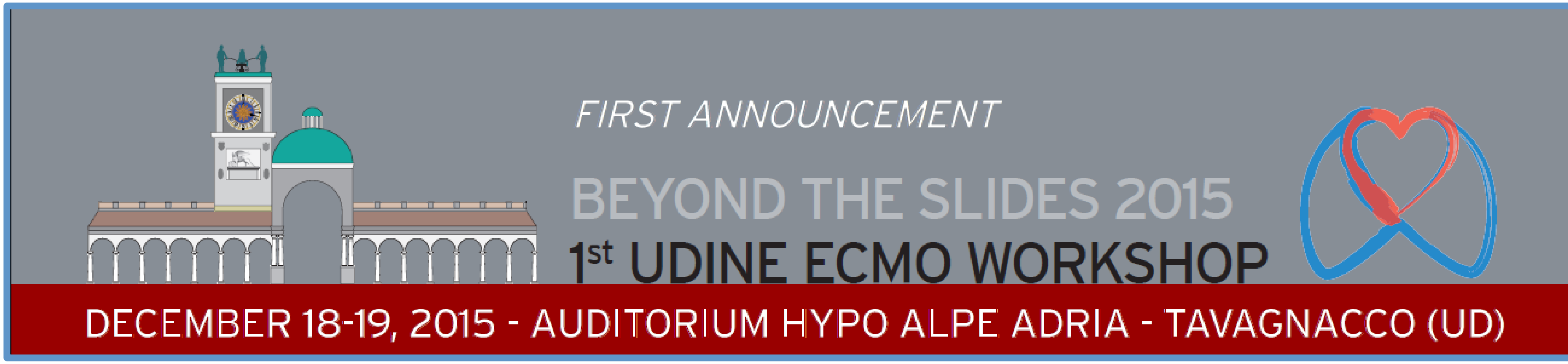

Recovery and weaning strategies

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Extra Corporeal Membrane Oxygenation

As

Bridge to Life

For refractory cardiogenic shock

Still a chance…

ECMO

Extra Corporeal Membrane Oxygenation

- Management life threatening pulmonary and/or cardiac failure

- Temporary support

  *-Bridge to decision **(Candidacy)***

  -Bridge to recovery

  -Bridge to transplantation

  -Bridge to bridge

  -Bridge to conventional surgery

Circulation
American Heart Association
Advances in Mechanical Circulatory Support
Mechanical Circulatory Support for Advanced Heart Failure
Patients and Technology in Evolution
Circulation March 13, 2012

Table 1. Implant Strategies and Target Populations for Mechanical Circulatory Support

Strategy	Definition	Target Population
Bridge to transplant (BTT)	For patients actively listed for transplant that would not survive or would develop progressive end-organ dysfunction from low cardiac output before an organ becomes available.	Patients with progressive end-organ dysfunction or refractory congestion, those anticipated to have a long waitlist time (eg, highly sensitized, blood group O), or who desire improved quality of life while waiting.
Bridge to candidacy (BTC)	For patients not currently listed for transplant, but who do not have an absolute or permanent contraindication to solid-organ transplant. This includes patients in whom potential for recovery remains unclear.	Patients who might be eligible for transplant after a period of circulatory support that allows for improved end-organ function, unloading (eg, pulmonary vasodilation) or nutrition, resolution of a comorbid condition (eg, cancer treatment) or institution of lifestyle changes (eg, weight loss, smoking cessation).
Destination therapy (DT)	For patients who need long-term support, but are not eligible for transplant because of one or more relative or absolute contraindications.	Older patients (eg, >70 y) or those with multiple comorbidities anticipated to require only left ventricular support.
Bridge to recovery (BTR)	For patients who require temporary circulatory support, during which time the heart is expected to recover from an acute injury, and mechanical support is then removed without need for transplant.	Patients with reversible cardiac insults such as post–myocardial infarction or post–cardiotomy shock, fulminant myocarditis, or peripartum cardiomyopathy.

Bridge To Recovery (BTR)

- **Weaning Strategies**
- **Predictors of ECMO weaning**

Intensive Care Med (2011) 37:1738–1745
DOI 10.1007/s00134-011-2358-2

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Predictors of successful extracorporeal membrane oxygenation (ECMO) weaning after assistance for refractory cardiogenic shock

ECMO weaning trials

- **Hemodynamically stable**
  - *MBP > 60 mmHg*
  - *No or low-dose vasoactive agents*
  - *Pulsatile arterial waveform*

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ECMO weaning trials

- **ECMO flow decreased to:**
  - **66% for 10-15 min**
  - **33% for 10-15 min**
  - **Minimum of 1-1.5 L/min for another 10-15 min**

If MBP dropped significantly and was constantly < 60 mmHg during the trial, ECMO flow was returned to 100% of the initial flow and the trial was stopped

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ECMO weaning trials

- **Doppler echocardiography at each ECMO flow level:**
  - **Minimum of 1-1.5 L/min**
  - **LVEF >20-25%**
  - **VTI >10 cm**

Weaning successful completed and ECMO removed after prolonged (10-20 min) complete circuit clamping in the OR

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Predictors of successful extracorporeal membrane oxygenation (ECMO) weaning after assistance for refractory cardiogenic shock

Table 1 Patients' clinical characteristics at time of ECMO implantation according to weaning trial performance

Characteristic	Tolerated weaning trial ($n = 38$)	Did not undergo/tolerate weaning trial ($n = 13$)
Age (years)	49 ± 14	67 ± 11
Males	26 (68)	8 (62)
ECMO indications		
Dilated cardiomyopathy	6 (16)	2 (15)
Ischemic cardiopathy	13 (34)	3 (23)
Fulminant myocarditis	3 (8)	0
Postcardiotomy	5 (13)	6 (46)
Posttransplantation	4 (11)	1 (8)
Others	7 (18)	1 (8)
Transfer from other centers	10 (26)	1 (8)
Femoral (versus central) ECMO	22 (59)	4 (31)
Cardiac arrest before ECMO	4 (11)	5 (38)
ECMO under CPR	5 (13)	2 (15)
Intraaortic balloon pump	11 (29)	2 (15)
SAPS II	65 ± 21	81 ± 17
SOFA score	14 ± 5	15 ± 7
Patients on mechanical ventilation	33 (87)	13 (100)
Renal replacement therapy	12 (32)	4 (31)
Serum creatinine (mmol/L)	152 ± 101	190 ± 85
pH	7.33 ± 0.10	7.35 ± 0.15
Lactate level (mmol/L)	7.3 ± 5.4	7.3 ± 6.1
Prothrombin activity (%)	52 ± 21	49 ± 19

Values are *n* (%) or mean ± SD
ECMO extracorporeal membrane oxygenation, *CPR* cardiopulmonary resuscitation, *SAPS* Simplified Acute Physiology Score, *SOFA* Sepsis-Related Organ Failure Assessment Score

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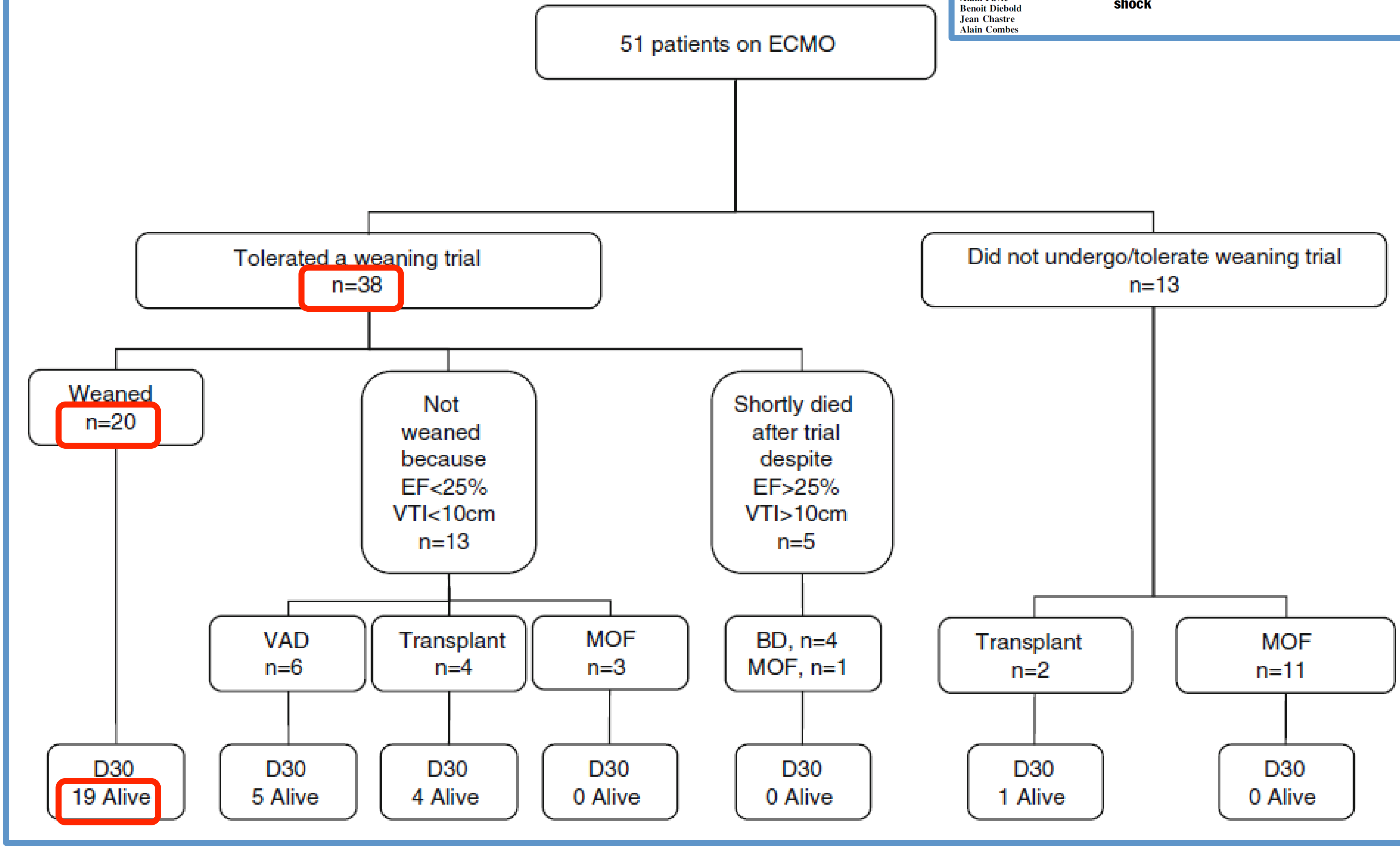

Table 2 Outcomes of the 51 patients who underwent ECMO support

Parameter	Tolerated weaning trial ($n = 38$)	Did not undergo/tolerate weaning trial ($n = 13$)
ECMO duration (days)		
Mean ± SD	8 ± 6	4 ± 2
Median (IQR)	7 (3–10)	3 (2–4)
Serious complications under ECMO	16 (42)	7 (54)
Major bleeding	7 (18)	6 (46)
Arterial ischemia	1 (3)	1 (8)
Surgical wound infection	2 (5)	1 (8)
Pulmonary edema	7 (18)	0
Stroke	2 (5)	1 (8)
Need for renal replacement therapy	12 (32)	4 (31)
ICU length of stay, days	19 (9–33)	3 (2–5)
30-Day survivors	28 (74)	1 (8)

Values are *n* (%) or median (interquartile range, IQR)

ECMO extracorporeal membrane oxygenation, *ICU* intensive care unit

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Predictors of successful extracorporeal membrane oxygenation (ECMO) weaning after assistance for refractory cardiogenic shock

Table 3 Hemodynamic and Doppler echocardiography characteristics (at minimal ECMO flow) of the 33 hemodynamically stable patients who tolerated an ECMO weaning trial the day before successful/unsuccessful weaning

Characteristic	Weaned ($n = 20$)	Nonweaned ($n = 13$)
ECMO duration (days)		
Mean ± SD	7 ± 4	11 ± 7
Median (interquartile range)	6 (3–8)	7 (5–17)
Pulse pressure (mmHg)	52 ± 12	39 ± 15
Heart rate (b/min)	95 ± 16	115 ± 19
Echocardiographic parameters		
Aortic VTI (cm)	16.4 ± 3.6	8.5 ± 2.3
LVEF (%)	37 ± 11	10 ± 7
TDSa (cm/s)	7.9 ± 1.2	4.3 ± 0.7
E (cm/s)	76 ± 16	71 ± 18
TDI Ea (cm/s)	10.1 ± 4.9	8.5 ± 3.0
E/Ea	8.7 ± 3.4	9.4 ± 4.6

Values are *n* (%) or mean ± SD

ECMO extracorporeal membrane oxygenation, *aortic VTI* aortic time–velocity integral, *LVEF* LV ejection fraction, *TDSa* spectral tissue Doppler imaging mitral annulus peak systolic velocity, *E* transmitral early peak diastolic velocity, *E/Ea* ratio of transmitral early peak (E) diastolic velocity to spectral tissue Doppler lateral mitral annulus peak systolic early diastolic (Ea) annular velocity

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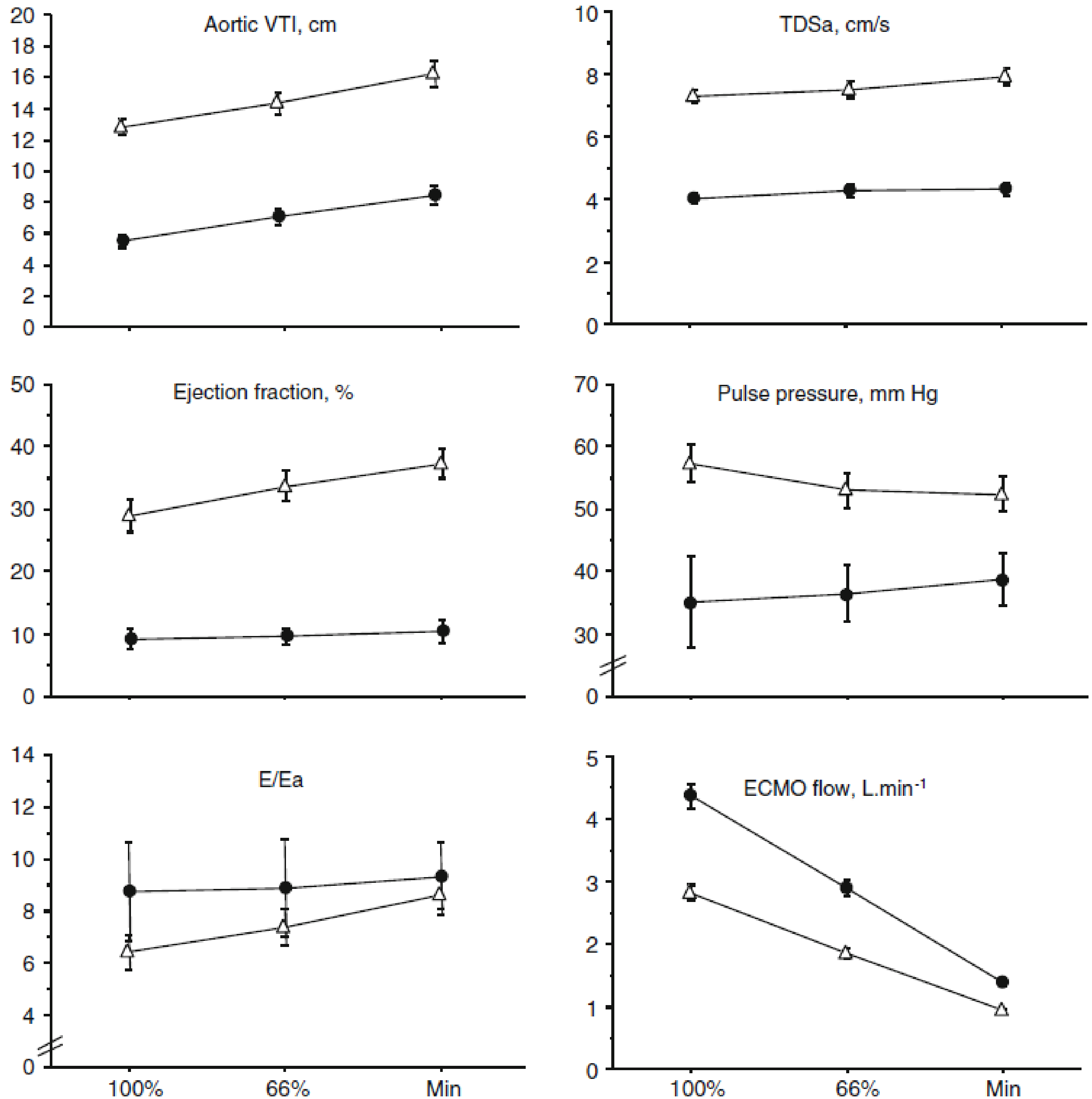

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Fig. 2 Evolution of clinical and Doppler echocardiography parameters for the 33 hemodynamically stable patients who tolerated maximal ECMO flow reduction at different flow levels for weaned (*open triangles*) and nonweaned (*closed circles*) patients. Significant differences existed between weaned and nonweaned patients (repeated-measures analysis of variance) for aortic VTI ($p < 0.0001$), TDSa ($p < 0.001$), LVEF ($p = 0.04$), and pulse pressure ($p = 0.007$), but not for mitral E wave or E/Ea. *VTI* time–velocity integral, *TDSa* spectral tissue Doppler imaging mitral annulus peak systolic velocity, *E/Ea*, ratio of transmitral early peak (E) diastolic velocity to spectral tissue Doppler lateral mitral annulus peak systolic early diastolic (Ea) annular velocity

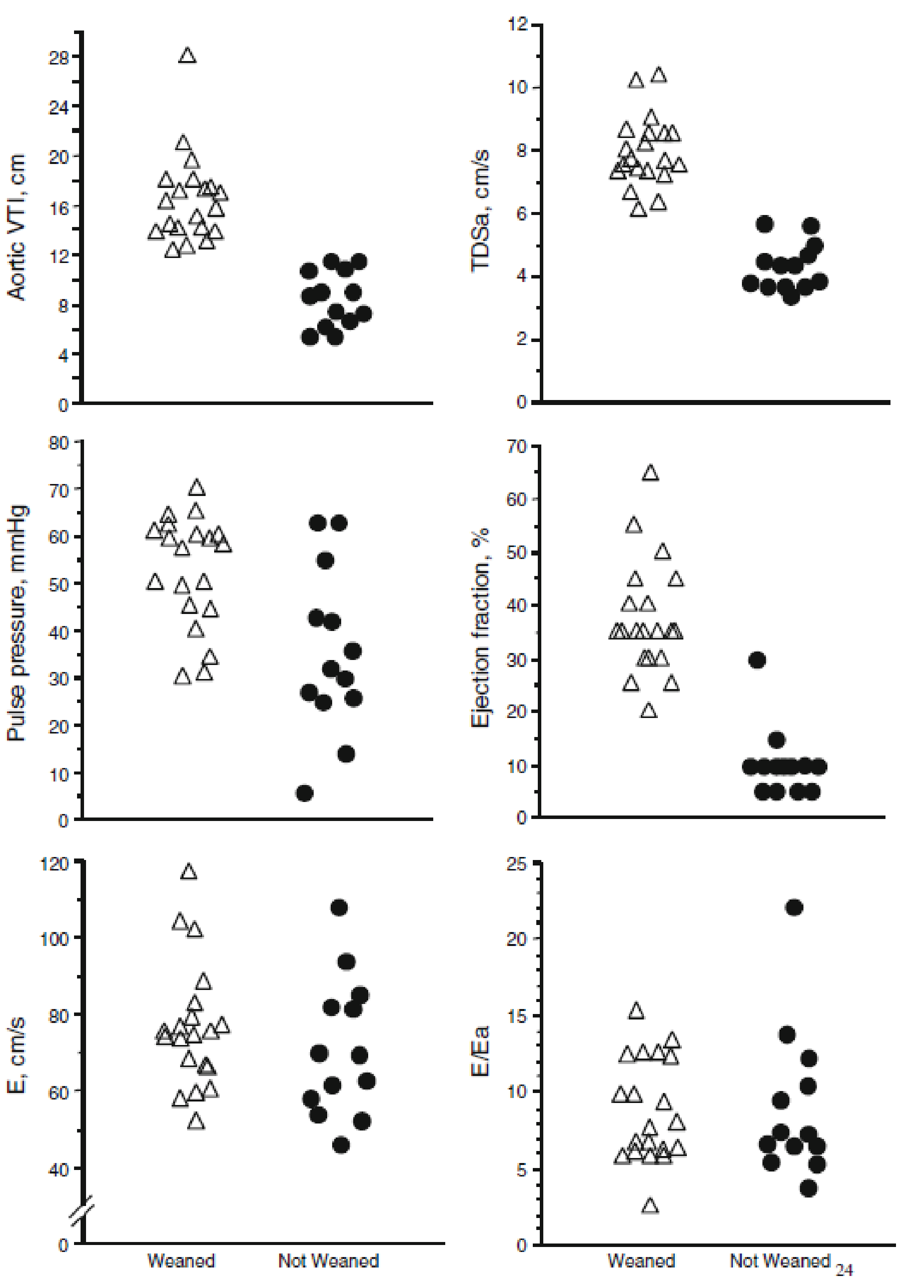

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Fig. 3 Clinical and Doppler echocardiography parameters at minimal ECMO flow for the 33 hemodynamically stable patients who tolerated maximal ECMO flow reduction and were weaned (*open triangles*) and nonweaned (*closed circles*)

Full ECMO weaning trial

- ***Aortic VTI ≥10 cm***
- ***LVEF > 20-25%***
- ***TDSa ≥ 6cm/s***

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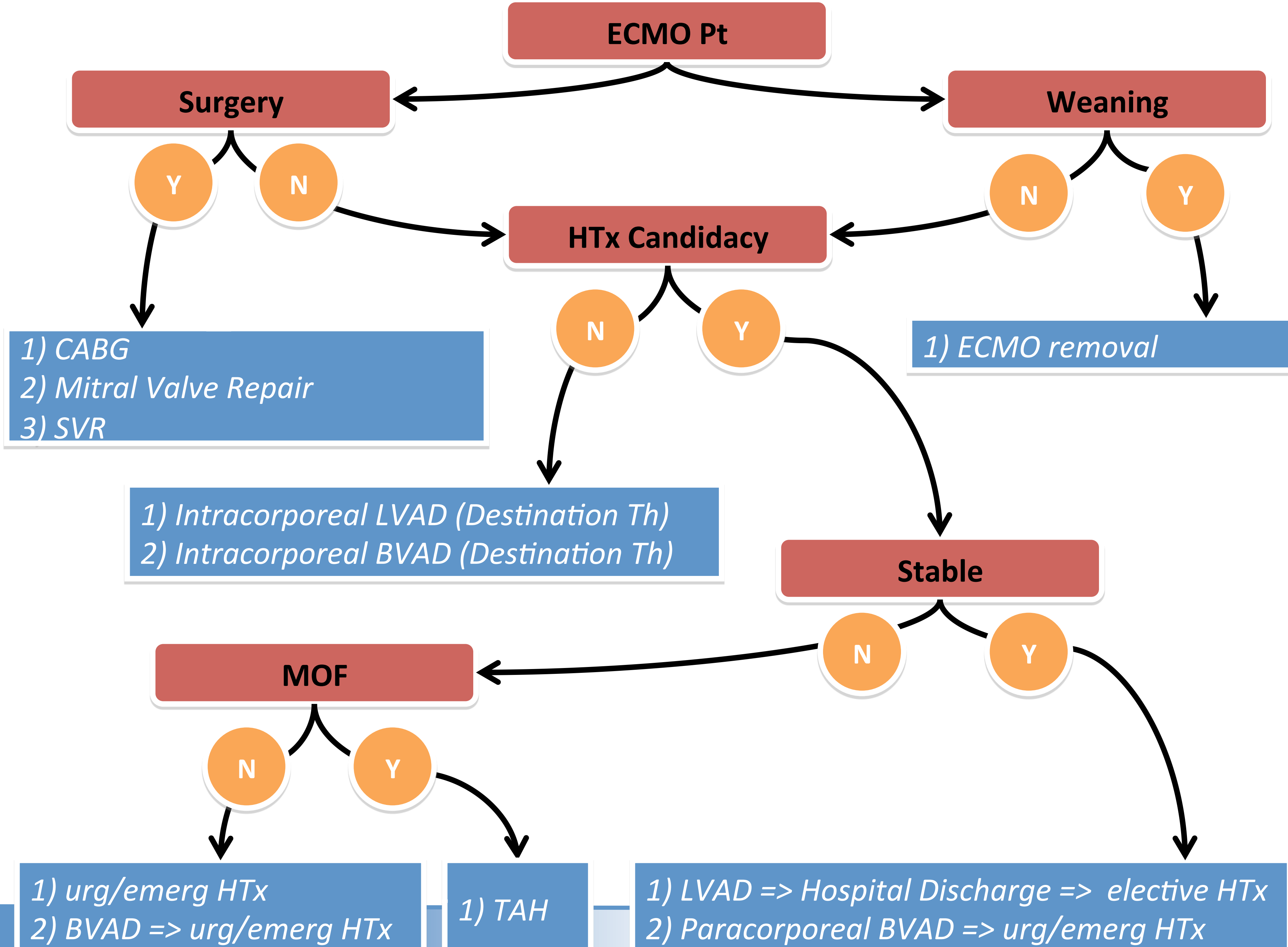
Bridge To Recovery (BTR) Padua Experience

- **Weaning Strategies**
- **Predictors of ECMO weaning**


ECMO Pt
Surgery
Weaning
Y
N
N
Y
HTx Candidacy
1) CABG
2) Mitral Valve Repair
3) SVR
1) ECMO removal
N
Y
1) Intracorporeal LVAD (Destination Th)
2) Intracorporeal BVAD (Destination Th)
Stable
N
Y
MOF
N
Y
1) urg/emerg HTx
2) BVAD => urg/emerg HTx
1) TAH
1) LVAD => Hospital Discharge => elective HTx
2) Paracorporeal BVAD => urg/emerg HTx

ECMO
Padua Experience

- ECMO System
- ECMO Placement
- Anticogulant Management
- ECMO and Pt Management
- Weaning Trial

ECMO
Padua Experience

- ECMO System
- ECMO Placement
- Anticogulant Management
- ECMO and Pt Management
- Weaning Trial

PLS™ ECMO (Maquet)

Pre-assembled, portable, "all-in-one" design including *oxygenator* (Quadrox D™), *centrifugal pump* (Rotaflow™), and heparin coated tubes as well as an optional heat exchanger

ECMO
Padua Experience

- ECMO System
- ECMO Placement
- Anticogulant Management
- ECMO and Pt Management
- Weaning Trial

ECMO
CONFIGURATIONS

- **Veno-Venous (VV) ---** only respiratory failure
- **Veno-Arterial (VA) ---** respiratory and cardiac support

- **Central** (Right Atrium - Aorta)

- **Peripheral (Cannulas inserted percutaneously)**

  -VV ECMO (Jugular Vein - Femoral Vein)

  -VA ECMO (Femoral Vein - Femoral or Subclavian Artery)

CONFIGURATIONS

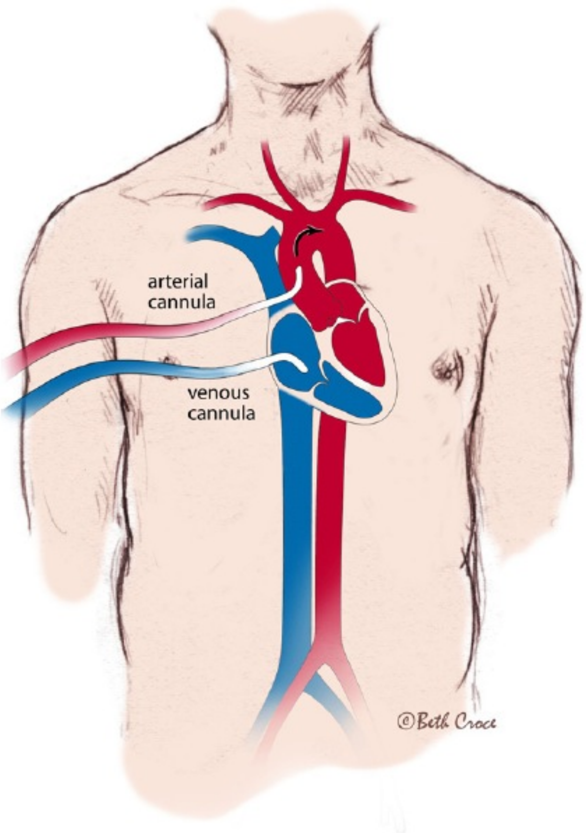


Figure 1. *Central ECMO cannulation.*

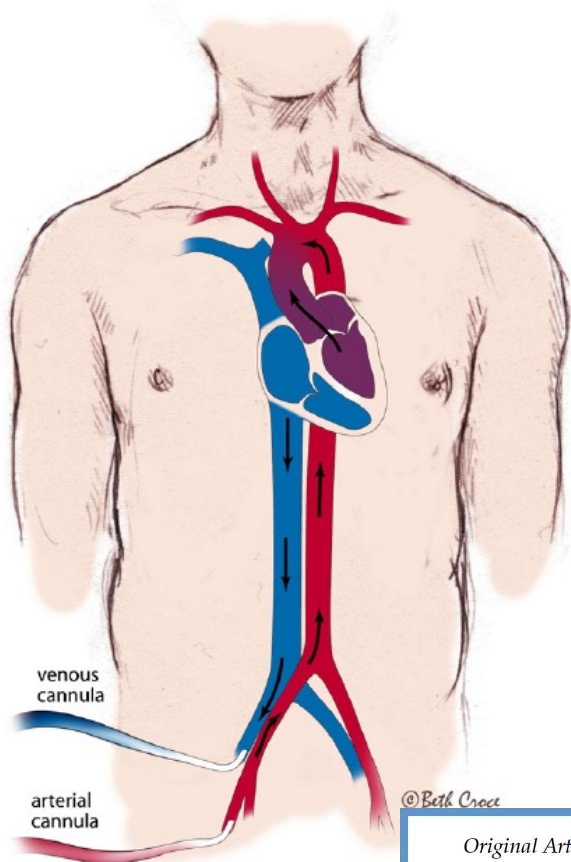


Figure 2. *Peripheral ECMO cannulation.*

Original Article

Review of ECMO (Extra Corporeal Membrane Oxygenation) Support in Critically Ill Adult Patients

Silvana F. Marasco, MS, FRACS[a,b,*], George Lukas, MBBS[c], Michael McDonald, CCP[d], James McMillan, CCP[d] and Benno Ihle, MD, FRACS[e]

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(Heart, Lung and Circulation 2008;17S:S41–S47)

ECMO
Padua Experience

- ECMO System
- ECMO Placement
- Anticogulant Management
- ECMO and Pt Management
- Weaning Trial

Anticoagulant Management

- *Before implant*: Heparin 5000 UI bolus -> ACT 180 s
- *In ICU*: Heparin infusion -> aPTT 50-60 sec
- ROTEM to manage thrombotic/hemorragic complications

ECMO
Padua Experience

- ECMO System
- ECMO Placement
- Anticogulant Management
- **ECMO and Pt Management**
- Weaning Trial

ECMO and Pt Management

I Phase: Full flow support (BSA*2.4 L/min)

- Cardiac function totally replaced
- Circulatory support and organ perfusion

II Phase: Partial support

- **Pulsatility**
- Maintain inotropes/IABP: heart opens aortic valve -> no need for vent
- MR (>3+/4): vasodilation
- Wake the pts to guarantee sympathetic tone
- Weaning from mechanical ventilation
- Extubation to reduce pulmonary resistance
- Reduce ECMO support (monitoring pulsatility, urine output, CVP, PCWP)
- 50-60% of estimated CO (BSA*2.4 L/min), monitoring lactates
- Reduce inotropic support

III Phase: Weaning

ECMO
Padua Experience

- ECMO System
- ECMO Placement
- Anticogulant Management
- ECMO and Pt Management
- **Weaning Trial**

Weaning Strategy

III Phase: Weaning Trial

- Hemodynamic stabilization
- Improvement of organ function (neurologic, respiratory, renal, or hepatic)

- **ECMO flow decreased to:**
  - **50% (I d)**
  - **35% (II d)**
  - **20% (III d)**
  - **Minimum of 1L/min for another day**
- **Doppler echocardiography at each ECMO flow level:**
  - **Ventricular function (LVEF)**
  - **Ventricular volume (EDVi, TR)**

Weaning Strategy

III Phase: Weaning Trial

Goal for weaning

- ECMO flow: 1 L/min
- aPTT 60-70 sec
- Awake and breathing independently
- Hemodynamically stable (monitoring pulsatility, lactates, urine output, CVP, PCWP)
- Systolic blood pressure > 85 mmHg
- Low dose inotropic support
- LVEF > 35%
- Normal right ventricular contractility
- EDVi < 100ml
- TR < severe

CARDIOTHORACIC TRANSPLANTATION AND MECHANICAL CIRCULATORY SUPPORT

Extracorporeal life support in cardiogenic shock: Impact of acute versus chronic etiology on outcome

Vincenzo Tarzia, MD,[a] Giacomo Bortolussi, MD,[a] Roberto Bianco, MD,[a] Edward Buratto, MBBS,[a] Jonida Bejko, MD,[a] Massimiliano Carrozzini, MD,[a] Marco De Franceschi, BSS,[a] Dario Gregori, MA, PhD,[b] Dario Fichera, CCP, MS,[a] Fabio Zanella, CCP,[a] Tomaso Bottio, MD, PhD,[a] and Gino Gerosa, MD[a]

The Journal of Thoracic and Cardiovascular Surgery • August 2015

PLS™ ECMO (Maquet)

Pre-assembled, portable, "all-in-one" design including *oxygenator* (Quadrox D™), *centrifugal pump* (Rotaflow™), and heparin coated tubes as well as an optional heat exchanger

METHODS

Between January 2009 and March 2013 64 patients in primary cardiogenic shock refractory to optimal conventional therapy (inotropes and intra-aortic-ballon-pump) were treated with the extracorporeal life support implantation. Veno-arterial extracorporeal membrane oxygenation has been implanted either at bedside under local anesthesia or in operating room.

Cardiogenic Shock
64 pts
(Jan 09 - Mar 13)

56pts → **ECMO** **Hub** Center

8 pts → **ECMO** **Spoke** Center

Refractory
Primary Cardiogenic Shock

- Systolic BP < 90 mmHg (inotropes/IABP)
- Pulmonary congestion
- Altered mental status
- Cold, clammy skin
- Oliguria (urine output < 30 ml/h for 3 hrs)
- Lactates > 2.0 mmol/L
- AST/ALT/bilirubin > 3 x normal limit

Refractory Primary Cardiogenic Shock

- **Exclusion criteria**:
  - Postcardiotomy shock
  - Severe neurologic involvement
    (anisocoria, signs of decerebration or focality)

- **Relative contraindications**:
  - Age > 75 yrs
  - Severe PVD

Acute vs Chronic

- ACUTE   Primary Cardiogenic Shock (A-PCS)

  "Acute event on a previously healthy heart"

- CHRONIC   Primary Cardiogenic Shock (C-PCS)

  "Acute deterioration of a chronic cardiomyopathy"

Patients

- **Patients** **64 (Jan 2009 – Mar 2013)**
- **Age (yrs)** **50 ±16**
- **Gender (M/F)** **52/12**
- **BSA (mq)** **1.83±0.2**

AETIOLOGY	**Overall (n=64)**	**"Acute" A-PCS (n=37)**	**"Chronic" C-PCS (n=27)**
AMI	26 (41%)	26 (70%)	0
Myocarditis	4 (6%)	4 (11%)	0
Pulmonary embolism	6 (9%)	6 (16%)	0
Post-partum CM	1 (2%)	1 (3%)	0
DCM	20 (31%)	0	20 (74%)
ICM	5 (8%)	0	5 (19%)
Congenital	2 (3%)	0	2 (7%)

Preoperative characteristics

	Overall (n=64)	A-PCS (n=37)	C-PCS (n=27)	*p (A vs C)*
Malignant arrythmia	29 (45%)	18 (49%)	11 (41%)	*0.0368*
CPR within 72h	32 (50%)	26 (70%)	6 (22%)	*<0.0001*
N. of inotropes	1.9 ± 1	1.7 ± 1	2.1 ± 1.1	*0.009*
IABP	25 (39%)	19 (51%)	6 (22%)	*0.0014*
Respiratory failure	55 (86%)	32 (86%)	23 (85%)	*0.0417*
Mechanical ventilation	46 (72%)	29 (78%)	17 (63%)	*0.0118*
Renal failure	32 (50%)	14 (38%)	18 (67%)	*0.0014*
CVVH	8 (13%)	4 (11%)	4 (15%)	*0.71*
Hepatic failure	20 (61%)	7 (19%)	13 (48%)	*0.0007*
MOF	24 (38%)	12 (32%)	12 (44%)	*0.32*

Technique of implantation

A-PCS group
(n=37)

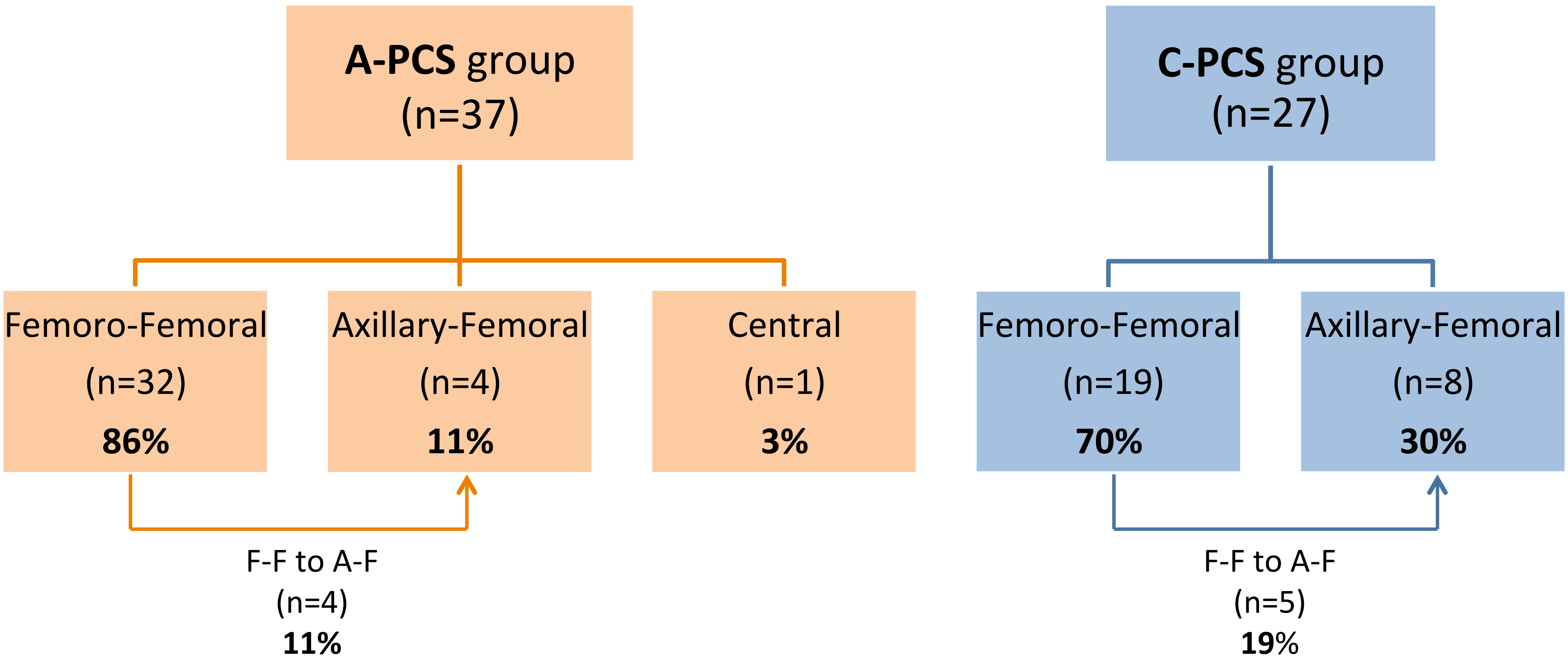
- **Bedside** (n=21) **57%**
- **O.R.** (n=16) 43%

C-PCS group
(n=27)

- **Bedside** (n=10) **37%**
- **O.R.** (n=17) 63%

	Overall (n=64)	A-PCS (n=37)	C-PCS (n=27)	*p (A vs C)*
Salvage CPR	17 (26.5%)	14 (37.8%)	3 (11%)	*0.02*

Cannulation site



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Results

	Overall (n=64)	A-PCS (n=37)	C-PCS (n=27)	*p (A vs C)*
Duration (days)	8.9 ±8.7	8.3 ±7.6	9.7 ±10.1	*0,540*
Flow (% of theoretical CO)	61 ±15	57 ±13	67 ±15	*0,004*
N. of inotropes (mean)	2.6 ±1.1	2,2 ±1.1	3,14 ±0.8	*<0,001*
Serum lactates (mmol/L)	3.2 ±2.6	2,6 ±1.4	3,8 ±3.6	*0,152*
TnI peak (µg/L)	86 ±160	135 ±192	20 ±56	*0,003*

Complications

	Overall (n=64)	A-PCS (n=37)	C-PCS (n=27)	*p (A vs C)*
Neurological	12 (19%)	8 (22%)	4 (15%)	*0,490*
Limb ischemia	9 (14%)	6 (16%)	3 (11%)	*0,720*
Bleeding	13 (20%)	8 (22%)	5 (19%)	*0,760*
Hemolysis	1 (2%)	1 (3%)	0	*1,000*
CVVH	22 (34%)	10 (27%)	12 (44%)	*0,140*
Oxygenator change	14 (22%)	5 (14%)	9 (33%)	*0,058*
Malfunction	4 (6%)	2 (5%)	2 (7%)	*1,000*
ARDS/Pulmonary congestion	5 (8%)	1 (3%)	4 (15%)	*0,150*
Sepsis	9 (14%)	3 (8%)	6 (22%)	*0,150*
MOF post	14 (22%)	8 (22%)	6 (22%)	*0,950*

Outcomes

A-PCS group (n=37)		**C-PCS** group (n=27)
Bridge-to-**Recovery** (n=18) **49%**	*p<.0001*	Bridge-to-**Recovery** (n=0) **0%**
Bridge-to-**Bridge** (n=9) **24%**	*p=.001*	Bridge-to-**Bridge** (n=14) **52%**
Bridge-to-**Transplant** (n=3) **8%**	*p=.001*	Bridge-to-**Transplant** (n=9) **33%**
Bridge-to-**Surgery** (n=1) **3%**		Bridge-to-**Surgery** (n=1) **4%**
Bridge-to-**Decision** (n=6) **16%**		Bridge-to-**Decision** (n=3) **11%**

Outcomes (2)

	Overall (n=64)	A-PCS (n=37)	C-PCS (n=27)	*p (A vs C)*
Mortality in ECMO	9 (**14%**)	6 (16%)	3 (11%)	*0,720*
Mortality 30-day	13 (20%)	6 (16%)	7 (26%)	*0,024*
In-Hospital Mortality	27 (42%)	15 (41%)	12 (44%)	*0.802*
Discharged from hospital	37 (**59%**)	22 (59%)	15 (56%)	*0,750*

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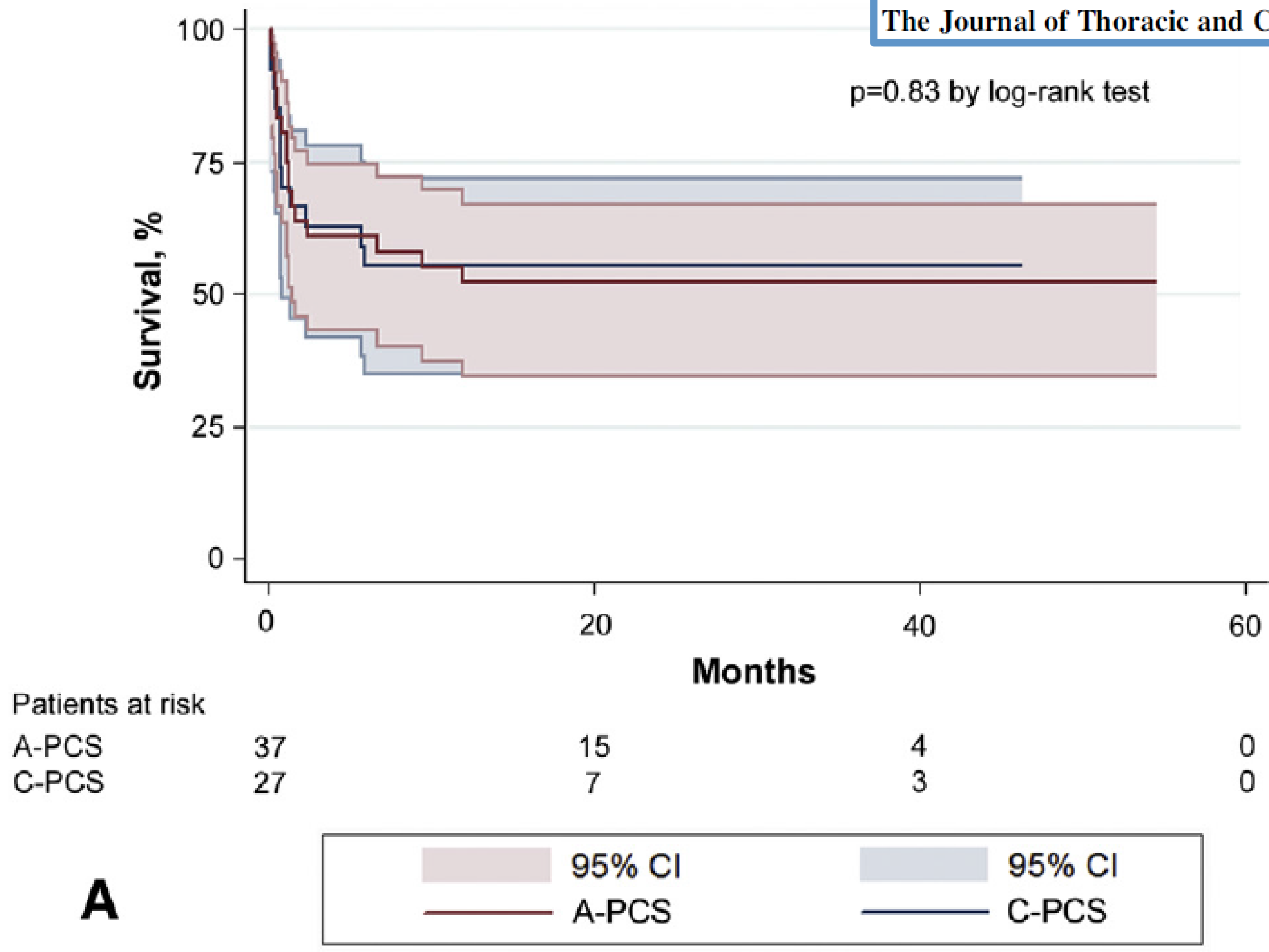

All Patients

Extracorporeal life support in cardiogenic shock: Impact of acute versus chronic etiology on outcome

Vincenzo Tarzia, MD,[a] Giacomo Bortolussi, MD,[a] Roberto Bianco, MD,[a] Edward Buratto, MBBS,[a] Jonida Bejko, MD,[a] Massimiliano Carrozzini, MD,[a] Marco De Franceschi, BSS,[a] Dario Gregori, MA, PhD,[b] Dario Fichera, CCP, MS,[a] Fabio Zanella, CCP,[a] Tomaso Bottio, MD, PhD,[a] and Gino Gerosa, MD[a]

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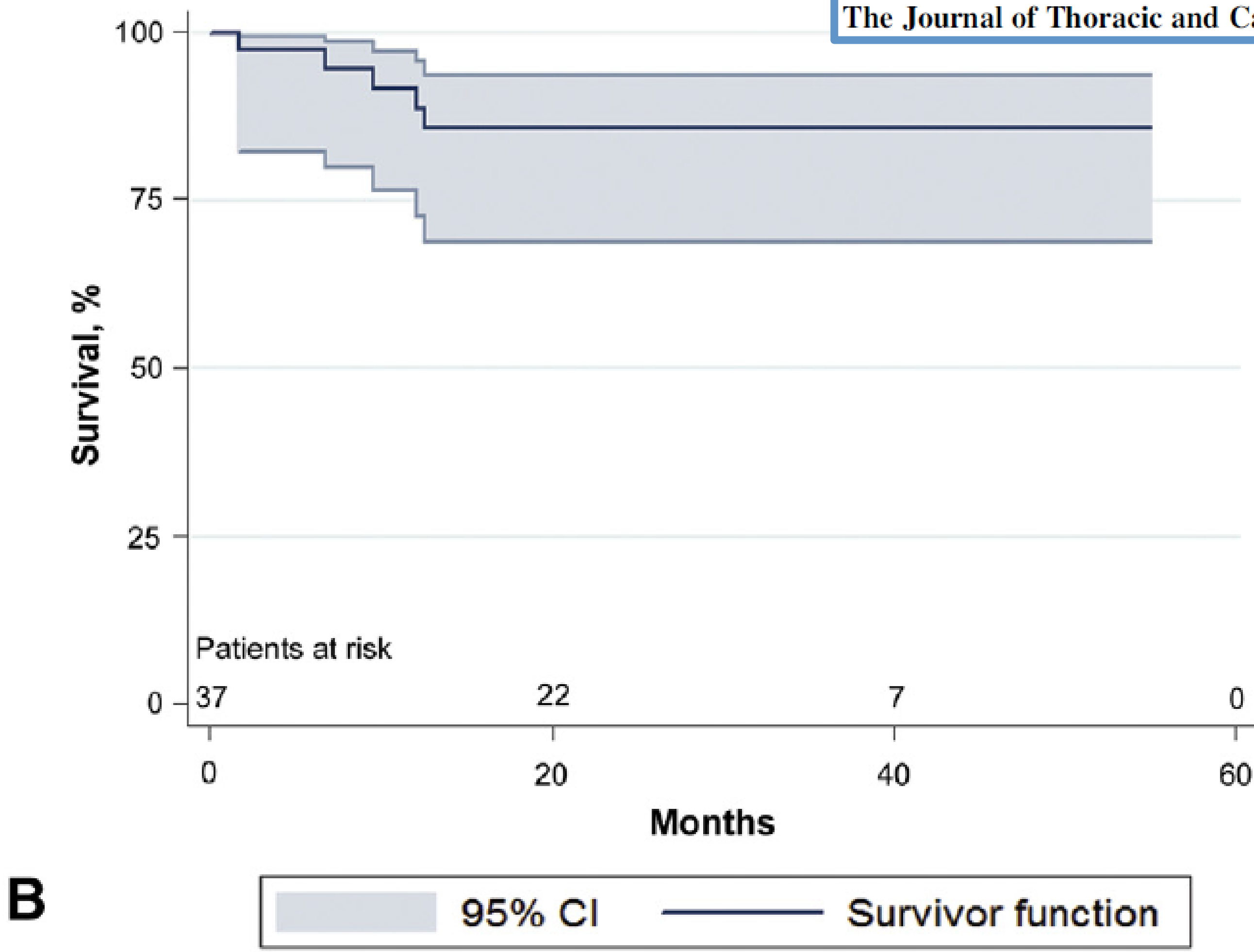

Discharged Patients

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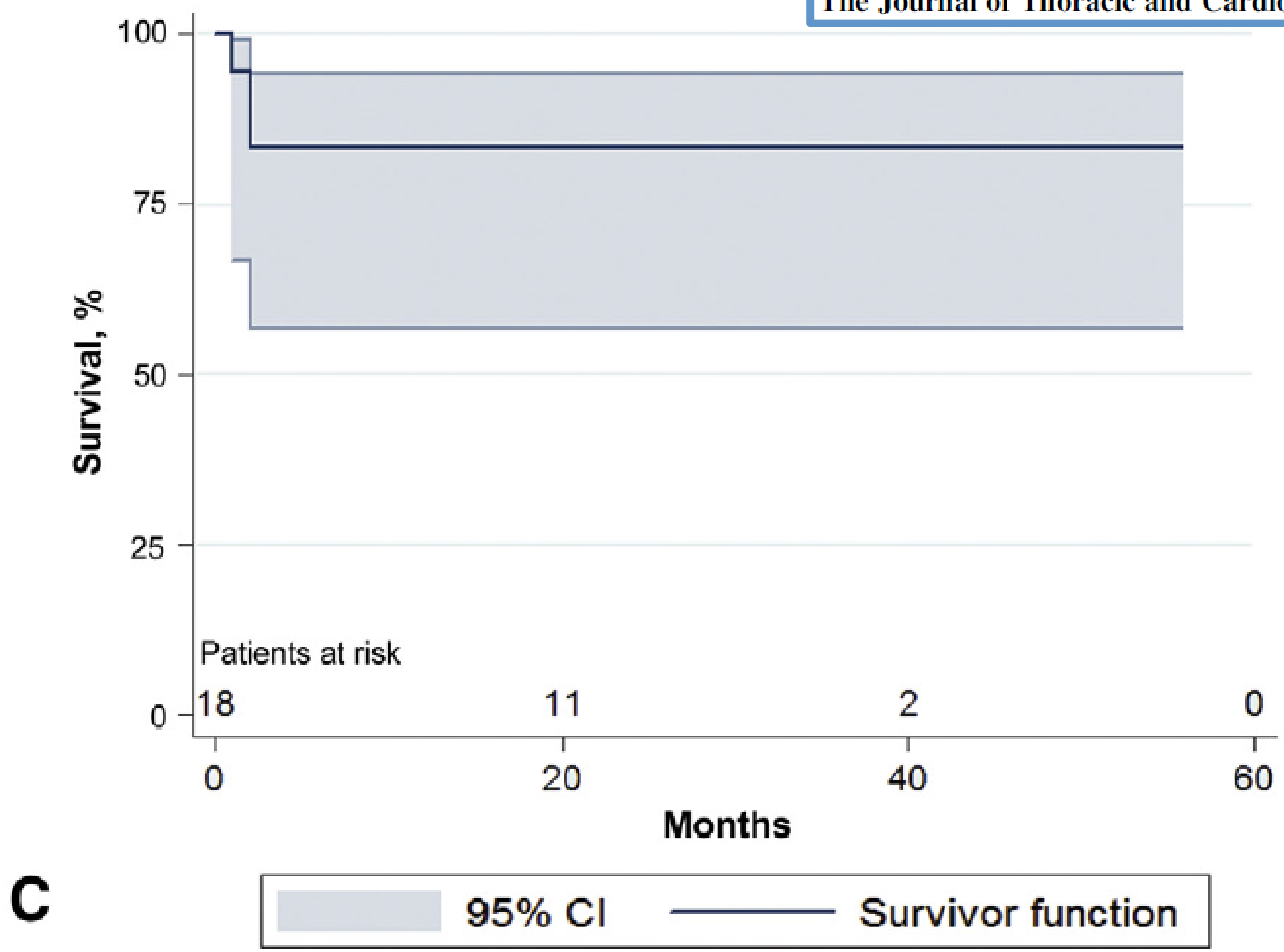
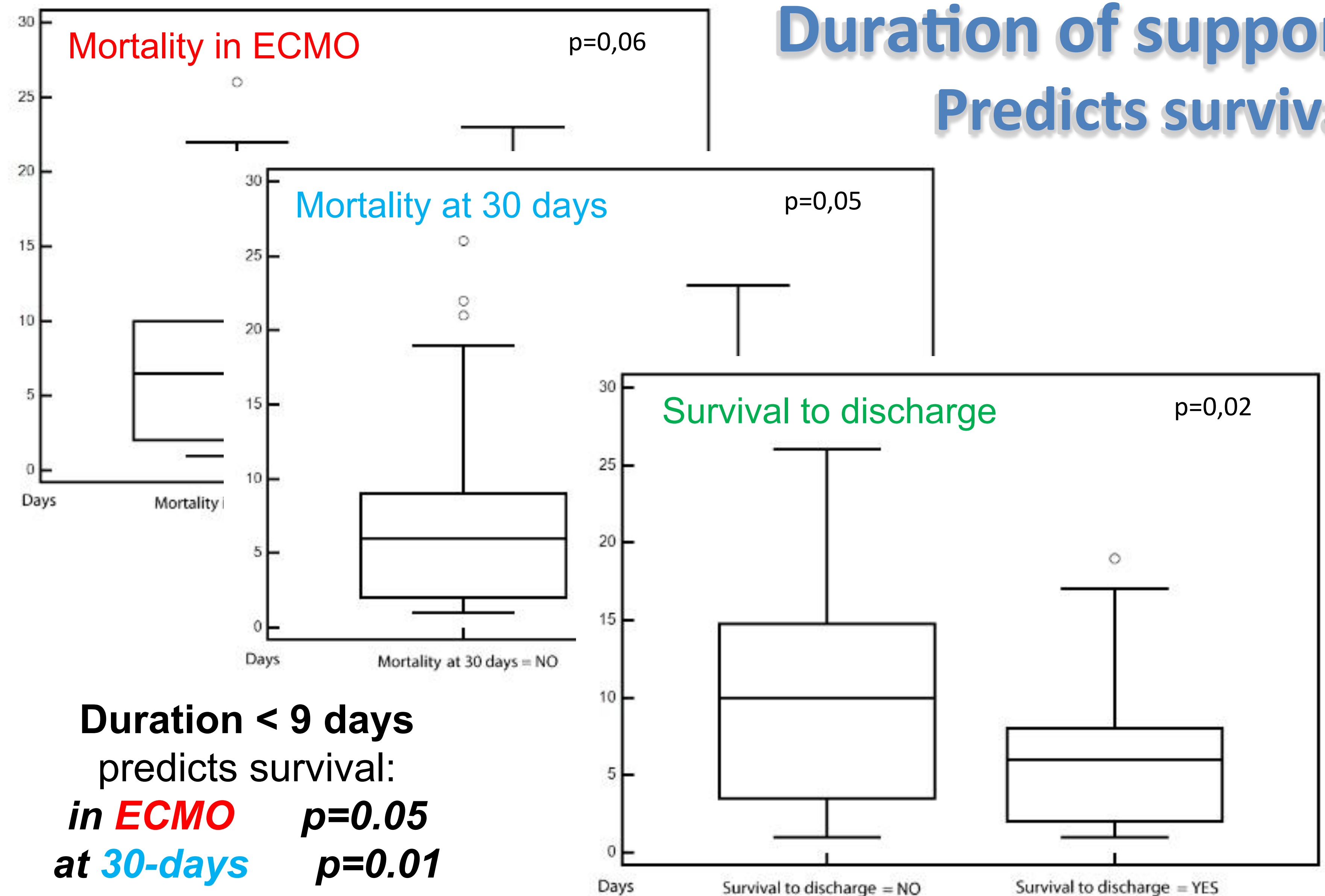


Bridge To Recovery

Duration of support Predicts survival



Duration < 9 days
predicts survival:

in ECMO ***p=0.05***
at 30-days ***p=0.01***
to discharge ***p=0.002***

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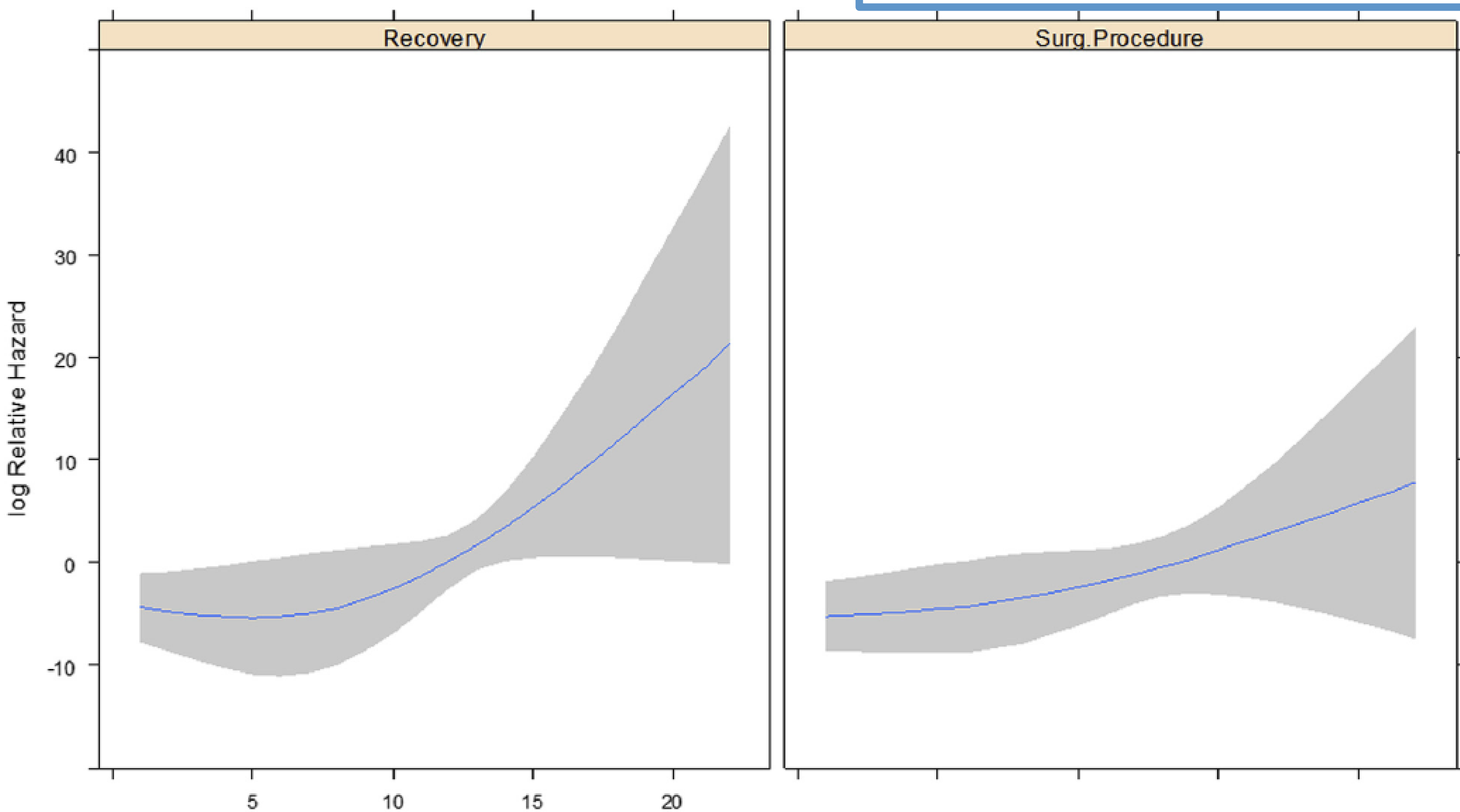
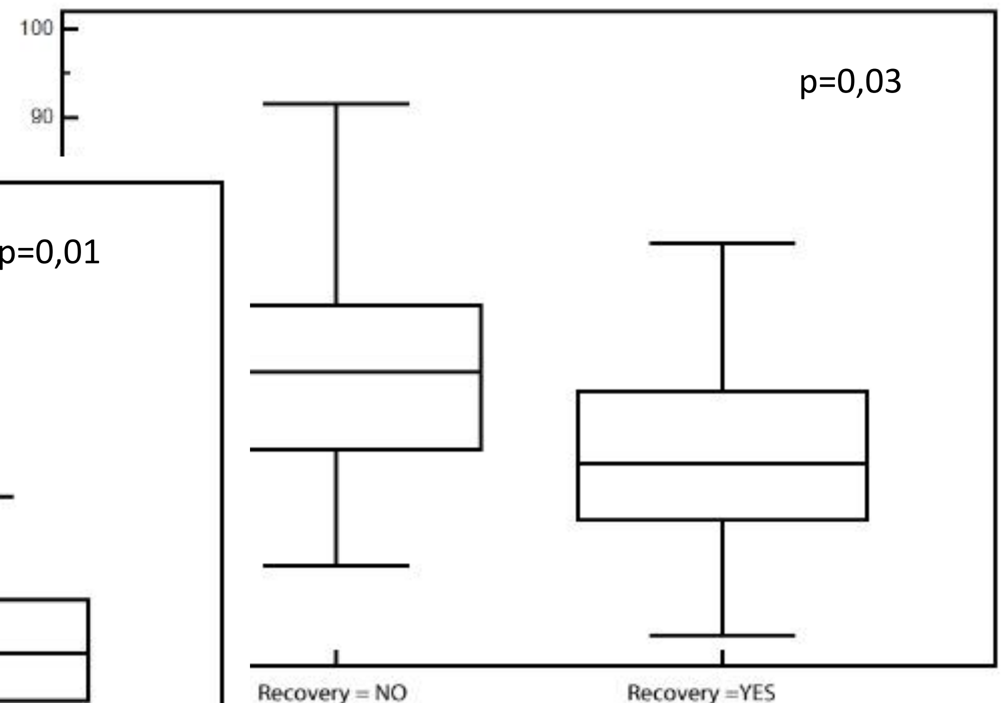


FIGURE 1. Impact of duration of ECLS on 30-day survival for the 2 distinct states: "recovery" and "surgical procedure." Risk of dying at 30 days increases at a constant rate throughout the duration of ECLS for patients in the surgical procedure stage. In patients who recovered, the risk of dying at 30 days increases steadily only after 9 days on ECLS. *Surg*, Surgery; *ECMO*, extracorporeal membrane oxygenation.

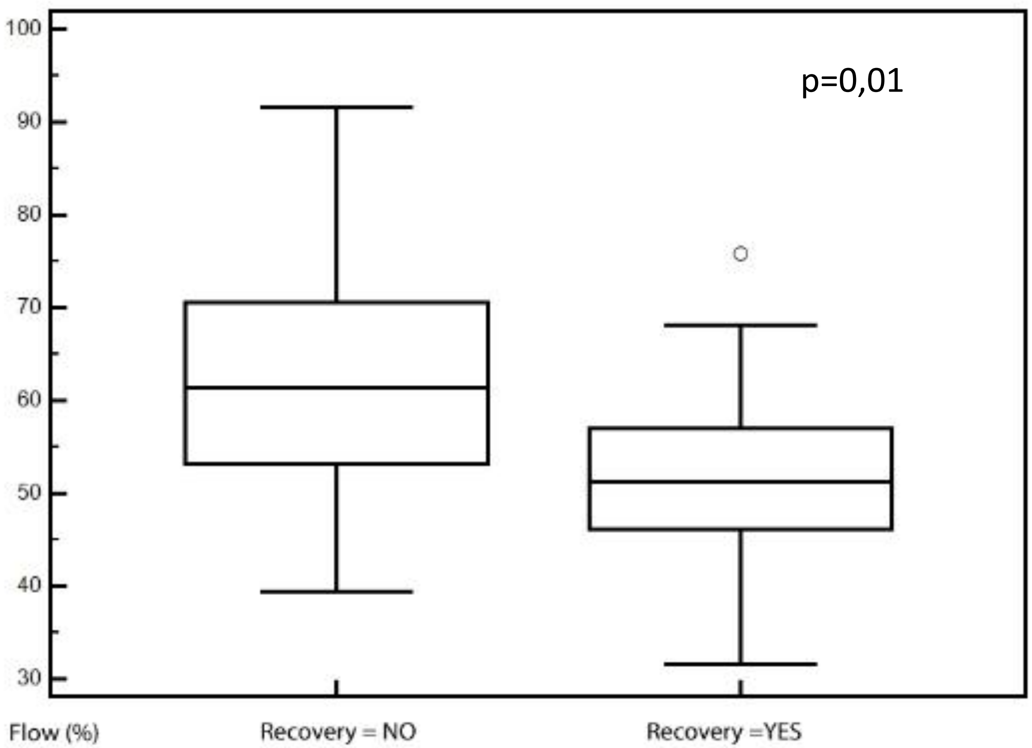
Flow (% of theoretical)
Predicts weaning

Required % of support is significantly related with recovery

Group A-PCS (n=37)



AMI subgroup (n=26)



Flow < 60%
Predictor of recovery
p=0.02

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Conclusions

- Mortality in ECMO: **14%**
- Survival to discharge: **59%**

ECMO as a
*"**Bridge-to-Life**"*

A-PCS Group, *acute* → **BTR**

C-PCS Group, *chronic* → **BTB, BTT**

Support < 9 days → Survival

Flow < 60% → Recovery

Padua Experience

•**Patients**	**132**
•**Period**	**Jan 2009 – Nov 2015**
•Age (yrs)	52 ±15
•Gender (M/F)	105/30 *(80% males)*
•BSA (mq)	1.86±0.2

AETIOLOGY	**Overall (n=132)**
AMI	46 (35%)
Myocarditis	8 (6%)
Pulmonary embolism	7 (5%)
DCM	38 (29%)
ICM	14 (11%)
Other	19 (14%)

Percutaneous implant: 55%

Mean **duration**: 8,3±8,5 Days

Mortality ECMO: 19%

Survival to discharge: 54%

A-PCS Group, *acute* → **BTR (47%)**

Take home message

- **Weaning Protocol**
- **Avoid Complications**
- **Etiology**
- **Flow**
- **Time**

Bridge To Recovery

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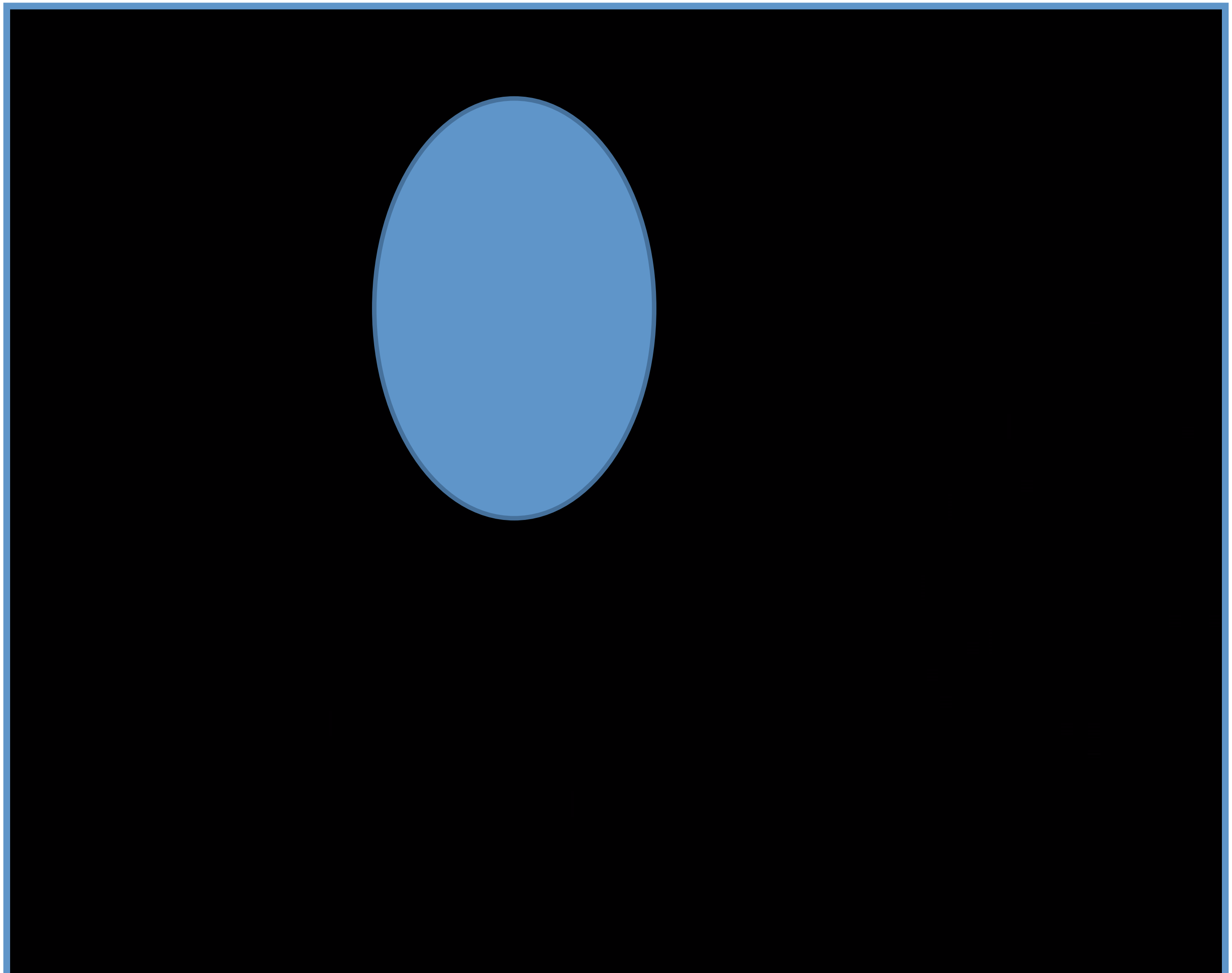
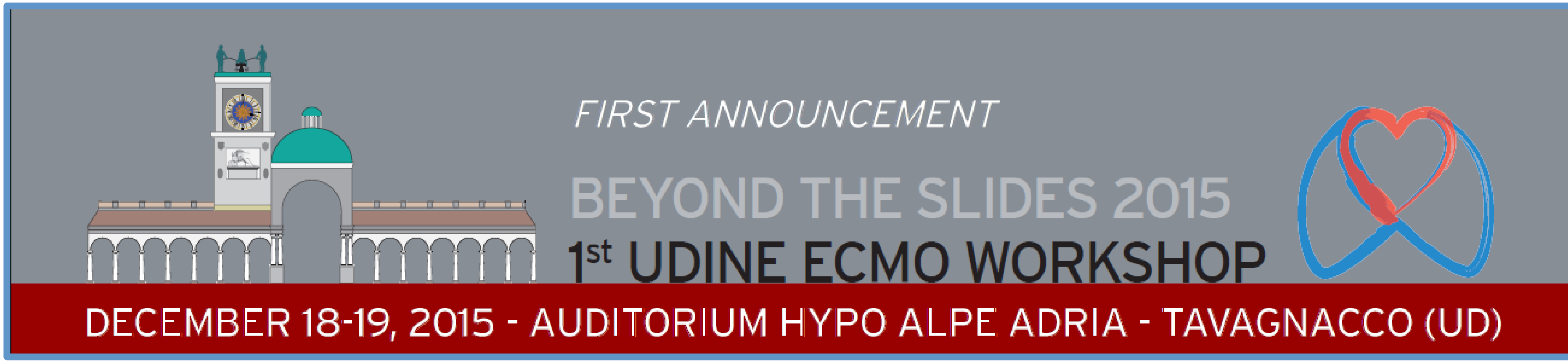
ECMO Placement

ECMO Management





Recovery and weaning strategies

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