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Topic: 2 - Adult - Cardiac failure

Abstract: 6

Application of ECMO support during transcatheter valvular procedures

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Objective: ECMO has gained use as a rescue therapy in refractory cardiovascular and respiratory compromise. Increasingly, it is considered for cardiopulmonary support during percutaneous coronary and structural heart interventions.

Methods: We report 3 cases wherein ECMO successfully facilitated transcatheter valvular procedures in patients who were not surgical candidates due to the severity of their illness.

Results: A 51-year-old male presented with myocardial infarction and cardiogenic shock. Echocardiogram showed severe mitral regurgitation from posterolateral papillary muscle rupture. He developed refractory hypoxia from pulmonary edema. He underwent emergent MitraClip under VV-ECMO. He was decannulated 4 days post-procedure and discharged home on day 7 of hospitalization.

A 47-year-old female presented with acute coronary syndrome, and despite revascularization, arrested from ventricular fibrillation. She was emergently placed on VA-ECMO. Echocardiogram showed severe functional mitral regurgitation. After optimization of hemodynamics and volume status on ECMO, she underwent MitraClip procedure 5 days later and was decannulated the same day. She was discharged a week later.

A 34-year-old male presented to an outside hospital with cardiac arrest from myocardial infarction requiring VA-ECMO and Impella support. Following decannulation, he was found to have acute severe aortic regurgitation related to a flail aortic valve cusp, which was likely injured during Impella placement. VV-ECMO was subsequently instituted for refractory hypoxemia. At our center, he underwent transcatheter aortic valve replacement (TAVR) with VV-ECMO support. His pulmonary status rapidly improved and efforts were directed at weaning ECMO. Unfortunately, the patient suffered a large intracranial hemorrhage and expired 6 days after his TAVR.

Conclusions: The emerging patient population with compromised cardiopulmonary function undergoing percutaneous therapies has seen the use of ECMO as a rescue intervention or for perioperative prophylaxis. Our cases illustrate instances that utilize ECMO for stabilization during high-risk percutaneous valvular procedures which might otherwise not be tolerated. Applications of ECMO in these situations deserve further examination.

Abstract: 9

The role of extracorporeal membrane oxygenation in major aortic surgery with particular reference to aortic dissection

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Objective: Very little is known about the role of extracorporeal membrane oxygenation for the management of patients undergoing major aortic surgery with particular reference to aortic dissection. We sought to review the available literature to determine if there was any evidence

Methods: A systematic literature search was undertaken through PubMed and EMBASE according to specific key words combined as follows: ECMO and aortic surgery; ECMO and aortic dissection; ECLS and aortic surgery; ECLS and aortic dissection

Results: The search retrieved 29 publications relevant to the subject: 1 brief communication; 1 surgical technique report; 1 invited commentary; 1 retrospective case review; 1 observational study; 4 retrospective reviews; 13 case reports and 7 conference abstracts. A total of 194 patients were included in these publications of whom 77 survived. The articles had been published between 1994

peripheral perfusion but for the cost of increased demands on the LV workload. To protect the myocardium from harm, VA ECMO flow should be adjusted with respect to not only systemic perfusion, but also to LV parameters.

Abstract: 423

Quantification of recirculation during veno-venous extracorporeal membrane oxygenation: In vitro evaluation of a thermodilution technique

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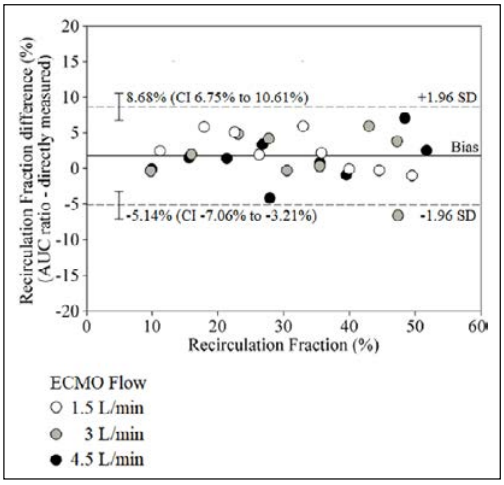
Objective: During Veno-Venous Extracorporeal Membrane Oxygenation (vv-ECMO) a certain amount of extracorporeal oxygenated blood can flow from the reinfusion cannula back into the drainage one without delivering oxygen to the patient. Recognition and quantification of this dynamic phenomenon, defined recirculation, are pivotal to maximize ECMO efficiency. This study aimed to quantify the recirculation fraction (RF) by means of a thermodilution technique.

Methods: We assembled an in-vitro circuit simulating a patient undergoing vv-ECMO with a recirculation bridge to achieve different known RFs. A cold bolus of 20 ml was injected downstream the ECMO pump, temperature was recorded on both the reinfusion and drainage lines. RF was computed as the ratio of the area under the temperature-time curves (AUC) of the drainage over reinfusion. We tested three ECMO flows (1.5, 3, and 4.5 L/min) with recirculation fractions ranging from 0% to 50% (5% incremental steps) performing three different thermodilutions for each step.



Corrected Bland-Altman plot for repeated measurements comparing the thermodilution with the known RF.

Results: A Bland-Altman analysis, see figure, showed an overall bias of 1.77%. Test-retest reliability showed an excellent intraclass correlation coefficient of 0.997 while the linear mixed model showed a significative effect of ECMO flow according to the following equation RF(%) = (-5.078- 1.454 x set ECMO flow) + (1.086 - 0.039 x set ECMO flow) x AUC ratio(%).

Conclusions: The thermodilution technique tested in this in-vitro study proved to be feasible and measure the RF of a vv-ECMO with high accuracy and precision. In vivo studies are needed to confirm these results.

Abstract: 425

End-organ effects of VA-ECMO flow rates in an animal model of severe cardiopulmonary failure

S.M. Colombo[1,2], S. Heinsar[1], S. Rozencwajg[1,3], C. Ainola[1], K. Sato[1], J.S. Jung[1,4], K. Wildi[1], X. Wang[1], G. Abbate[1], N. Sato[1], J. Reid[1], M. Bouquet[1], M. Passmore[1], V. Lo Coco[5], E. Wilson[1], J. Suen[1], A. Combes[3], R. Lorusso[5], A. Pesenti[2], G. Li Bassi[1], J.F. Fraser[1]

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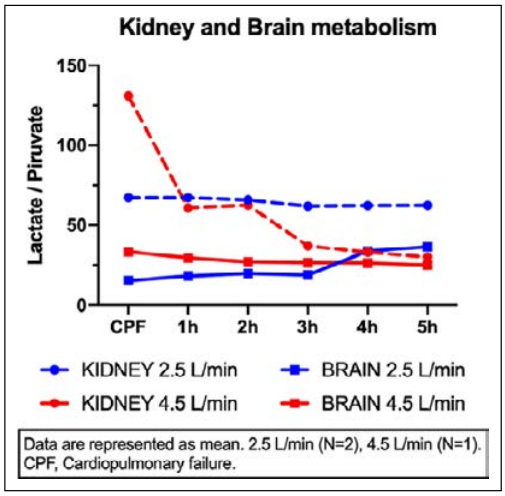
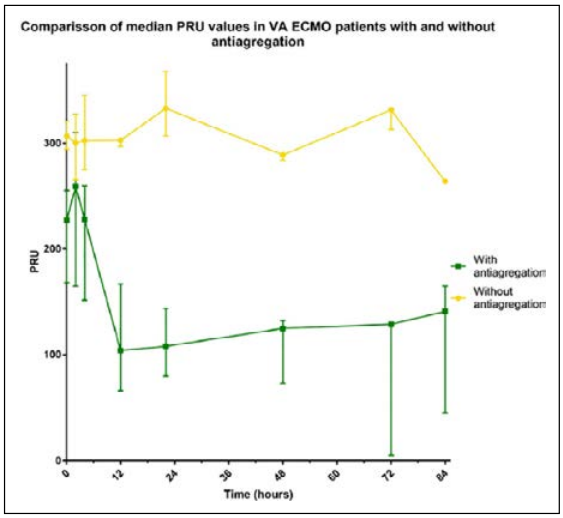
Objective: In severe cardiopulmonary failure (CPF), the appropriate veno-arterial extracorporeal membrane oxygenation (VA-ECMO) flow rate to efficiently support failing organs, while avoiding iatrogenesis is still questioned. We evaluated the effects of different VA-ECMO flow rates on end-organ parameters.

Methods: Three sheep (62±7 Kg) were anaesthetized, and mechanically ventilated. The humeral artery was cannulated for hemodynamic monitoring and blood sampling. Probes for appraising tissue oxygenation and blood flow (OxyLite and OxyFlo, Oxford Optronix, UK) and micro-dialysis (CMA63MD and 70MD, Kista, Sweden) were inserted into the brain and kidney. We cannulated the femoral artery and jugular vein and VA-ECMO commenced at 1 L/min. CPF was induced through multiple sub-epicardial injections of ethanol into the left ventricle and by reducing ventilatory support. Sheep were then randomized to VA-ECMO flow rate of either 2.5 or 4.5 L/min. Assessment were recoded hourly, up to 5 hours of follow-up. Due to the limited



Lactate-piruvate ratio in brain and kidney at different VA-ECMO blood flows.



Comparison of median PRU values in VA ECMO with and without antiaggregation.

number of evaluated animals, only descriptive statistics were performed.

Results: Two and one animals were included into the 2.5 and 4.5 L/min groups, respectively. Lactate/pyruvate showed better brain/kidney trends at 4.5 L/min (Figure1). As expected, higher kidney perfusion was found at 4.5 vs 2.5 L/min (789.6±168.5 vs. 7.6±5.3 BPU). While an inverse trend was found in brain oxygenation (0.4±0.5 vs 36.3±10.9 mmHg).

Conclusions: Very preliminary results provide interesting insights on benefits (improved tissue metabolism) and potential drawbacks (decreased brain oxygenation) of higher vs. lower VA-ECMO flow rates during CPF.

Abstract: 459

Platelet reactivity in patients treated with VA-ECMO and P2Y12 inhibitors

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Objective: One of the most frequent indications for veno-arterial (V-A) ECMO is the acute pump failure of the heart as a result of acute myocardial infarction. In these patients urgent coronarography and PCI are performed. Acetylsalicylic acid (ASA) and P2Y12 receptor inhibitors are used to prevent in-stent thrombosis. To find out the effect of ECMO membrane on platelet aggregation the prospective non randomised study was conducted. We present the preliminary results of the study.

Methods: The patients were divided into two groups: patients treated with V-A ECMO who simultaneously received P2Y12 receptor inhibitors and as a control group patients treated with V-A ECMO without antiaggregating drugs. The doses of antiaggregating drugs were standard and in accordance with the guidelines. Blood samples were taken prior and at 2, 4, 12, 22, 48, 72 after ECMO insertion and after removal of an ECMO. We performed optical aggregometry with VerifyNow®System (AccrivaDiagnostics) PRU test. High on-treatment platelet reactivity was defined as PRU >208.

Results: 19 consecutive patients with cardiogenic shock treated with V-A ECMO were included, 12 of them received P2Y12 inhibitors. Using Mann-Whitney U test PRU values in group with antiaggregating drugs were significantly lower from 4h hours onward ($p < 0.05$).

Conclusions: Inhibition of platelet aggregation with P2Y12 receptor inhibitors in patients on ECMO was effective but slowed down probably due to a critical illness, slowed metabolism and drugs administered (opioids, relaxants, sedatives).

Abstract: 470

Rescue extracorporeal resuscitation in refractory cardiac arrest after transport in different body position in a porcine model

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Objective: The extracorporeal cardiopulmonary resuscitation including extracorporeal membrane oxygenation

Abstract: 314

Extracorporeal membrane oxygenation during cardiac arrest (ECPR): Case report

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Objective: To report a case of ST-segment elevation acute myocardial infarction associated with severe cardiogenic shock and the use of extracorporeal life support.

Methods: Case report

Results: FNW, 56 years old, male patient, is admitted to the emergency room complaining of severe chest pain radiating to the left arm, sweating and unwell. Diagnosis of acute myocardial infarction in the inferior wall, with ST segment elevation on electrocardiogram. The patient was transferred to hemodynamics to perform a coronary angiography and there he developed severe arrhythmia, followed by cardiac arrest. At this moment, an Intraortic balloon passage was performed and extracorporeal membrane oxygenation cannulation was performed in the venoarterial mode, and immediate hemodynamic improvement was evidenced. The patient was transferred for intensive care unit (ICU) and the ECMO support was maintained for 5 days, with cardiac recovery and decannulation.

Conclusions: The patient was discharged from the ICU after 20 days and discharged from the hospital after 38 days of admission, without sequels, with minimal assistance, in rehabilitation care.

Abstract: 320

Echocardiographic assessment of cardiac function in a pioneering animal model of cardiopulmonary failure

K. Sato[1], S. Heinsar[1], S. Rozencwajg[1,2], S.M. Colombo[1,3], K. Wildi[1], J.-S. Jung[1,4], A. Carmen[1], X. Wang[1], G. Abbate[1], N. Sato[1], J. Reid[1], M. Bouquet[1], V. Lo Coco[5], E. Wilson[1], J. Suen[1], A. Combes[3], R. Lorusso[5], A. Pesenti[6], G. Li Bassi[1], J.F. Fraser[1], Critical Care Research Group

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Objective: To comprehensively assess cardiac function by trans-epicardial echocardiography in a novel animal model of severe cardiopulmonary failure (CPF)

Methods: Three healthy female sheep (weight 62±7.0 kg) were anesthetized, tracheally intubated and mechanically ventilated. An arterial catheter was placed for blood sampling and pressure monitoring. Left femoral artery and right jugular vein were cannulated and veno-arterial extracorporeal membrane oxygenation support commenced at a rate of 1.8±0.5 L/min. A left mini-thoracotomy was performed to access the pericardial sac and we developed heart failure through fifty 1-mL ethanol injections into the left ventricle myocardium. Ventilatory support was substantially decreased to develop pulmonary failure. Cardiac function pre and post development of CPF was evaluated by trans-epicardial echocardiography (Philips IE-33, North Ryde, Australia) and analyzed by dedicated software (TOMTEC Imaging Systems GmbH, Germany). Due to the limited number of evaluated animals, only descriptive statistics was performed.

Results: CPF caused a drop in mean arterial pressure and oxygenation, which resulted in an upsurge of blood lactate level (Table 1). Of note, echocardiographic indexes of LV function, such as left ventricular (LV) fractional area change, global circumferential and radial strain similarly decreased, post development of CPF.

Conclusions: In an innovative animal model of CPF, epicardial echocardiography is a reliable and feasible mean to follow up dynamics of cardiac disfunction.

Abstract: 327

Emergency CABG on VA following complex aortic dissection repair

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Objective: We report a case of type A dissection repair complicated by ischaemic right ventricular failure following de-cannulation managed with coronary artery bypass grafting (CABG) under VA ECMO support.

Methods: A 51 presented with a type A aortic dissection from the root to iliac arteries. He underwent emergency root, ascending and arch replacement using a frozen elephant trunk technique with extra-anatomical bypass to the left subclavian artery. Cardiopulmonary bypass (CPB) was established by ultrasound guided cannulation of the ascending aorta true lumen and two-stage venous cannula via the right atrium (RA) with cold cardioplegia into the coronary ostia. Around one hour post de-cannulation from CBP, he developed inferior ST-elevation and severely right ventricular impairment. The working diagnosis was of ischaemia and shock team consulted as a further CPB run including cardioplegia

recorded. Data were used to develop a multivariate logistic regression model predicting in-hospital mortality.

Results: There were 29 patients with a diagnosis of acute myocarditis support by extracorporeal membrane oxygenation from 2013 through 2019. 22 patients weaned from extracorporeal membrane oxygenation and 21 patients survival to hospital discharge. The average age of the population was 36.8 ±11.8 years, the median weight was 71.4±17.7kg, and females (n = 10) accounted for 34.5% of the patients. Hospital survival rate was 76%. 2 patients need Impella because of left ventricle distanding when support by extracorporeal membrane oxygenation, one patient of extracorporeal membrane oxygenation +Impella dead after weaning from extracorporeal membrane oxygenation and survival to discharge was 50%. Extracorporeal membrane oxygenation was deployed during extracorporeal cardiopulmonary resuscitation in 4 patients. In a multivariate model time before extracorporeal membrane oxygenation support, pre-extracorporeal membrane oxygenation arrest were associated with increased odds of in-hospital mortality.

Conclusions: Extracorporeal membrane oxygenation is effective in adults with acute myocarditis. Extracorporeal membrane oxygenation deployment early and prior to cardiac arrest may be associated with better outcomes.

Topic: 3 - Adult - Lab session - fundamental research

Abstract: 11

Testing extra corporeal life support devices to military environmental standards

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Objective: The objective of this work was to determine if a standard extracorporeal life support device that provides both kidney and lung support is able to withstand environmental extremes seen in military environments

Methods: The US Army Medical Materiel Development Activity (USAMMDA) provided the US Army Aeromedical Research Laboratory (USAARL) with extracorporeal life support devices that are able to provide lung and kidney support simultaneously for environmental testing in accordance with the methods and procedures outlined in MIL-STD-810H. The device was exposed to high and low temperature environments for operation and storage testing, vibration testing, drop testing, humidity testing, altitude testing, settling dust testing, blowing sand testing, and blowing dust testing.

Results: To be determined

Conclusions: To be determined

Abstract: 19

An innovative ovine model of severe cardiopulmonary failure supported by veno-arterial extracorporeal membrane oxygenation

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Objective: Cardiogenic shock (CS), complicated by pulmonary failure, often requires veno-arterial extracorporeal membrane oxygenation (VA-ECMO) to sustain end-organ perfusion. Currently used ovine models, such as coronary ligation are unstable, often resulting in ventricular fibrillation and cardiac arrest. Therefore, we aimed to develop a clinically-relevant but also controllable model of severe cardiopulmonary failure supported by VA-ECMO.

Methods: Three Leicester Cross sheep (62±7 kg) were anaesthetized, intubated and mechanically ventilated. The right humeral artery was cannulated for hemodynamic and metabolic assessment. Peripheral V_jA_f-15/24-ECMO was started at flow rate of 1 L/min. After a left minithoracotomy and administration of anti-arrhythmic drugs, CS was induced through multiple 1 mL sub-epicardial injections of 96% ethanol into the left ventricle. CS was confirmed by systolic blood pressure (SBP) < 90 mmHg, lactate >4 mmol/L and bed-side echocardiography. Then, ventilatory support was reduced to achieve PaO2 < 60mmHg and ECMO support increased to maintain mean arterial pressure of 65 mmHg. Echocardiography and Troponin I (TnI) samples were performed at baseline, upon CS and pulmonary failure. After 5h, animal was euthanized and the cardiac tissue samples assessed by immunohistochemistry.

Results: Ethanol injections (54±18 mL) rapidly induced CS in all animals. TnI levels increased 2000-fold (from 0.04 to 80.5 ng/L). SBP decreased from 99±25 at baseline to 73±11 mmHg upon CS, respectively, and lactate from 1.5±1.0 to 5.5±0.4 mmol/L. Baseline PaO2 was 77.5±17.6 and decreased to 40.3±11.5 mmHg, when ventilation was reduced. Echocardiography revealed a dose-dependent effect on heart function and fractional

area change decreased from 34.7±13.5% upon baseline to 19.7±6.3% after CS.

Histological samples and macroscopic evaluation resemble acute myocardial infarction with both necrosis and inflammatory infiltrates present.

Conclusions: We successfully developed a titratable model of severe cardiopulmonary failure through intramyocardial ethanol injections. This model could be essential to further characterize left-sided heart failure and develop future treatments.

Abstract: 20

Blood drainage performance characteristics of VV-ECMO drainage cannulas

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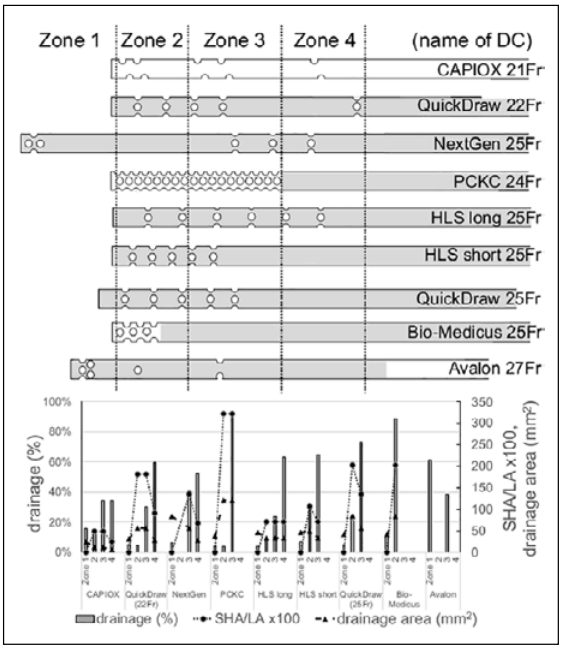
Objective: To evaluate the blood drainage volume from the end hole (EH) and side holes (SHs) of different types of VV ECMO drainage cannula (DC).

Methods: Nine DCs were tested. A water tank filled with 33% vol glycerin solution was divided into 4 compartments; the EH was positioned in Zone 1, and the SHs were equally spaced horizontally along the side of the tank unless the DC configuration necessitated otherwise. The suction volume of each compartment was measured at a constant flow rate of 3 L/min.

Results: The suction volumes of each DC are shown in the figure. For most DCs, the drainage areas (DAs) of distal side (Zones 1 and 2), and proximal side (Zones 3 and 4) were similar but the drainage volumes of proximal side were greater. The PCKC DC, which had a large SH area (SHA) and a high SHA-to-lumen cross-sectional area (SHA/LA), had an especially high drainage volume from proximal side. In contrast, the CAPIOX DC, which had a small SHA and a low SHA/LA, had a relatively high drainage volume from Zones 1 and 2. The CAPIOX and Avalon DCs had about 20% and 60% drainage from the EH, respectively, while most of the other DCs had less than 5%.

Conclusions: The drainage volume from the EH and the SHs depends on the SH positions, SHA, and the SHA/LA. Understanding the DC characteristics facilitates optimal placement of the holes, leading to maximum effectiveness.



Nine DCs and the suction volumes of each DC.

Abstract: 59

Effects of hyperoxia on platelet aggregation, inflammation and oxidative stress during ex-vivo extracorporeal membrane oxygenation

K.K. Ki[1,2,3], M.R. Passmore[1,2], C.H.H. Chan[4,5], T.J. Lee[1,2], M. Bouquet[1,2], E.S. Wood[1,2], S. Raman[6], S. Rozencwajg[7], A.J. Burrell[8], C.I. McDonald[9], D. Langguth[10], K. Shekar[1,2], M.V. Malfertheiner[11], J.Y. Suen[1,2], J.F. Fraser[1]

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Objective: Despite increasing use of extracorporeal membrane oxygenation (ECMO) for support of refractory cardiac and pulmonary failure, it remains a complex, high-risk intervention. Current practice often exposes patients to higher doses of oxygen (hyperoxia) during ECMO in order to avoid episodes of hypoxia.

Conclusions: Impella CP and PA cannula on top of VA ECMO offer significant LV unloading and adequate end-organ perfusion. Impella CP guarantees a stronger LV unloading effect, reducing more effectively the total mechanical energy generated by the left ventricle.

Abstract: 129

A new, minimally invasive and highly effective extracorporeal CO_2 removal device combined with a continuous renal replacement therapy

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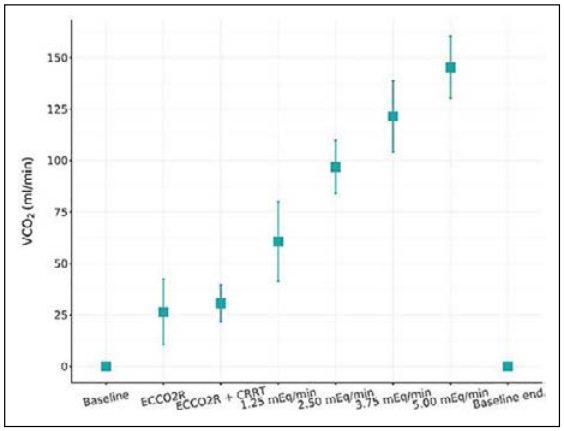
Objective: Extracorporeal carbon dioxide Removal ($ECCO_2R$) is used to treat patients suffering from acute respiratory failure. Its use is hampered by the high blood flow required to achieve a relevant CO_2 clearance.

We developed an ultra-low blood flow device to effectively remove CO_2 and perform continuous renal replacement therapy (CRRT).

Methods: Six pigs were connected to an extracorporeal circuit where 200 ml/min of blood flowed through a hemofilter connected to a closed-loop dialysate circuit. An ion-exchange resin acidified the dialysate flow upstream a membrane lung to increase PCO_2, thus enhancing CO_2 removal. Different levels of acidification were tested (from 0 to 5 mEq/min). Two l/h of post-dilution CRRT were constantly performed. At each step, we decreased the respiratory rate to maintain arterial PCO_2 at 50 mmHg

Results: Increasing acidification increased CO_2 removal of the membrane lung from 30±5 (0 mEq/min) up to 145±8 ml/min (5 mEq/min), a 483% increase, representing the 73±7% of the total CO_2 production. Minute ventilation decreased accordingly from 6.5±0.7 to 1.7±0.5 l/min. No major side effects occurred, but transient tachycardia episodes



Extracorporeal VCO2 at each experimental step.

Conclusions: This new extracorporeal ion-exchange resin-based multiorgan support device, proved extremely high efficiency in CO2 removal and continuous renal support. Future evaluations of long-term efficacy and safety will be required.

Abstract: 138

Temperature monitoring during ECMO: An in vitro study

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Objective: Monitoring patient central temperature during ECMO is not clear, but potentially useful for the detection of "unexpressed" fever, related to septic complications.

We conducted two in vitro experiments to estimate ECMO heat dispersion and, consequently, patient central temperature during extracorporeal support.

Methods: Exp.A. We analyzed ECMO circuit heat dispersion (Maquet Rotaflow PLS System) at 36 combinations of BF (1-3-5 L/min), GF (0-5-10 L/min) and T set (36-37-38-39°C). Heat dispersion was considered equal to the power (Watts) generated by heat exchanger at steady state, defined as stable temperature throughout the circuit.

Exp.B. By a reservoir bag, we connected two circuits (pump+oxygenator+heat exchanger), simulating patient and ECMO circuit. Patient and ECMO T set ranged 36-39 and 35-39°C, respectively, for overall 63 conditions; ΔT was patient - ECMO circuit T set difference. The power generated by the two heat exchangers was recorded at constant patient BF (5 L/min) and ECMO BF and GF (3 L/min each).

Results: A) Overall, BF was 3.0±1.7 L/min, GF 5.0±4.1 L/min, pump rate 1299±615 rpm, T set 37.5±1.1°C and circuit heat dispersion 58±12 W (range 37.5-90), corresponding to a supposed patient metabolic consumption of 1196±246 Kcal/die (range 774-1857) in case of heat exchanger absence or inactivation. It was affected by GF and T ($p< 0.001$), but not by BF (p=0.9).

B) For $\Delta T>0$ heat exchanger did not generate energy, while for $\Delta T< 0$ it supplied energy proportional to ΔT ($p< 0.001$). For $\Delta T=0$ heat exchanger power was 49±7 W (range 40-55).

Conclusions: ECMO heat dispersion depends on GF and temperature, but not on BF. Therefore, heat