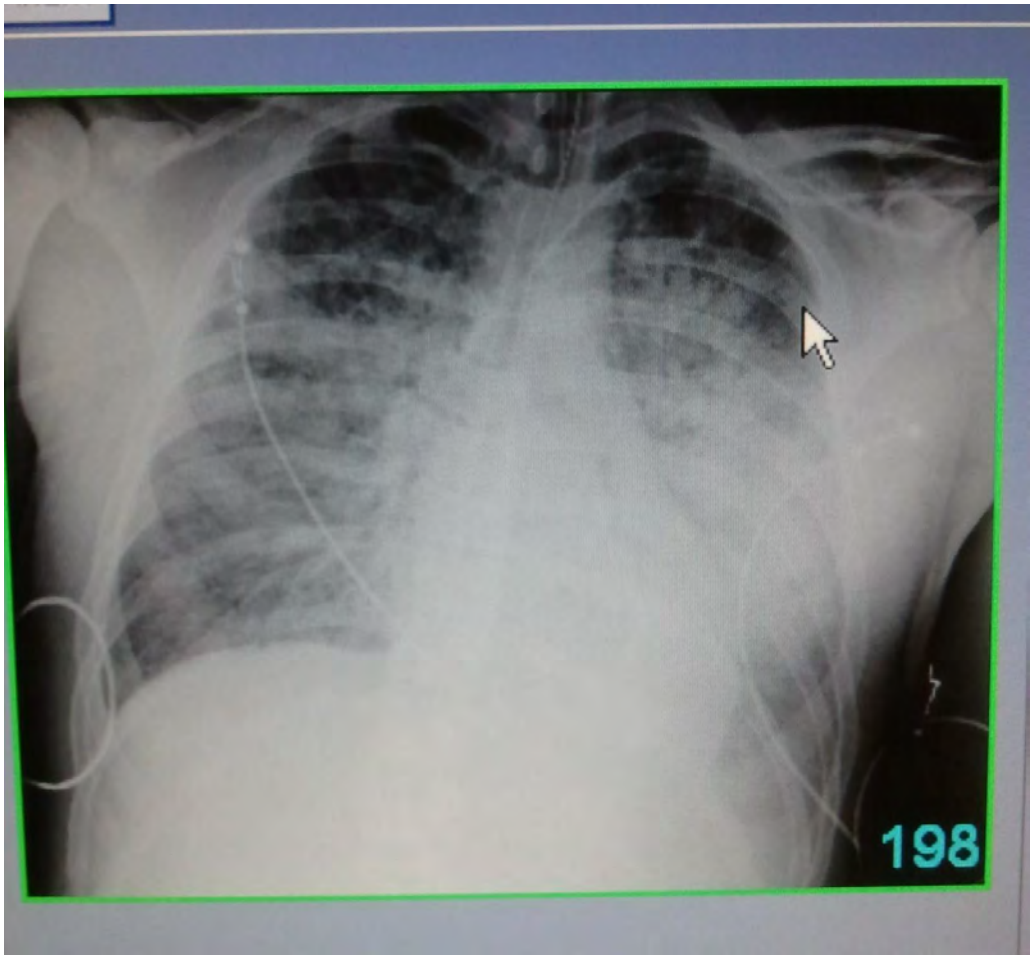
KIDNEYS

BLOOD

- Severe Respiratory Failure
  - P/F ratio 64, pH 7.01, CO2 86
  - O2 saturation 70-78% on maximal support
  - Rescue Ventilator modes ineffective
- Shock – distributive and cardiac – EF 30%
  - High dose norepinephrine (35 mcg/min)
  - High dose epinephrine (20 mcg/min)
  - Vasopression (0.4u/min)
  - Fluids + 14L crystalloids/colloids
- Liver failure – infection, shock liver
  - AST 21,000, ALT 15,000
- Coagulopathy
  - PT 49, PTT 48, Platelets 48
- Acute Kidney Injury – no urine output

PEEP 22, FiO2 1.0,
Mean Airway pressure 34,
Plateau pressure 44,
Tidal volumes 500-700ml

Damaging settings required to sustain life



Failure of lung protective ventilation
Neuromuscular blockade
Prone positioning

- This is failure of optimal therapy
- Unable to meet gas exchange goals with

  TV < 6ml/kg IBW, Plateau pressure < 30, P/F < 150
- Acidosis compromising perfusion
- Not improving after 6 hours…

→ **ECMO**

pH below 6.95 for over 12 hours

Despite Bicarb ggt

Date:	30-12-12	30-12-12	30-12-12	30-12-12	30-12-12	30-12-12	30-12-12	30-12-12
Time:	15.30	15.55	16.10	16.20	16.40	17.00	17.35	17.55
Initials:	AA	AA		AA	AA	AA	AA	AA
	Art/Ven	Art/Ven	Art/Ven	Art/Ven	Art/Ven	Art/Ven	Art/Ven	Art/Ven
pH	6.96	6.85	6.89	6.83	6.91	6.95	6.92	6.83
PCO_2	11.26	14.99	9.36	13.50	10.02	9.37	8.17	9.38
PO_2	12.7	9.1	13.0	9.9	8.3	7.2	8.6	8.8
BE	-13	-14	-19	-17	-17	-16	-20	-22
HCO_3	19.2	20.0	13.6	17.0	15.3	15.6	12.8	11.7
TCO_2	22	23	16	20	18	18	15	14
SO_2	90	73	90	76	71	66	75	70
Na+	137	137	135	138	139	/	135	133
K+	3.9	4.6	4.5	3.8	3.4	/	5.0	5.2
iCa	1.12	1.13	1.10	1.07	1.00	/	1.51	1.23
HCt	60	64	64	60	54	/	60	55
Hb	20.4	21.8	21.8	20.4	18.4	/	20.4	18.7
Lactate	4.38	5.51	7.01	6.95	/	5.25	5.07	9.59
BM	/	7.4	/	8.4	/	7.2	4.8	5.3

Is he a candidate for

Extracorporeal support?

If so, which kind?

British hospital in Afghanistan

Commander says NO ECMO!

Question: Imagine you are in a high volume ECMO center. What is the best option for this patient?

A. VA ECMO – Femoral vein to femoral artery

B. VV ECMO – femoral vein to internal jugular vein

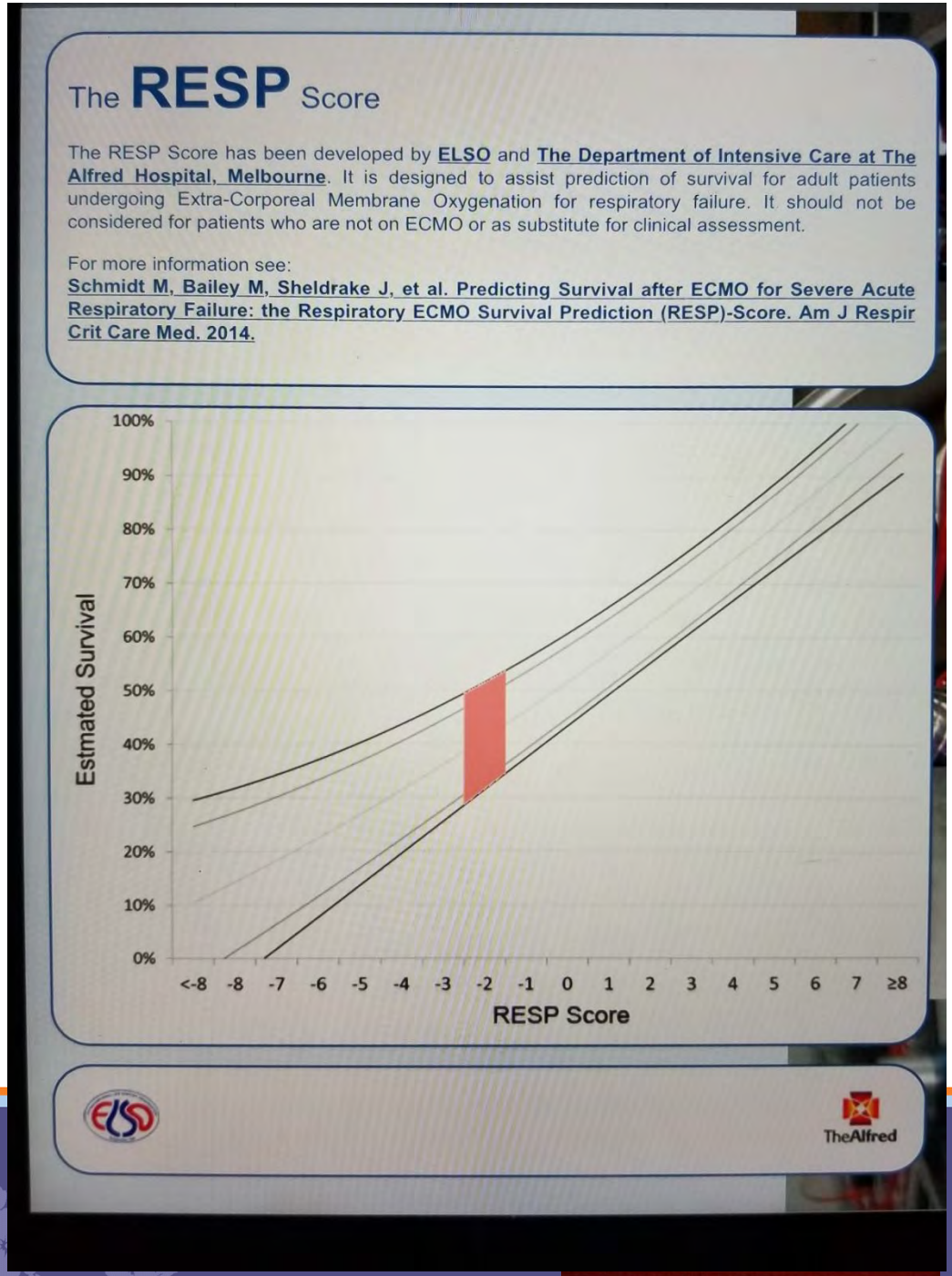
C. Withdraw care, severe brain injury portends poor outcome

D. APRV, start CRRT, continue current supportive therapy

Resp score Estimates 40% survival
www.respscore.com

Increased mortality:
Age
Organ dysfunction
Immunocompromised
CNS dysfunction
Impaired compliance
  high PEEP, Plateau, minute vent
Cardiac arrest

Increased survival:
MV < 7 days
Prone positioning
Neuromuscular blockade
Infection related ARDS
Trauma
Asthma



RESP score for the British soldier with anaphylaxis, multi organ failure is -2; confers 30-50% survival

- High CO2
- High peak inspiratory pressures
- Bicarbonate infusion
- Non respiratory organ dysfunction

- Everyone says he is going to die, his brain injury is now severe, kinder for him to let him go?

- What do you want to do? Command, political issues…

VV ECMO

Gas exchange
And
Perfusion quickly
Improved

Fem 23F

IJ 17F

VV ECMO – Fem to IJ

On back of C17
before take off

11 days later – in Regensberg Hospital, Germany

Survived
Gentle VATS
R lung for
Hemothorax

Liver recover
After 3 weeks

Still on CRRT

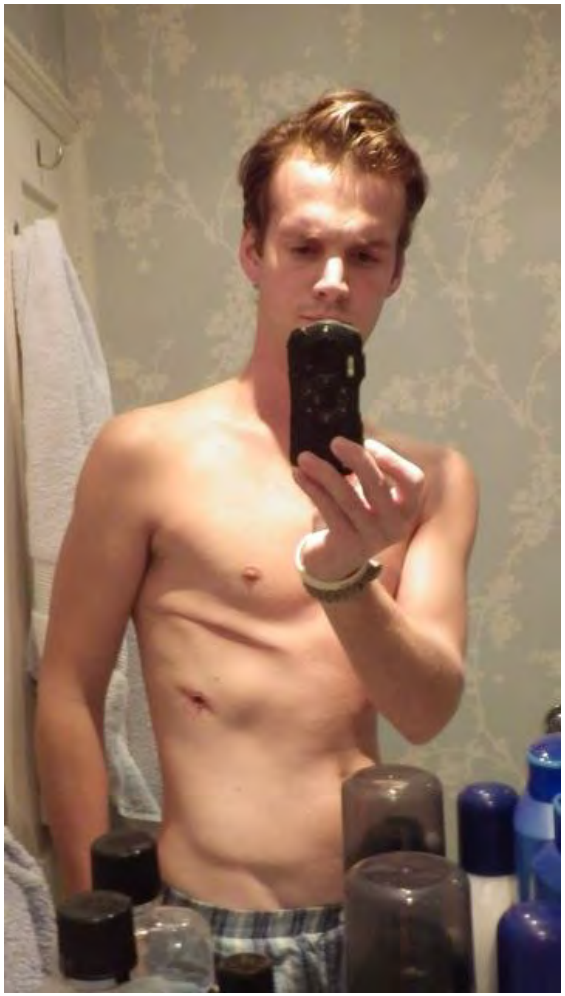
4 months later - Discharged from UK hospital

What was the infection?

Hemodialysis 9 weeks

Cardiomyopathy

What about his brain?



8 months later

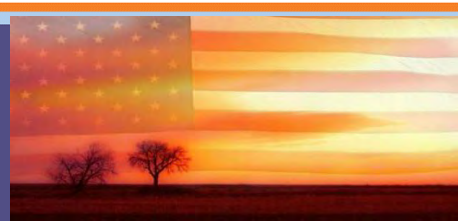
Hiking with his new wife in Verona, Italy

Able to run for 40 minutes – mild chest tightness

They bought a dog and named him ECMO

Patient selection for VV ECMO

- Failure of optimal therapy
  - Earlier ECMO is better
- Reversible process
  - Tolerate anticoagulation
- Good neurologic outcome possible
- If chronic organ dysfunction exists – ECMO reasonable if they are a transplant candidate
- Active bleeding – acceptable if the bleeding is reversible and not large CNS bleed
  - CNS bleed: if small, wait 6-12 hours, repeat head CT, go on ECMO without anticoagulation for 1-3 days



Evidence for VV ECMO

CESAR Trial

- Referral to an ECMO center improves outcome
- Old technology used, roller pumps, 15% MARS; not reflective of current practice
- The other older trials also not reflective of todays technology and critical care practice

EOLIA Trial

Early VV ECMO at high volume centers versus

Early lung protective ventilation with high PEEP

- 11% reduction in mortality with ECMO p value 0.07
- higher bleeding requiring transfusion (46% ECMO v 28%)
- severe thrombocytopenia (27% ECMO v 16%)
- 28% emergency crossover rate to ECMO
- p value if include cross over patients 0.01

N Engl J Med 2018;378:1965-75

EOLIA Trial

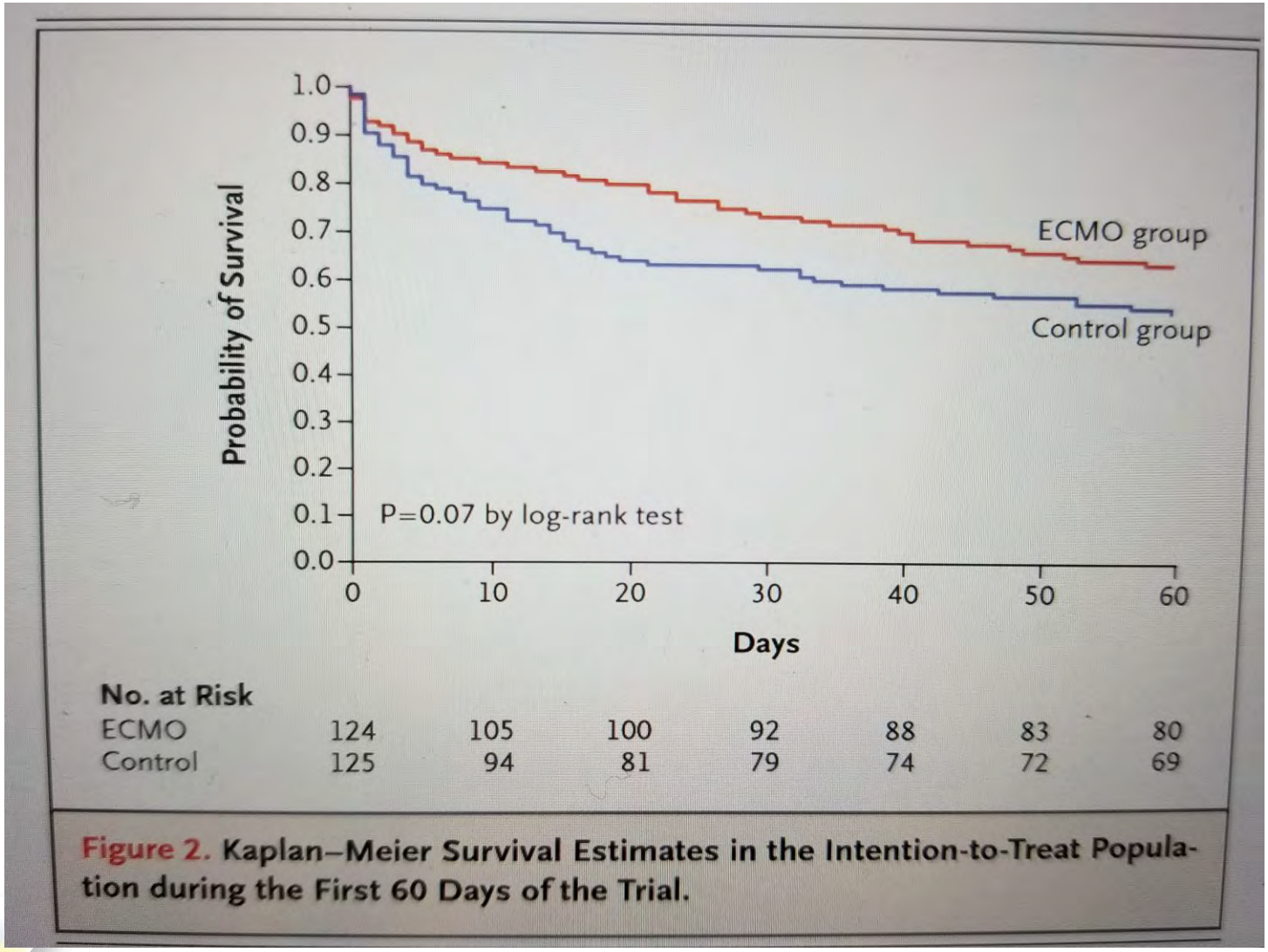
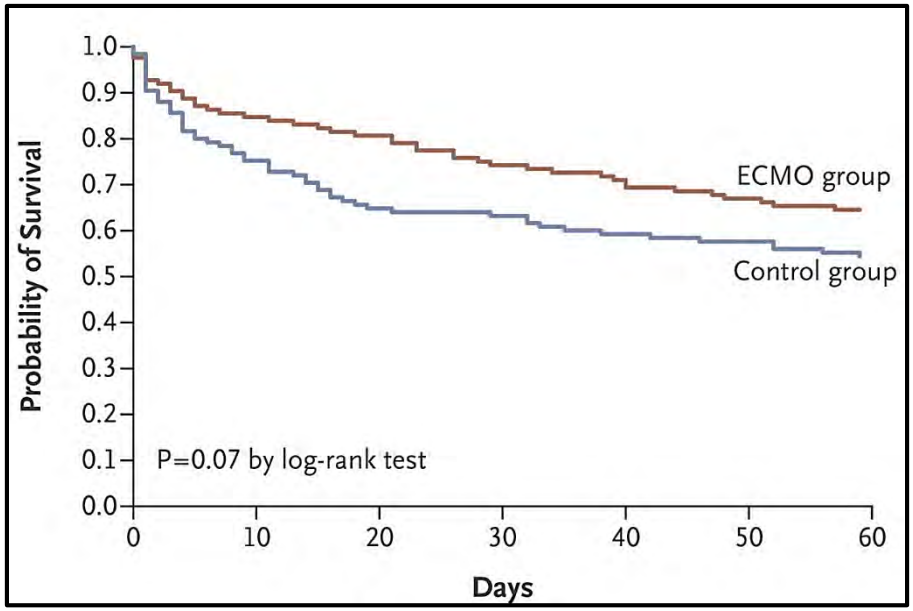
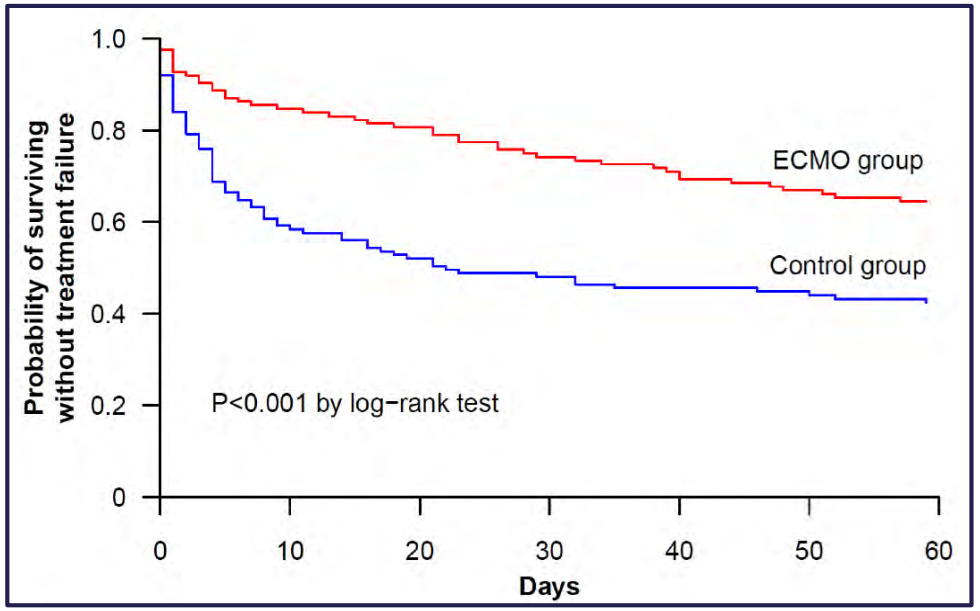


Figure 2. Kaplan–Meier Survival Estimates in the Intention-to-Treat Population during the First 60 Days of the Trial.

EOLIA Trial in Severe ARDS





Inclusion Criteria:
-P/F <50 for 3 hours
-P/F <80 for 6 hours
-pH <7.25 and pCO_2 <60 for 6 hours

Crossover Criteria:
-SaO_2 <80% for >6 hours

-28% crossover with 43% survival

New Engl J Med 2018;378:1965-1975.

Indications expanding rapidly

- Hypercapnic failure (COPD, asthma, toxic overdose)
- Bridge to lung transplantation
- Pulmonary hypertension with right heart failure
- Earlier use in less severe hypoxic respiratory failure
  - Ultra lung protective ventilation
- Resuscitation of donor lungs prior to transplantation
- Bridge to early mobility

- Includes ECCO2R – low flow VV ECMO

REST, SUPERNOVA trials underway

ELSO guidelines – VV ECMO

- Relative contraindications:
  - Mechanical ventilation for 7+ days at high settings (FiO_2 >90% P_{plat} >30) – based on older data
  - Major immunosuppresion
  - Recent or progressing CNS hemorrhage
  - Non recoverable co-morbidity
  - Terminal malignancy
  - “Increasing risk with increasing age”
  - Not a candidate for transplant
  - Chronic organ dysfunction

Jihye
32 yo presents for routine prenatal appointment at 32 weeks

- Ob notices her fingers are blue
- O2 saturation is 81% on RA
- Pt wants to return to work, dyspnea normal for pregnancy
- ECHO shows massive ASD
  - R to L shunt after long standing L to R shunt – Eisenmengers
  - Right heart failure, severe pulmonary hypertension

Progressive cardiopulmonary failure

- Rising O2 requirements on HFNC 50L, 90%
- Increasing pressor requirements
- Intubation carries risk for “RV suicide” and arrest

Is she a candidate for extracorporeal support?

A. Yes

B. No

Some team members say…

- She needs a heart lung transplant
- Too late to try and fix it
  - If you try and fix it heart will fail fatally
- She will lose the child…
- Call palliative care…

- Safest way is to place her on awake VA ECMO and then intubate if necessary

Planned C section on VA ECMO

- Uterine bleeding post partum – embolized
- Pulmonary hemorrhage
- Pseudomonas infection – develops resistance
- Right heart improves with venous drainage from ECMO cannula, diuresis, and treatment of pulmonary HTN
- Transitioned to VV with double lumen cannula in R IJ


140
113/79

O2 sats

90% tubed

65% extubated…

O2 sats

53%...
Briefly
Mental status
Normal

Cardiac output

Hgb

65%

Goal O2 sat
> 60%

iPhone


CVICU


EXIT


Ensure

VA ECMO

Cardiogenic Shock – inadequate tissue perfusion due to cardiac dysfunction

- Persistent hypotension:

  systolic blood pressure < 80-90 or mean arterial pressure 30 mmHg lower than baseline

- Cardiac Index reduction:

  < 1.8 L/min/m2 without support

  < 2.0 L/min/m2 with support

- Adequate or elevated filling pressures
- Evidence of end organ dysfunction

Refractory Cardiogenic Shock

Shock persists despite volume administration, inotropes, vasoconstrictors, with or without IABP

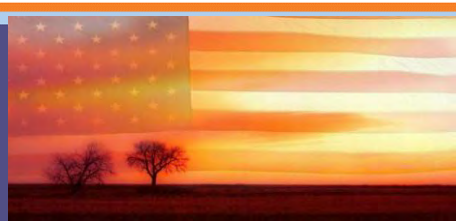
Systemic hypoperfusion – cold, oliguric, altered mental status

Severe systemic hypotension

Respiratory distress due to pulmonary congestion

Cardiogenic shock

- Primary RV, LV, bivent failure – lungs working
  - Impella, Centrimag, TandemLife
- RV, LV, bivent failure with pulmonary instability
  - VA ECMO
- End organ dysfunction despite multiple pressors and ionotropes
- Use ECHO and PA catheter



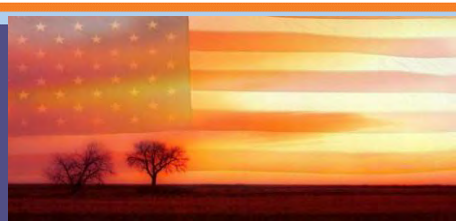
VA ECMO - Indications

- 74 male POD 6 2nd kidney transplant, cardiogenic and septic shock with multiorgan failure.
  - NSTEMI Trop 22, S/P remote CABG, EF 30% down from 60%.
  - Chronic immunosuppression due to transplant. Acute liver and renal failure.
  - Norepi at 300, Milrinone 0.5, neosynephrine at 250. Max doses. Lactate rising to 9. BP 60s/40s.
  - Respiratory failure O2 sat 85% on 100% and high PEEP.
- Transplant surgeons requesting VA ECMO

What do we decide?

A. Yes

B. No



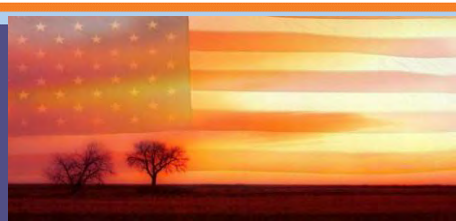
Contraindications to VA ECMO

Absolute

- Unrecoverable heart and not a transplant or VAD candidate
- Chronic organ dysfunction (COPD, cirrhosis, renal failure)
- Compliance (financial, cognitive, psychiatric, social limitations) for further therapies if needed

Relative

- Contraindication for anticoagulation
- Advanced age



Estimate survival in VA ECMO

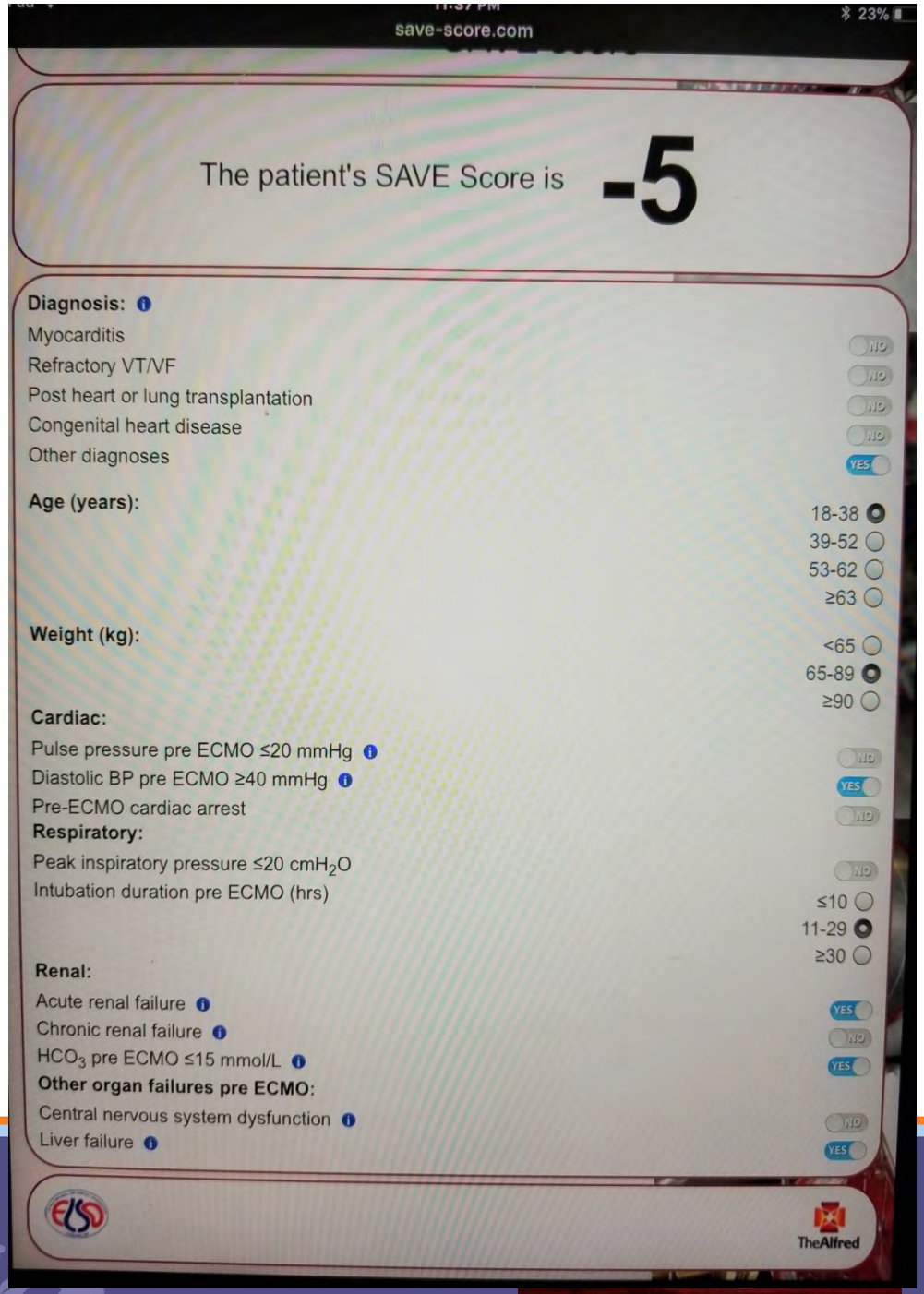
Save score www.save-score.com

3846 patients

Increased mortality:
Chronic renal failure, longer MV,
Pre ECMO organ failure, cardiac arrest,
Congenital heart disease,
lower pulse pressure, lower HCO3

Increased survival:
Younger age, lower weight,
Acute myocarditis, heart transplant,
VT/VF, higher diastolic pressure, and
Lower peak inspiratory pressure

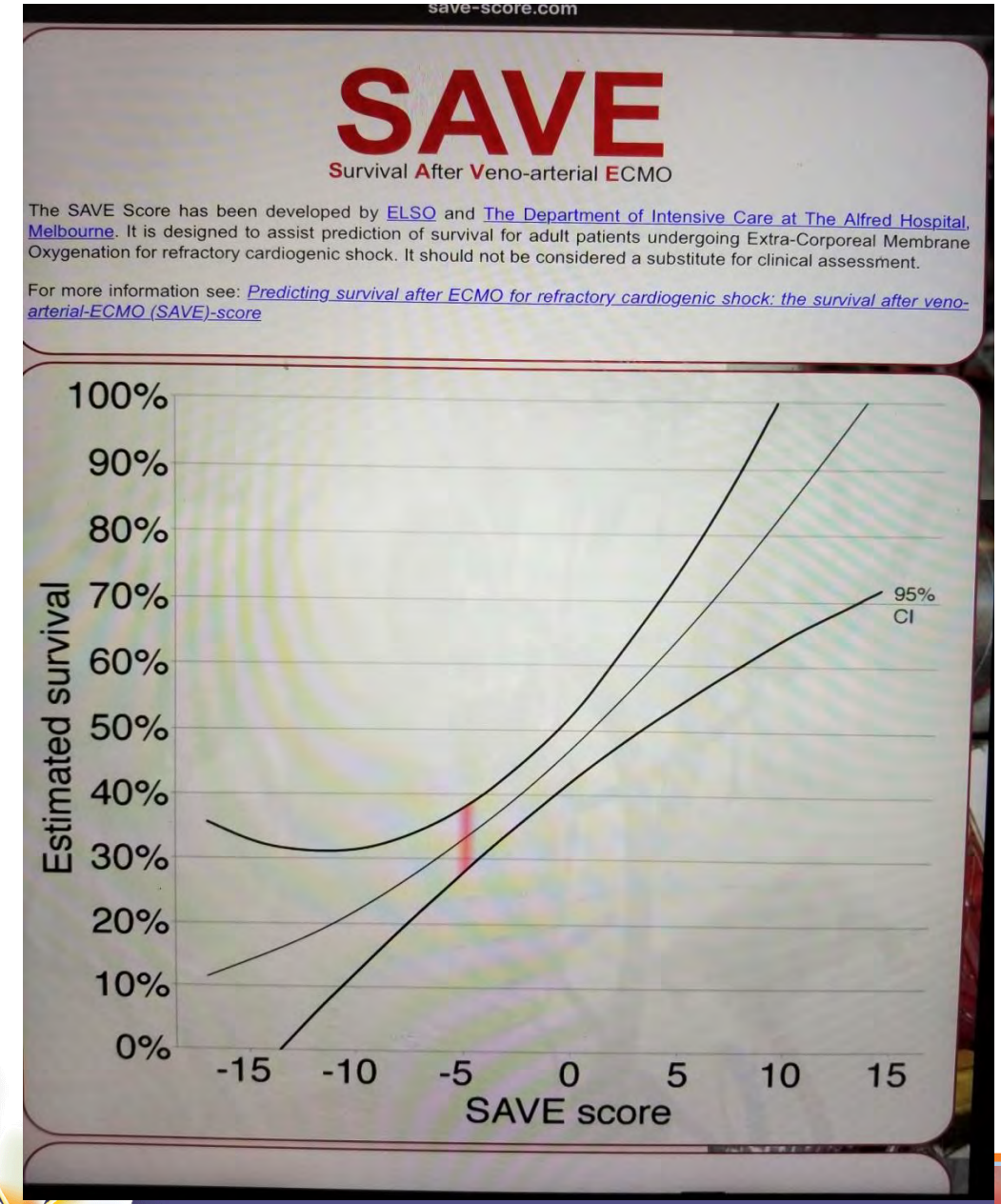
Eur Heart J. 2015
Sep 1;36(33)2246-56



Predicted Survival 35%

SAVE score For British pt

-5



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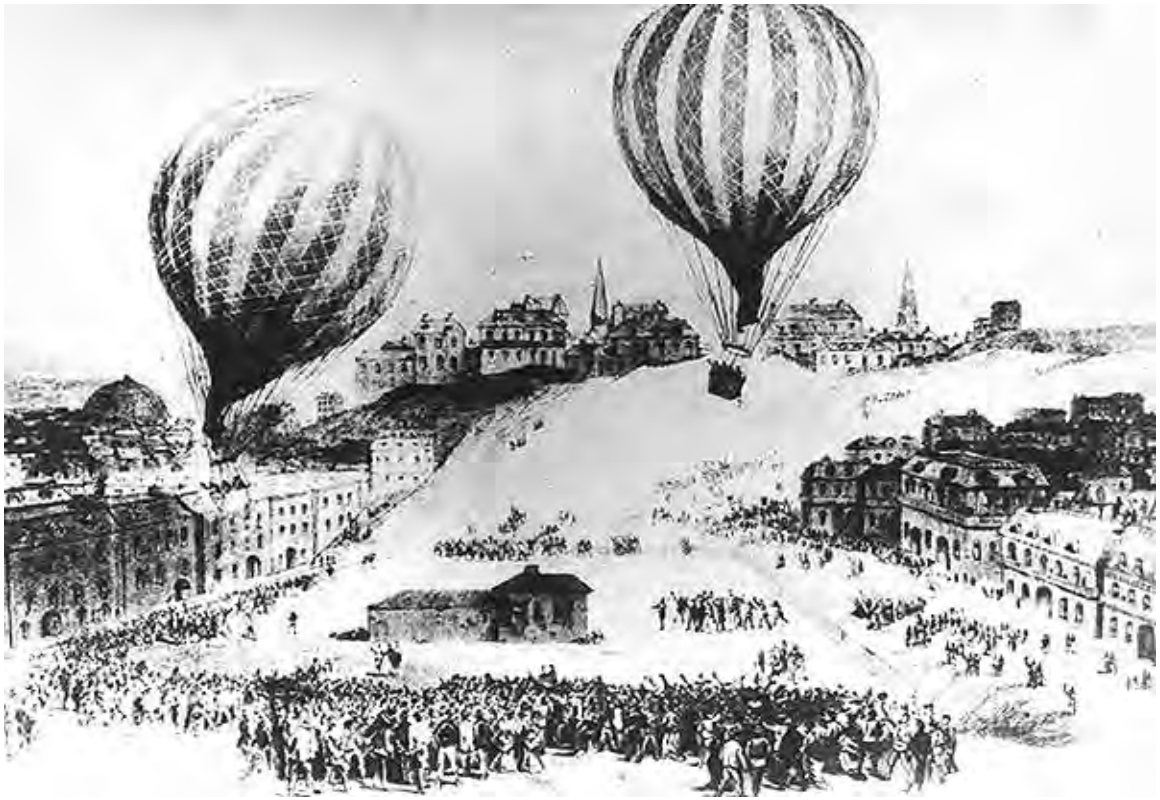
History of Medical Air Evacuation: Franco Prussian War 1870 – Hot Air Balloons



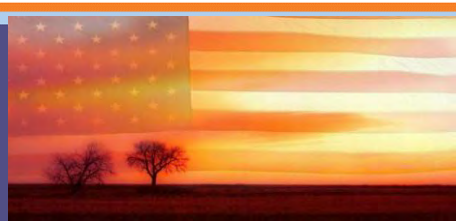
Historians debate if medical evacuation actually occurred ?

Lam DM, Aviation, Space Environmental Med, Oct 1988

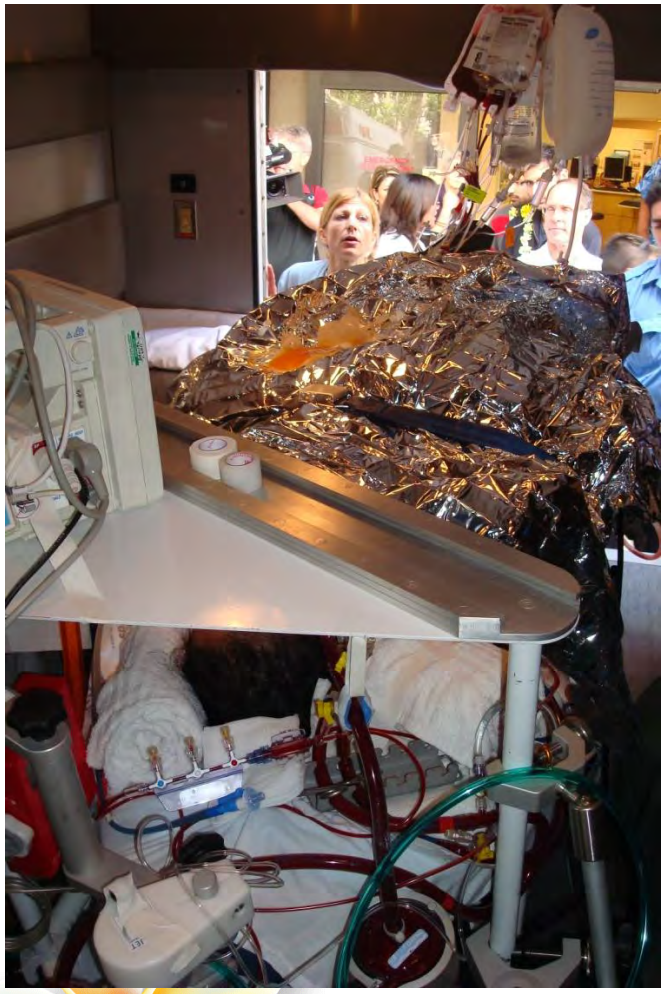
Basics of Long Range Air Transport – with right team… ECMO transport is actually easier and safer

- 6 phases, 6 procedure process

1. ICU to ambulance
2. Ambulance to plane
3. Flight
4. Plane to ambulance
5. Ambulance to ICU
6. Transfer care to new team



1. ICU to ambulance



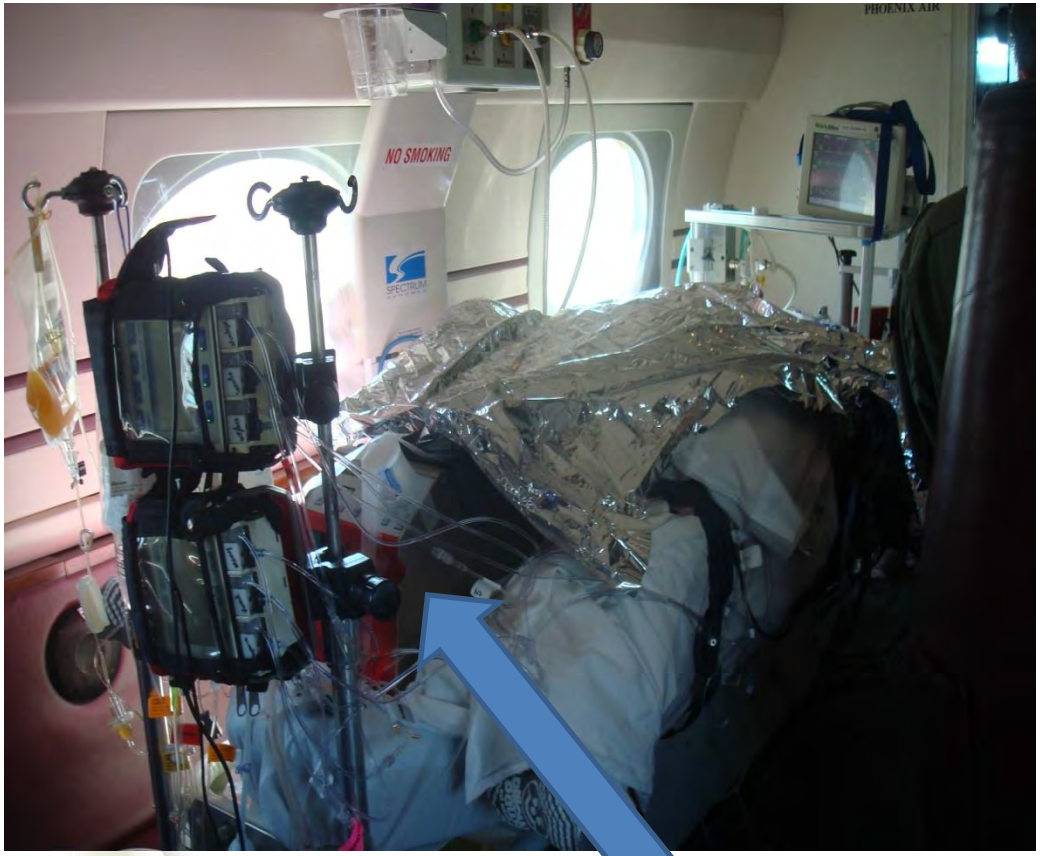
56 year old civilian we started at Straub Hospital in Hawaii then flew to Iowa

2. Ambulance to plane

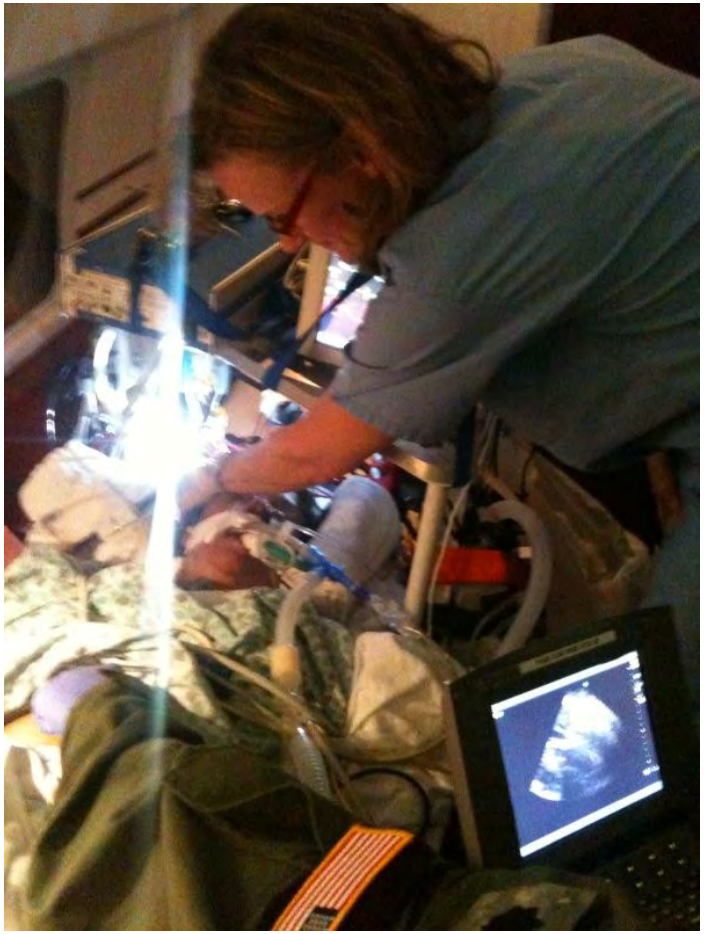
Conveyor belt, almost fell off at top

3. Flight – did well

Ultrasound for cannula position



Drive Console
Overheated



4. Plane to ambulance

Forklift

5. Ambulance to ICU

Had to Reconfigure Equipment

6. Transfer care

New circuit

Transient hypotension

Michael: 23 year old Marine with Severe Respiratory Failure
Japan → Hawaii → Iowa

Day 2 of ECMO

Cough, dyspnea,

Hypoxic, hypercarbic

13 days on ventilator

Large Right Air Leak

CO2 94, HCO 53

P/F ratio 88

Follows commands, writing to us via notepad

Prior health excellent

Massive bleeding in Hawaii

Right lung
Bleeding

Bronch in
Japan, HI

Antithrombin

Transport from Hawaii to Iowa

After 3 hours of flight; Mixed venous 48%, pulse oximetry on finger also 66%, Hgb 14.8

Pool or ocean?

After Starting Flolan - O2 and SvO2 Saturation quickly improved

38 days of ECMO, complex course at Tripler and Iowa

Coded X2 Iowa
PEA epi, shock
VF epi X2, shock X2

Prolonged hypoxia..

What about his Brain?

Video – made for non medical people

Initiation of Extracorporeal Support in Adults

- VV ECMO, VA ECMO, eCPR
  - Three different groups of patients
- Recognize failure of optimal management early
- Ensure that optimal evidence based therapy has been achieved
- Select patients with a reasonable chance for a bridge to recovery, device, or transplant…

Extracorporeal support will define the future of the modern ICU.

Questions?
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