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Indian Journal of ECMO

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ESOI

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Indian Journal of ECMO

1. Aims and Scope

Indian Journal of ECMO, the official publication of ECMO Society of India (ESOI) (https://www.ecmosocietyofindia.com), is a peer-reviewed print + online Quarterly journal. The *Indian Journal of ECMO* aims to publish Extracorporeal Membrane Oxygenation (ECMO) is an evolving branch in the critical care specialty. Recognizing the increasing need to consolidate the field and to promote awareness, continuing education, and research in this field, the "ECMO Society of India (ESOI)" was formed in September 2010 with the headquarters in Mumbai, India. Which will include editorials, original articles, case reports, review articles and a quiz.

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Informed Consent

Informed consent of the patients must be taken before they are considered for participation in the study. Patient-identifying information, such as names, initials, hospital numbers or photographs, should not be included in the written descriptions. Patient consent should be obtained in written and archived with the authors.

Protection of Human Subjects and Animals in Research

When conducting experiments on human subjects, appropriate approval must have been obtained by the relevant ethics committees. All the procedures must be performed in accordance with the ethical standards of the responsible ethics committee (institutional and national) on human experimentation and the Helsinki Declaration of 1964 (as revised in 2008). When reporting experiments on animals, authors must follow the institutional and national guidelines for the care and use of laboratory animals.

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From the Editors' Desk

10.5005/ijecmo-1-1-iv

Dear colleagues,

We are delighted to bring out the first issue of *Indian Journal of ECMO* (IJECMO), the official publication of **ECMO Society of India (ESOI)**. ECMO is an evolving branch in the cardiopulmonary critical care specialty. It has evolved from a salvage form of life support, used only in cases in which all other therapies have failed, to a mainstream therapy for patients experiencing acute severe cardiac and/or respiratory failure. It is important to acknowledge that at present ECMO plays a role that no other conventional life support system can provide for critically ill but otherwise promising patients with few comorbidities.

Recognizing the increasing need to consolidate the field and to promote awareness, continuing education and research, the ESOI was formed in September 2010 by two enthusiastic ECMO practitioners, Dr Pranay Oza and Dr Venkat Goyal along with interested clinicians from all over the country. We progressed from 2010 till date and especially in the past 5 years.

South and West Asia Chapter of Extracorporeal Life Support Organization (SWAC ELSO) was established in the year 2013 as a result of combined efforts of the members of ESOI and ELSO.

Nearly two years into the pandemic, the importance of ECMO for COVID-19 has really come into focus, ECMO utilization has increased, the guidelines have evolved, and an unprecedented number of patients were referred for and managed with ECMO support.

It has been a great journey since the conceptualization and inception of IJECMO. It gives us great sense of gratification to release this first Issue at 9th Annual Conference of South West Asian African Chapter (SWAAC ELSO) and 12th National Conference of ESOI. We would like to thank all members of the ESOI, members of the editorial board, reviewers, all authors, and the secretary office for their support toward this journal.

The aim of the journal is to meet the needs for continuing education of the members and national and international communities and to publish articles of scientific excellence.

We are sure that our journal will continue to provide top-quality original papers and articles, case reports, and letters to the editor that will help everyone interested in extracorporeal life support. The editorial board is committed to get the journal indexed in major search engines, indices, and databases to increase the visibility and recognition in wider scientific community. On behalf of the editorial team, we again hope that the journal will continue to be an important conduit for scientific information on a very broad national and international level.

We would appreciate your feedback and support by way of your valuable comments and contribution to make the journal a more vibrant platform for sharing knowledge.

Best Wishes!

Editor-in-Chief
Vinod Kumar Singh

Editor-in-Chief, Pediatrics Section
Suneel Kumar Pooboni

IJECMO
Indian Journal of ECMO

Volume 1 Issue 1 January–March 2023

Contents

15th ECMO training course ECMO society of India

Presents

"A Six days (Hybrid – 3 days Virtual & 3 days onsite) Interactive learning sessions On ECMO "

JUNE 2023

5 – 7 – VIRTUAL TALK

10 – 12 – HANDS ON & SIMULATION

Venue – Riddhi Vinayak Multispecialty Hospital

Nallasopara (west), Mumbai, India

RIDDHI VINAYAK
Critical Care & Cardiac Centre

ECMO SOCIETY OF INDIA

Who should join & how?

- Interested people
  - Registered medical professionals who are keen to adapt ECMO as a career choice., like....
  - Intensivists – adult, pediatric, neonates
  - Perfusionists
  - Registered critical care nurses
  - Respiratory therapists
  - Cardiologists, Cardiac or Vascular surgeons or Anesthetists
  - Post graduate candidates MD,MS
  - Preferably teams of 3 to 5 people from the critical care centers which include intensivist, perfusionist & registered nurse
- Course fees Including Redbook (5th Edition ELSO)
  - For training course – Rs 18000 / per person for doctors
  - For training course – Rs 15000/ per person for paramedical
  - For members of ESOI only – Rs 16000/- for doctors and Rs 12000 for paramedical
  - For ESOI students – Fellowship – Rs 13000 & certificate – Rs 10000
  - For foreign delegates – $ 350
- Contact number – 9821214971 / 9820321815
- For registration - https://www.ecmosocietyofindia.com/Conference_Registration.php

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Salient features –

- Hard core training for those who are keen for ECMO as a carrier
- Audio – visual training with wet lab experience
- 6 days course (Hybrid – 3 days Virtual & 3 days onsite) from 5th to 12th June 2023
- From 5 – 7 June 2023 Virtual talks from 5 PM to 9 PM
- Around 32 lectures by ECMO & field experts – national & international
- Practical sessions –
  - 21 hours for practical session – water drill, Demonstration, Hands on & High Fidelity Simulation
  - The delegates will be divided in 6 groups for 6 interactive station & mandatory hands on experience.
- Simulation and Exam on day 6
- Study material includes – book on ECMO, videos & slide presentations.
- Limited seats around 60

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ESOI Training Course, Day 1, 5th June 2023, Monday

	Pre Course Test MCQ – 20 marks – ONLINE on 3/1/2023 via Google form	
17.00 – 17.05	Inauguration & Lamp Lightening	
17.05 – 17.20	Course overview	Pranay Oza/ Venkat Goyal
17.20 – 17.40	ECMO – introduction & Indications	Dipanjan Ch
17.45 – 18.05	History & statistics	Suneel Pooboni
18.10 – 18.30	ECMO – physiology	Dipanjan Ch
18.35 – 18.55	Type of ECMO - VA ECMO	Venkat Goyal
19.00 – 19.20	VV ECMO	Suneel Pooboni
19.25 – 19.45	Hybrid ECMO & Nomenclature	Pranay Oza
19.50 – 20.10	Cannulation	Vivek Gupta
20.15 – 20.35	Initiation & Monitoring	Nandkishore
20.40 – 21.00	Management	Rakesh V
21.05 – 21.25	ECMO organization	Ramanathan K R

ESOI Training Course, Day 2, 6th June 2023, Tuesday

17.00 – 17.15	Recap	
17.20 – 17.40	Ventilation strategy during ECMO	Pranay Oza
17.45 – 18.05	Sedation & analgesia during ECMO	Rakesh V
18.10 – 18.30	Neurological monitoring of ECMO	Suneel Pooboni
18.35 – 18.55	Patient related complications & management	Vinod Singh
19.00 – 19.20	Blood transfusions – when & what	Venkat Goyal
19.25 – 19.45	Proning, Nursing care & Physiotherapy of patient on ECMO	Nandkishore
19.50 – 20.10	Transport of patient on ECMO	Dipanjan Ch
20.15 – 20.35	Weaning, trial off & decannulation	Vivek Gupta
20.40 – 21.00	Anticoagulation during ECMO	Lakshmi Raman
21.05 – 21.25	Renal issues & Dialysis during ECMO	Indira Jayakumar

ESOI Training Course – Day 3, 7th June 2023, Wednesday

17.00 – 17.15	Recap	
17.20 – 17.40	Surgical interventions during ECMO	Vivek Gupta
17.45 – 18.05	Role of Echo in ECMO	Poonam Malhotra
18.10 – 18.30	Infections during ECMO	Suneel Pooboni
18.35 – 18.55	ECPR	Arpan Chakraborty
19.00 – 19.20	CO2 Removal device	Arpan Chakraborty
19.25 – 19.45	ECMO in Transplant ICU	K Madhan
19.50 – 20.10	Paediatric respiratory ECMO	Indira Jayakumar
20.15 – 20.35	ECMO in sepsis	Vivek Gupta
20.40 – 21.00	Newer indication & future of ECMO	Venkat Goyal
21.05 – 21.25	Cardiac stunning – prevention & management	Venkat Goyal

ESOI Training Course, Day 4, 10th January 2023, Saturday

07.45 – 08.15	Registration & Breakfast	
08.30 – 08.45	Inauguration & Lamp Lightening	
08.45 – 09.00	Recap	Pranay Oza/ Venkat Goyal
9.00 – 10.00	Practical Session – Demonstration of Components, Circuit preparation & Circuit priming	Pranay Oza & Venkat Goyal
10.00 – 10.45	Practical Session – Demonstration of Initiation & Monitoring of ECMO	Pranay Oza & Venkat Goyal
10.45 – 11.00	Tea Break	
11.00 – 14.00	Practical sessions	
	Station I – Initiation of ECMO – Planning & strategy	Pranay Oza
	Station II – Circuit preparation – selection of component & making circuit & calculation of priming volume	Rakesh V
	Station III – Circuit priming – priming volume & priming solution	Kapil Thakkar
	Station IV – Cannulation selection, site & Technic	Dipanjan Ch
	Station V – Cannulation – Hands on VV ECMO	Vivek Gupta
	Station VI – Cannulation – Hands on VA ECMO	Venkat Goyal
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14.40 – 15.25	Simulation on Ambulance Transport scenario Simulation on Proning	Pranay Oza & Venkat Goyal
15.30 – 18.30	Practical Session Station I – Initiation & monitoring of ECMO – Hemodynamic changes Station II – Monitoring of circuit & patient Station III – Weaning, Trial off & weaning failure VV ECMO Station IV – Weaning, Trial off & weaning failure VA ECMO Station V – Transport on ECMO Simulation Station VI – Proning on ECMO Simulation	 Pranay Oza Kapil Thakkar Vivek Gupta Rakesh V Venkat Goyal Dipanjan Ch

ESOI Training Course – Day 5, 11th June 2023, Sunday (Application of ECMO)

07.30 – 08.00	Breakfast	
08.00 – 08.15	Recap	
08.15 – 09.00	Panel discussion – Ethical Issues In ECMO, Panellist – Pooboni, Venkat Goyal, Vivek Gupta, Nandkishore	Arpan Chakraborty
09.00 – 10.00	Practical Session – Demonstration of Management of complications	Pranay Oza & Venkat Goyal
10.00 – 10.40	Trouble shooting	Pranay Oza
10.40 – 10.55	How to make ECMO Economical	Pranay Oza
	Tea Break	
11.00 – 14.00	Practical Session Station I – Mechanical Complication – Power failure Station II – Mechanical Complication – Pump failure Station III – Mechanical Complication – Oxygenator failure Station IV – Mechanical Complication – Air Embolism Station V – Patient related Complications – Haemolysis Station VI – Patient related Complications – Recirculation	Kapil Thakkar Vivek Gupta Rakesh V Venkat Goyal Dipanjan Ch Pranay Oza
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14.45 – 18.00	Simulation Scenarios on mechanical emergency – Arterial/ venous line obstruction Gas flow Failure Flow issue – Tube Chattering & cavitation Accidental Decannulation Heat Exchanger Failure	Pranay Oza

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07.40 – 08.20	Breakfast	
	EXAMS – MCQ 40 marks (ONLINE on 14/1/2023 late evening)	
Simulation Station – 12 Scenarios (5 students in each group)		
08.35 – 09.05	Simulation Case I	Venkat Goyal Pranay Oza Vivek Gupta Suneel Pooboni Indira Jayakumar
09.10 – 09.40	Simulation Case II	
09.45 – 10.15	Simulation Case III	
10.15 – 10.35	TEA BREAK	
10.40 – 11.10	Simulation Case IV	Venkat Goyal Pranay Oza Suneel Pooboni Vivek Gupta Arpan Chakraborty
11.15 – 011.45	Simulation Case V	
11.55 – 12.25	Simulation case VI	
12.30 – 13.00	Simulation Case VII	
13.00 – 13.45	Lunch Break	
13.45 – 14.15	Simulation Case VIII	
14.20 – 14.50	Simulation Case IX	Venkat Goyal Pranay Oza K Madhan kumar Suneel Pooboni Arpan Chakraborty
14.55 – 15.25	Simulation Case X	
15.30 – 16.00	Simulation Case XI	
16.05 – 16.20	Validating Function & Group photo	

Time Distribution of the course

	Content of course	Time Spent in Minutes						Total time in mins
		D1	D2	D3	D4	D5	D6	
1	Didactic Lectures	200	200	200	00	120	0	675 (11 hrs & 15 mins)
2	Central Demonstration	00	00	00	105	60	0	165 (2 hrs & 45 Mins)
3	Work station & Simulation session	00	00	00	405	315	360	1080 (18 hrs)
4	Lunch & Tea time	00	00	00	55	75	60	190 (3 hrs & 10 mins)
5	Question / answer & Recap time	50	65	65	15	15	15	105 (1 hr & 45 mins)
6	Total time	250	265	265	580	580	435	2210 (36 hrs & 50 mins)

RESEARCH ARTICLE

Outcomes of Prolonged Extracorporeal Membrane Oxygenation (>30 days) in COVID-19 Patients on Conservative Management

Prachi Kar[1], Dipanjan Chatterjee[2], Arpan Chakraborty[3]

Received on: 31 January 2023; *Accepted on:* 20 February 2023; *Published on:* 09 March 2023

Abstract

Introduction: The onset of COVID-19 pandemic overwhelmed hospital resources with a high admission rate to critical care units. In patients experiencing progressive respiratory failure despite conventional therapies such as mechanical ventilation and prone positioning, venovenous extracorporeal membrane oxygenation (VV-ECMO) offered the only hope for survival. The VV-ECMO duration for COVID-19 is often described as longer than other respiratory illnesses. The outcome of these cases varies from country to country. As the literature available on the outcome of prolonged ECMO in an Indian setting is sparse, we planned to study the same.

Methods: This retrospective study included all adult patients who had undergone VV-ECMO of more than 30 days for COVID-19 illness at Medica Medica Superspecialty Hospital, Kolkata, West Bengal, India between 1 April 2020 and 31 March 2022. Patients who were still in the hospital at the end of the study period were excluded from the study. Data on total ECMO days, in-hospital mortality, age, sex, BMI, symptom onset to ECMO duration, intubation to ECMO duration, mechanical complications such as oxygenator failure or pump failure, patient complications such as major hemorrhage, ischemic stroke, liver/renal dysfunction, thrombocytopenia, culture-proven infection and use of prone position ventilation were collected from an electronic database. Patients who were discharged from the hospital were followed up at 6 months. The data were analyzed using the statistical package for the social sciences (SPSS) software, version 26 (IBM, Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD) and evaluated using Student's *t*-test. Categorical data were expressed as frequency (in %) and evaluated using the Chi-square test or Fischer's exact *t*-test as applicable.

Observation: Twenty patients who had prolonged ECMO (>30 days) were found eligible for the study. The average ECMO days and in-hospital mortality were 54.75 ± 33.14 and 60%, respectively. An early decision to ECMO after symptom onset and prone positioning during ECMO were factors associated with a favorable outcome. The requirement of renal replacement therapy (RRT) for renal failure was a poor prognostic factor.

Conclusion: Prolonged ECMO for COVID-19 poses many challenges in terms of thrombotic and bleeding complications, major organ dysfunction, and high mortality. However, this remains the only survival hope for sick COVID-19 acute respiratory distress syndrome (ARDS) patients.

Keywords: COVID-19, Extracorporeal membrane oxygenation, Venovenous extracorporeal membrane oxygenation.

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Introduction

The outbreak of coronavirus disease 2019 (COVID-19) has led to a pandemic associated with a high critical care unit admission rate (14.2%).[1] Many of the admitted patients required mechanical ventilation (12%).[1] Hypoxia in COVID-19 patients has been found to be refractory to conventional mechanical ventilation as well as lung protective strategies, prone positioning, and pulmonary vasodilators. In an article by Macedo et al., mortality in hospitalized patients varied from 11.5% in general hospital patients to 40.5% in the critical care unit during the first wave of COVID-19.[2] For patients who experience progressive respiratory failure despite these conventional therapies, VV-ECMO may be considered to support gas exchange. The overall outcome of an ECMO center may vary from place to place and heavily depends on the previous experience and expertise of the center, the severity of COVID-19 respiratory illness, patient ethnicity, genetic constitution, and preoperative comorbidities. Thus, mortality data in the literature on ECMO in COVID-19 patients varies from country to country. Further, the literature on the outcome of ECMO in the Indian population is scarce. Thus, we planned to study the outcomes of COVID-19 patients requiring long-term ECMO in Indian patients.

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Conflict of interest: None

Methods

The data were collected retrospectively from the ECMO unit of Medica Superspecialty Hospital, Kolkata, West Bengal, India as a part of the ECMO fellowship program thesis. All patients who

Table 1: Comparison between the two groups

Variable	*Discharged patients (8)*	*Death (12)*	*p-value*
Age (in years)	42.38 ± 8.4	46.75 ± 13.17	0.418
Sex (M:F)	4:4	9:3	0.35
BMI	22.91 ± 3.64	25.06 ± 5.01	0.268
Onset of symptom to initiation of ECMO (in days)	5 ± 2.67	10.9 ± 4.35	0.003
Intubation to ECMO (in days)	2.13 ± 2.03	4.5 ± 3.3	0.09
Total ECMO (in days)	46.75 ± 21.66	60.08 ± 39	0.39
Use of prone position ventilation	7/8	4/12	0.025
Oxygenator failure in number of patients (nil/once/twice)	6/1/1	8/3/1	0.77
Renal failure requiring RRT	0/8	5/12	0.042
Liver dysfunction	0/8	2/12	0.40
Thrombocytopenia <50,000/mm^3	2/8	3/12	0.24
Infection episodes (culture proven) (Bacteraemia/ECMO cannula site/CVC/UTI/VAP)	17 (2.12 per patient)	29 (2.41 per patient)	0.63

Continuous variables expressed as mean ± SD; Categorical variable expressed as frequency and percentage. BMI, body mass index; CVC, central venous catheter; ECMO, extracorporeal membrane oxygenation; RRT, renal replacement therapy; UTI, urinary tract infection, VAP, ventilator associated pneumonia

had a VV-ECMO run of more than 30 days due to COVID-19-related severe respiratory illness [severe ARDS; PaO_2:FiO_2 (P:F) ratio <100 as per Berlin criteria] between 1 April 2020 to 31 March 2022 were included in the study. Patients who were sent for lung transplants while on ECMO were excluded from the study. The electronically saved data were accessed with due permission from the appropriate authorities and information on the following variables [age, sex, body mass index (BMI), date of onset of symptom, date of intubation, date of initiation of ECMO, total number of ECMO days, mechanical complications like oxygenator failure or pump failure, patient complications such as major intracerebral bleed, liver/renal dysfunction, coagulation abnormality, thrombocytopenia, severe sepsis, and use of prone position ventilation] were obtained. The primary outcome studied was hospital discharge. Based on the hospital discharge the patients were divided into two groups (Survivor patients who were discharged from the hospital and non-survivor patients who died during their hospital stay). The Statistical analysis was done using SPSS, version 26 (IBM, Armonk, NY, USA). The continuous data were expressed as mean and SD. The categorical data were presented as frequency and percentage. A $p < 0.05$ was considered significant. The continuous data and categorical data between the two groups were compared using the Student's *t*-test and Chi-square test/Fischer's exact *t*-test, respectively. The significant variables in the univariate analysis were noted. Patients who were discharged from the hospital were followed up at 6 months to check their quality of life and physical activity.

Observation

Data on above mentioned variables were collected for all patients who had an ECMO run of above 30 days for COVID-19-related severe respiratory illness between 1 April 2020 and 31 March 2022.

The average age of patients in the study cohort was 45 years. There were more male patients as compared to female patients. The mean duration of ECMO was 54.75 days. Although 10 patients were weaned from ECMO, only 8 patients could be discharged from the hospital (2 patients had a failure of ventilator weaning). Prone position ventilation was attempted in 55% of patients while on ECMO. Oxygenator failure was the most encountered mechanical complication. Thrombocytopenia and renal failure were the leading patient-related complications. At least one episode of sepsis was seen in all patients on ECMO. A total of 46 culture-proven sepsis episodes were seen in this study. A total of 8 patients were discharged from the hospital and 6 patients had already been assessed at 6 months follow-up before the time of data collection. Five out of 6 patients had normal physical endurance and maintained a normal social life. All of them had joined back work. However, one of them still needed assistance with the day-to-day work.

Based on the hospital discharge the patients were divided into the following two groups:

- Group I: Patients who were discharged from the hospital.
- Group II: Patients who died during hospital stay.

The comparison of patient variables in both groups is tabulated in Table 1.

The average age of the patients was higher in patients who died although it was not statistically different from the patients who were discharged. The time from symptom onset to ECMO initiation was significantly longer in patients who died. The use of prone position ventilation seemed to have led to a favorable outcome. Renal dysfunction requiring RRT was implicated in a poor outcome.

Discussion

This retrospective study was conducted to assess the outcomes of severe COVID-19 patients requiring long-term ECMO (>30 days). The primary aim of the study was to record mortality and the secondary aim was to assess variables contributing to mortality.

In the pre-COVID-19 era, the average duration of VV-ECMO for severe respiratory illness was typically around 2 weeks. However, during the recent COVID-19 pandemic, it was realized that long ECMO runs invariably averaging more than 2 weeks was the norm rather than the exception. Also, COVID-19 ARDS often required an extended period of lung rest thus necessitating long periods

of ECMO. Prolonged ECMO runs are likely to lead to multiple complications like bleeding and other coagulation issues, infections, and oxygenator and pump failure. The literature pertaining to outcomes in long-term ECMO (>30 days) from Indian authors is sparse. Thus, we designed this study.

Our study cohort included 20 patients who had an ECMO run of above 30 days. Overall mortality in this study was high (60%). Although 10 (50%) patients were weaned from ECMO, two of them could not be weaned from a ventilator and succumbed. In the literature, mortality in severe COVID-19 ARDS patients requiring ECMO ranged 3.7–75.6%.[1,3] The mortality of the COVID-19 patients on ECMO also depended on the time of pandemic that the patients were affected (early or late).[3] Two meta-analyses conducted in the year 2021 and 2022, respectively, concluded that prolonged ECMO duration was associated with improved survival contradicting the popular belief.[4,5]

Most patients in this study were middle-aged groups and age was not found to be a factor contributing to mortality. Although there was wide variability in the patient age groups across studies, many studies reported the average age of the patient to be in the fourth decade of life like those in our study.[6–8]

However, few studies observed that the patients were nearly a decade older than those in our study.[9–11] The literature on the effect of a higher age on mortality is inconclusive. Most studies could not elicit an association between age and mortality which is like our result.[1,6,12] However, few authors found age as a significant contributor to mortality.[3,9,11]

Male gender constituted 65% of the total study population at our study center. Various other studies on ECMO in COVID-19 patients also reported a higher proportion of males in their cohort.[1,3,6,13] Interestingly, Kurihara et al. observed that non-COVID-19 ECMO cohorts had a lesser proportion of males as compared to COVID-19 patients.[6] Most of the earlier studies could not establish an association between gender and mortality in COVID-19 patients undergoing VV ECMO.[1,3,11,13] Higher weight and BMI is often considered poor risk factor for adverse outcomes. Although the mean BMI of non-survivors was slightly higher than survivors in this study, it did not reach statistical significance. Moreover, it was interesting to note that the study cohort had a normal average BMI (24.33) with the mean BMI of the non-survivor group (25.06) slightly drifting towards the overweight range. Many of the authors reported a high BMI (>30) in their study group.[8,9,11,13]

All these studies came from the Western world which is nutritionally better than Indian subcontinent. This explains why BMI was higher in the cited studies as compared to our study population. In contrast to the result of the aforementioned studies, Daviet et al. reported obesity as an independent factor associated with improved survival in VOVID-19 patient undergoing ECMO.[14]

This study suggests that early decision on initiation of ECMO after diagnosis of COVID-19 was useful in improving outcomes. The average time from onset of symptoms to ECMO initiation was 8.5 days in this study which was longer than the time period described by Biancari et al. (5.5 days).[1] However, Dreier et al. and Shaefi et al. reported a longer time interval of 18 days and 13 days, respectively.[12,13] The survivors in this study had a significantly shorter time to ECMO initiation as compared to non-survivors which is in agreement with the study by Shaefi et al. [13] Although the intubation to ECMO initiation interval was longer in non-survivors as compared to survivors, it did not reach statistical significance in this study cohort. This finding is similar to that reported by a few other authors.[3,9,13]

Kurihara et al. reported mortality of 100% in patients who required mechanical ventilation more than 1 week prior to the institution of ECMO and those with less than 1week of ventilation had 63.5% mortality.[6] In a study by Barbaro et al., the mean duration of intubation before the institution of ECMO was 4 days and 3 days in centers that adopted ECMO care early in the pandemic (A1) and late in the pandemic (A2), respectively.[3] Outcome at A1 centers was more favorable than that at A2 centers. It may be because the early adoption centers had better prior experience in ECMO and thus had a better outcome. A meta-analysis conducted recently also could not find an association between intubation to ECMO initiation interval and mortality.[5]

The prone position is often used in patients with severe ARDS to improve hypoxia. Some centers practice prone positioning even while the patient is on ECMO support. Eleven patients (55%) patients received prone positioning during ECMO in our study. The incidence of prone positioning ranges 15.2–81%.[7,10,13] This study found that prone positioning was associated with improved outcomes and agrees with a study by Barbaro et al.[3] However, other authors could not elicit any effect of prone positioning on mortality.[9,11,13]

Mechanical complications on ECMO are a nightmare for the ECMO physician. Due to the prothrombotic tendency observed in many sick COVID-19 patients, clots in membrane oxygenators, circuits, pump heads were described by many authors.[3,6,7]

Hemolysis, pulmonary embolism, deep vein thrombosis ischemic stroke were also frequently reported.[1,3,6,7,13] Oxygenator change was required in 6 (30%) of our ECMO patients and 2 patients needed oxygenator replacement twice during their intensive care unit (ICU) stay. The incidence of oxygenator failure in COVID-19 VV-ECMO ranges 5.8–42.3%.[3,6,9,15]

Ischemic stroke has also been reported as a complication of the prothrombotic milieu. Ischemic stroke incidence described in the literature varies in the range 1–14.4%. Major hemorrhage was a common complication during COVID-19 ECMO. Incidence as high as 45% has been reported.[15] The most common sites of bleeding reported in the literature are the cannula site, oronasal, gastrointestinal tract, intracranial and retroperitoneal bleed outs, urinary tract (Hematuria), lungs, and pleura (hemothorax).[3,7,9,13,15]

Renal decompensation requiring RRT was also a frequent complication reported by many authors and the incidence in our study (25%) falls within the range reported in the literature (5–37.9%).[1,6,7,9,13,15]

The rate of infection was remarkably high in our study. A possible explanation could be the inclusion of only long-term ECMO patients in our study. This obviously meant more hospital stays and more susceptibility to nosocomial infections.

Long-term recovery after hospital discharge in patients who had severe COVID-19 illness is not straightforward. A constellation of symptoms popularly known as "post-COVID-19 syndrome" continues to affect the quality of daily living in these patients.[16,17] The symptoms may range from simple fatigue, headache, and insomnia to more complicated chest pain, dyspnea, and palpitations. Although five patients in our cohort were leading a normal social life post-discharge and joined back work, they all were experiencing some form of mild post-COVID-19 syndrome symptoms. The commonest symptom presented were fatigue, joint pain, paroxysmal palpitations, and insomnia. One patient continued to require help with daily living due to significant

dyspnea. The computed tomography (CT) scan of this patient at 6 months follow-up showed significant lung fibrosis.

Limitation

This is a single-center retrospective study and has a small sample size. Thus, it is likely to have a biased outcome. Many patients included in the study, received treatment at other hospitals during the earlier part of their illness. They were either cannulated at the primary hospital by the ECMO mobile team or were cannulated immediately upon arrival at the study center. Thus, we could not collect data on many preoperative variables such as the use of sedation or neuromuscular blockers during ventilation. The details on renal function test, liver function test, and sequential organ failure assessment (SOFA) score at the time of ECMO cannulation was also missing from many case files. Thus, these variables could not be included in the study. Further multicentric studies with a higher number of patients are required to validate the results of this study.

Conclusion

An ECMO run offers the only hope for survival in desperately ill COVID patients. ECMO runs for these patients are often longer than conventionally described ECMO for another viral disease. Mortality in Long term COVID-19 ECMO is high. An early decision to ECMO after symptom onset and prone positioning were factors significantly affecting favorable outcomes and the requirement of RRT was associated with poor outcomes.

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REVIEW ARTICLE

Evolution of ECMO

Suneel Kumar Pooboni

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Abstract

ECMO (Extra Corporeal Membrane Oxygenation), synonymously known as ECLS (Extra Corporeal Life Assist) has been proven to be helpful in saving the lives of patients who have been critically unwell due to reversible, cardio-pulmonary failure. The knowledge and the scientific discoveries leading to the successful trials of ECMO happened over centuries. It is interesting to note how the beliefs and superstitions were replaced by proven, scientific data over millennia before we reached the latest era of working with bio-compatible materials.

Medical History has always been interesting. In this review article, I will briefly summarise the evolution of Medicine in different periods as the foundations were laid in this period.

I will narrate further concepts about the development of ECMO technology over a period of four centuries in part 2. Lastly, in Part 3, I will describe the birth and evolution of ECMO as a science and the perfection of the components of ECMO.

Keywords: Extra Corporeal Membrane Oxygenation, Evolution, Galen, History, Hippocrates, Sushruta.

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ECMO (Extra Corporeal Membrane Oxygenation), synonymously known as ECLS (Extra Corporeal Life Assist) has been proven to be helpful in saving lives of patients who have been critically unwell due to reversible, cardio-pulmonary failure. As it happens in most scientific discoveries, innumerable people put their thoughts together and worked hard for centuries. We are standing on the shoulders of great pioneers to reap the benefits of their hard work.

As we know, once the lungs or heart fails to perform it's intended function of gas exchange and perfusion to the vital organs, it is implied that the organs need rest. Nature has created the living being in an innovative way as it becomes nearly impossible to mimic. Hence researchers have been trying to find ways to understand physiology, pathology and pathophysiology to recreate the mechanisms that can be of help during this process of repair to the damaged organs. As some of the measures we use are against the mechanisms Nature has devised for us (for example, positive pressure ventilation against negative pressure ventilation) and it's subsequent ill effects inducing fibrotic changes as a result of high-pressure ventilation, researchers are continuing with their efforts in finding the best possible ways in mimicking the Nature.

Much of the understanding and development of extracorporeal support happened in the last century. Physicians and researchers have been thinking about a way forward to solve the problems concerning respiratory failure or cardiorespiratory failure. These thoughts developed over a few centuries. We shall review the histories of these pioneers contributing to the success of cardiopulmonary bypass.

Medical History has always been interesting. I would like to put forward a brief synopsis of the evolution of Medicine in different periods with a brief note on comparison to understanding the concepts of medicine in a few important cultures in part 1. I will narrate further concepts about the development of ECMO technology in part 2. Lastly, in part 3, we will talk about the birth and evolution of ECMO as a science and it's components.

- Evolution of concepts and knowledge of Medicine prior to the 20th century
- Evolution of concepts of ECMO
- Birth and Evolution of ECMO

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Part 1 – Foundations to the understanding of Human anatomy, physiology and practice of Medicine

It is amazing to learn the beliefs of physicians over centuries regarding the structure and function of the Human body. I will briefly describe the attributes of a few of the important scholars who contributed to the field of medicine till the beginning of the last century.

According to the allopathic system of medicine, we consider Hippocrates the father of modern medicine. His era dates back to 460 BC – 370 BC. His father was Hippocrates first and he was three second. Greek medicine existed before him as well. From the source of information from Soranus, it looks like Hippocrates learned the practice of medicine from his father. He was presumed to have been trained at the Asklepieion of Kos, the prestigious medical school in Greece in his time. The concepts of medicine in ancient times used to consist of beliefs regarding bad air, witchcraft, evil powers etc. Hippocrates seems to be the torch bearer to change the concepts causing illnesses as, not due to gods getting angry but attribution to some natural processes. It is possible that he thought about clinical observations and devised a classification of diseases. The Hippocratic oath is still taken by generations of physicians at the time of graduation.[1] Surprisingly, Hippocrates seems to have worked on the same principles of ancient Indian medicine, namely,

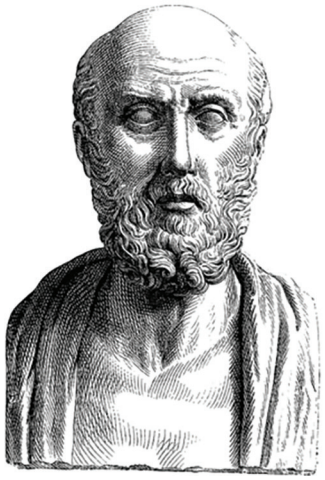

Fig. 1: Hippocrates by unidentified engraver – 1881 young persons cyclopedia of persons and places. Upload by RedWolf 05:45, Jan 10, 2005 (UTC), public domain, https://commons.wikimedia.org/w/index.php?curid=164808

black bile, yellow bile, phlegm and blood, prevalent at that time. Western medicine at the time of Hippocrates wasn't aware of the structure and function of the Human body, which happened after few centuries (Fig 1).

A brief review of the Indian literature (Ayurveda) shows some of the concepts from the Sustruta Samhita, containing the information about the knowledge shared by Susruta, which appears to be before 600 BCE. This was as per the Rudolf Hoernle.[2] The humors, as stated above, are still part of ayurveda theory as it is being practised from ancient times. The physicians from later centuries, such as Drdhabala seems to be aware of Sushruta Samhita. Drdhabala compiled the works of Gurus (teachers) prior to him and wrote one chapter by himself between the fourth and fifth centuries CE.[3] We also knew many subjects were learnt as slokas, which were passed on from Guru (teacher) to Shishya (disciple) during these times. Sushruta taught a number of young physicians the art of medicine for a period up to 6 years before taking up surgical training. Before commencing their training (in the period much before Hippocrates), they took a solemn oath to devote themselves to the care of humanity and to do no harm to others. It seems to be similar to Hippocratic Oath, which we adopted into our practice in current times (Fig. 2).

The students under Sushruta seem to have learnt their surgical techniques by experimenting on vegetables and dead animals. Next step used to be, preceptorship by watching senior physicians doing the procedures. At this time they used to establish their own surgeries.[4,5] Sushruta is famous for his methods on rhinoplasty. Even in ancient days, his medical knowledge is exhibited through his writings on rhinoplasty surgery, involving nasal reconstructions using skin from the patient's forehead or cheek. From the literature, it seems that Indian medicine was at a much-advanced stage than Greek Medicine in the contemporary period (Figs 3–5).

Exchange of information and studying overseas might explain some of the similarities. It is also possible that assumptions, hypotheses and independent research might have happened at the same time in different regions of the World for the solution of medical problems. Unfortunately, an important treasure cove of knowledge, the library of Alexandria which housed close to 200000 to 700000 books from multiple countries on various subjects was burnt around 48 BCE in the war between Ptolemy XIII and Caesar. The library was destroyed in the fire set to engulf the enemy's fleet by Caeser's army.[6] Another important source of ancient knowledge, the library of Nalanda university, India considered by historians to be the world's first residential university[7] and among the greatest centres of learning in the ancient world, which existed from 427 until 1197 CE was burnt down by Muhammad Bakhtiyār Khaljī in 1200 CE.[8]

Reviewing the Hippocratic period shows that during his period, he brought the concept of classification of diseases as acute, chronic, epidemic and pandemic (etc.). As an evidence, we can see his description of empyema chest in terms of clinical presentation, measures that can be taken and the outcomes. If the documentation matters for the historians as evidence, his methodology stays alive even in contemporary clinical practice.[9] Hippocrates was the first documented chest surgeon and his findings and techniques, while crude, such as the use of lead pipes to drain chest wall abscesses, were documented.[10]

Reviewing the Egyptian medicine with regards to the medical knowledge they have acquired is interesting. As it is evident from the mummification process, the texts described on the papyri found in various excavations besides the inscriptions on the temples stand as testimony for their knowledge about human anatomy and the treatment methodology they adopted for treating various ailments. This period dates back to approximately 3500 BC. Like Ayurveda, the Egyptian medicine describes the effects of various plants. They believed in animal products and minerals too. (Figs 6 and 7).[11]

As per the inscriptions and the documented evidence, probably it was the ancient Egyptian medicine (3300 BCE–525 BCE) where the first principles of modern medical care have been found, including orthopaedic principles of healing fractures, simple surgical methods, setting the teeth, and the use of different sets of medicinal plants.[12] Ancient Egyptians believed in evil spirits as the cause of the ill health. They also considered other animals and people responsible for keeping humans healthy or causing disease.[13] Egyptians had access to human dissection for the purpose of mummification. They had knowledge about the human anatomy. The papyri hold the evidence of their knowledge concerning different systems. They identified the heart function. They knew about cerebro spinal fluid too.[14] They presumed that the heart was

Fig. 2: Susrutahttps://wellcomeimages.org/indexplus/obf_images/d0/45/c210860bff03f531e5b1a2d4ce08.jpgGallery: https://wellcomeimages.org/indexplus/image/V0006619.htmlWellcome Collection gallery (2018-04-03): https://wellcomecollection.org/works/zqhc6qjz CC-BY-4.0, **https:**//commons.wikimedia.org/w/index.php?curid=36422819

originating centre for all body fluids such as blood, tears and urine.[15] Unfortunately, those details couldn't be decoded until the discovery of the Rosetta stone in July 1799 and further translational work to decode hieroglyphic language was done. Much of the knowledge was understood from the papyrus, stones, clay and carvings on the walls of the temples.

Coming back to the understanding and practice of Medicine in ancient Greece, Galen was the next physician who influenced medical science. His time period was from 129 AD to 216 AD. He was considered to be one of the most accomplished of all medical researchers of antiquity. Galen persuaded the development of various scientific disciplines concerning human organ systems such as anatomy, physiology, pathology, study of medicines and neurology. Additional disciplines such as philosophy and logic as separate disciplines. Galen continued to have belief in the four humors theory as proposed by Hippocrates. Surprisingly, in the western world, Galen's views were followed as authority on medical practice for the next 1,300 years. Human dissection was still a taboo at his time and for the next few centuries after him. His knowledge of anatomy was mainly based on dissecting Barbary apes. He dissected other animals such as pigs as well as studying humans and animals resembling humans (for dissection purpose) was forbidden. Galen's description of the human anatomy based on the dissection of animals stayed uncontested until 1543, till Vesalius published refined information based on dissections of human bodies of executed criminals in his book "De humani corporis fabrica". Galen's physiological concepts stayed the same until c. 1242 when Ibn al-Nafis published his book Sharh tashrih al-qanun li' Ibn Sina (Commentary on Anatomy in Avicenna's Canon), in which he reported the details about pulmonary circulation (Figs 8 and 9).[16]

Andres Veselius

Andreas Vesalius (1514–1564) was a new era in our understanding of human anatomy. He is regarded as the great anatomist of the

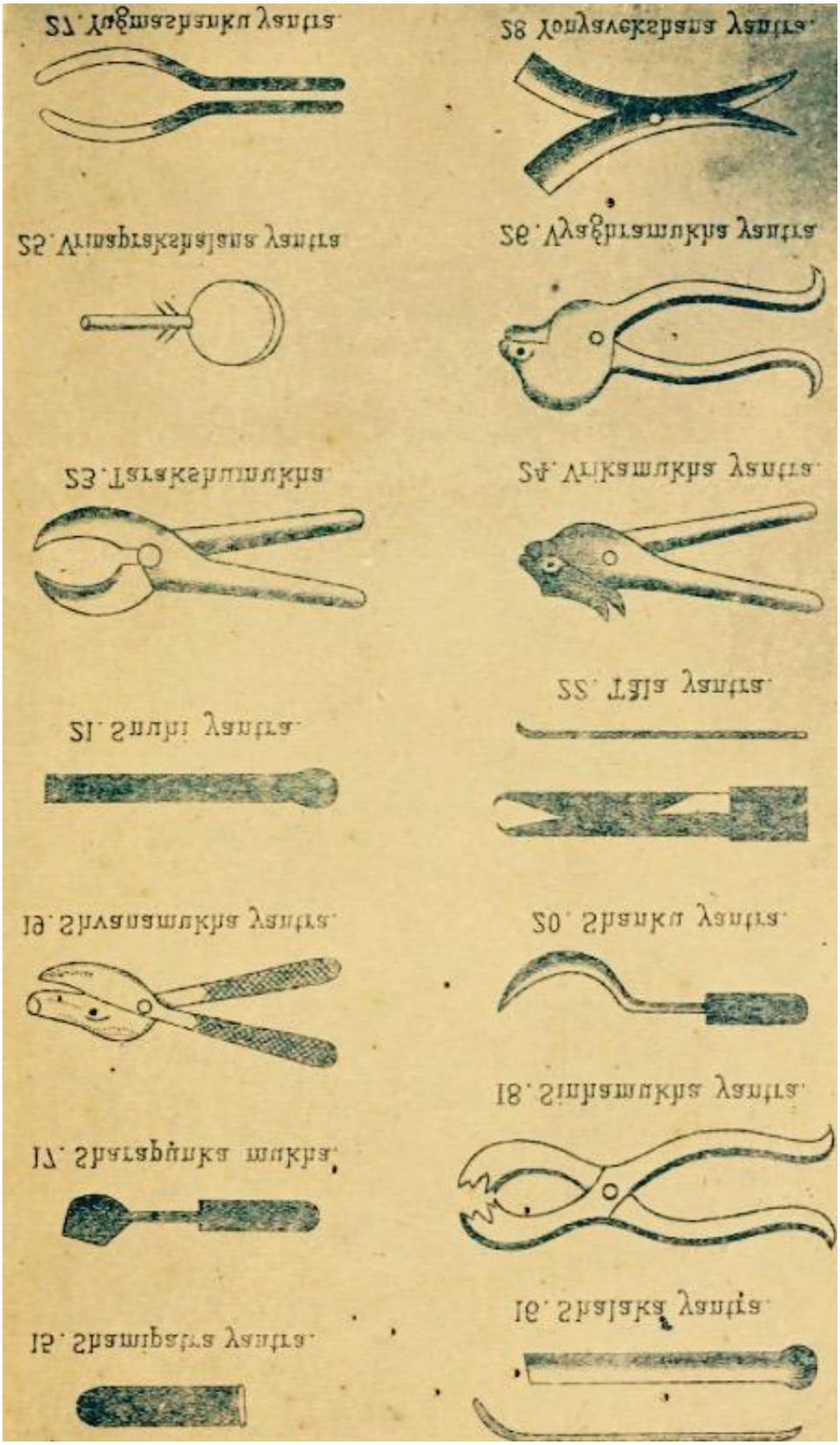

Fig. 3: Ancient poster by Shushruta, given in Sushruta Samhita showing surgical instruments, in which most of them still continue to exist today. By Kaviraj Kunja Lal Bhishagratna – https://archive.org/stream/englishtranslati01susruoft#page/n5/mode/2up, Public Domain, https://commons.wikimedia.org/w/index.php?curid=46924580

Fig. 4: Sushruta operating on a patient.
Source: Painting from Anatomy department, Kurnool Medical College, Kurnool, India

Fig. 5: Charak monument in yog peeth campus, Father of Medicine and Surgery by Alokprasad, Balajijagadesh – CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=8124213

16th centur. He was the author of one of the most influential books with illustrations on human anatomy, "De Humani Corporis Fabrica Libri Septem". It is based on studying human anatomy via dissections. Vesaleus got the support of rulers of his time for the supply for human cadavers for dissection purposes. This was a tremendous advance in overcoming the taboos of Galen's time. Vesalius encouraged his students to study Medicine by dissecting human bodies (Fig. 10).

The changes in the social-cultural circumstances helped Vasalius. In 1539, a judge at the Padua criminal court had been interested in Vesalius' work and sanctioned the dissection of human bodies. Hence forth, he had access to regular supply of the dead bodies of executed criminals for human dissection.[17]

In understanding the basics of human physiology, Galen interpreted that the arteries transported the purest blood to some of the organs such as the brain and lungs from the left ventricle of the heart, while veins passed blood to organs situated below the level of the heart such as the stomach from the right ventricle. So dominant was Galen's authority that for the next 1400 years, the physicians supported the finding of holes between the two chambers of the heart. Vesalius self-confessed

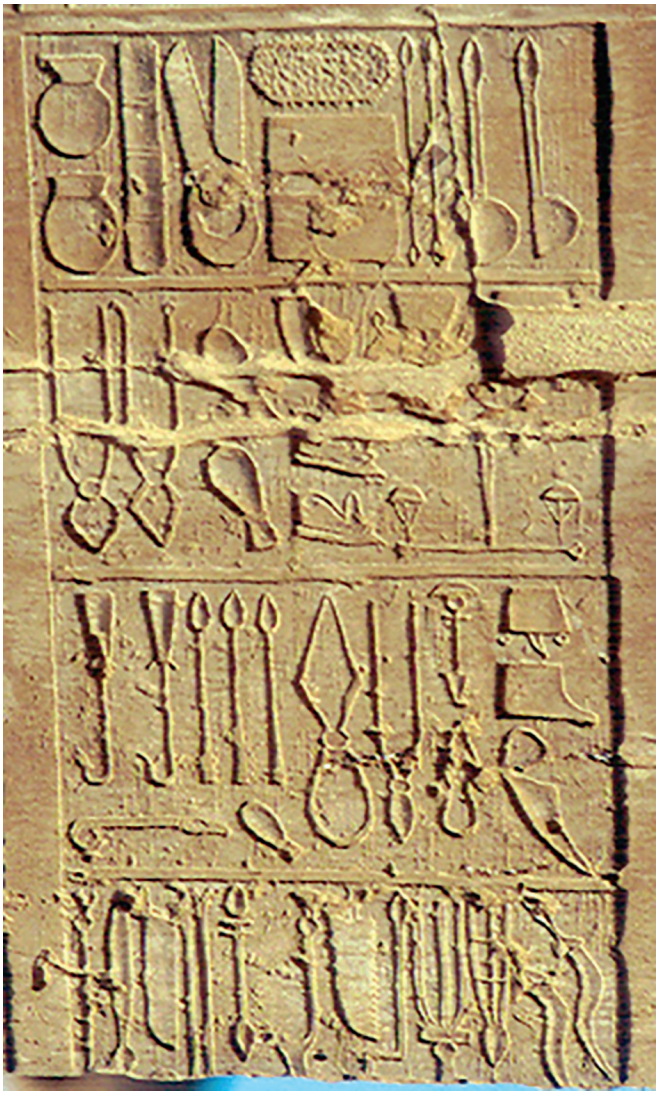

Fig. 6: The above inscription from Ptolemaic times was seen on the temple walls of the Temple of Kom Ombo. The inscription mentions the types of diverse medical instruments used for surgery besides the mummification process. https://commons.wikimedia.org/wiki/File:Ancient_Egyptian_medical_instruments.jpg
Jeff Dahl, CC BY-SA 3.0 https://creativecommons.org/licenses/by-sa/3.0, via Wikimedia

that he could not find these inter-connecting holes. Nonetheless, he did not venture to dispute Galen on the distribution of blood, as he couldn't offer any other explanation. He suggested that it diffused through the unbroken partition between the two ventricles.[18–20]

Then came the period of William Harvey (1578–1657). He was responsible for bringing new knowledge to the understanding of Human anatomy and physiology. He was the first known physician to describe completely, and in detail, the systemic circulation and properties of blood being pumped to the brain and the rest of the body by the heart (Fig 11).

Part 2 will follow with further concepts on evolution of ECMO.

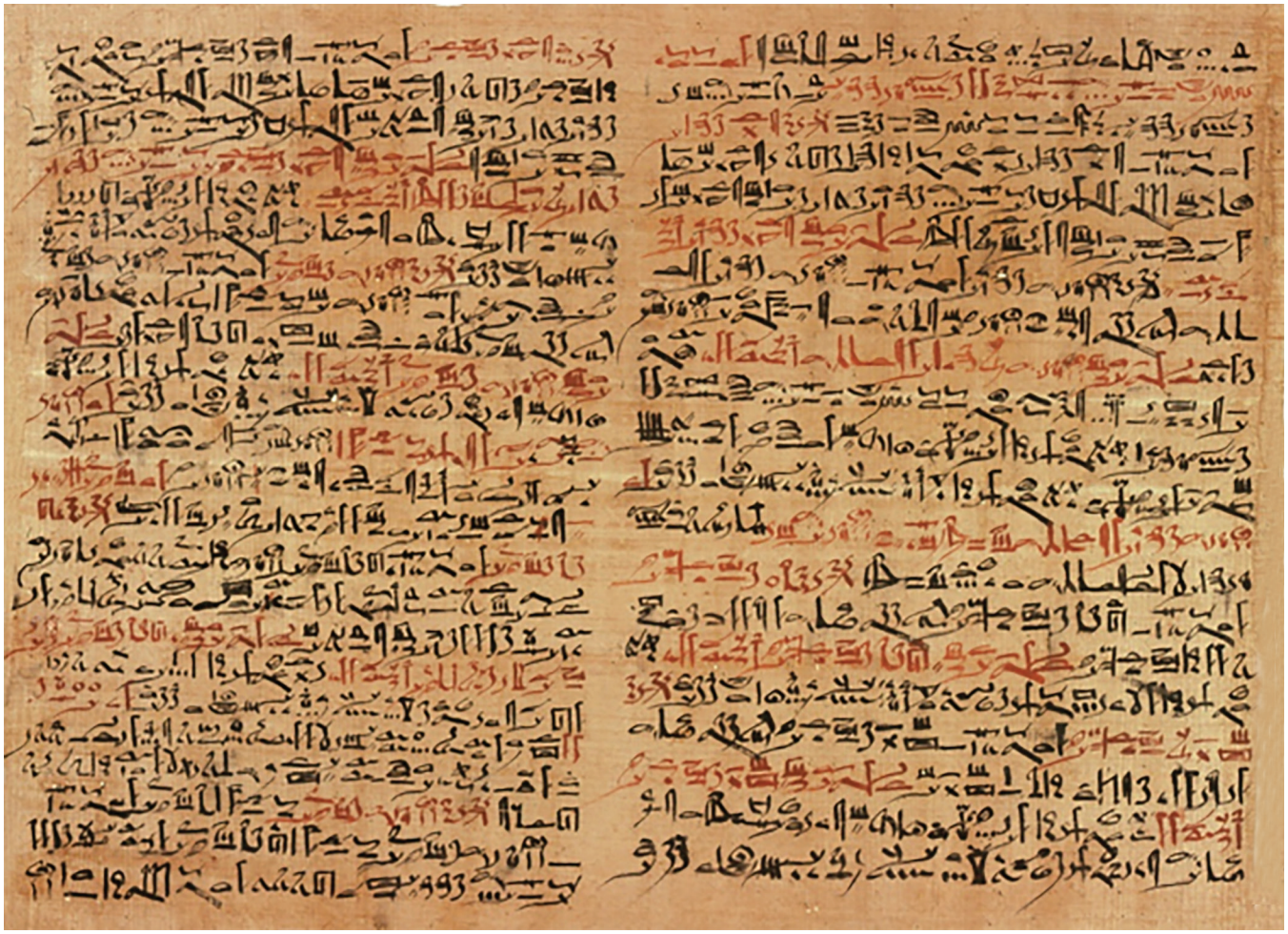

Fig. 7: The Papyrus documents collected by Edwin Smith show ancient Egyptian awareness about the diagnostic methodology and the approach they used for treatment of various cases of traumatic injuries. This period dates to c. 1500 BC. It is unclear if it could be dated back to 3000–2500 BC as well. Jeff Dahl - EdSmPaPlateVIandVIIPrintsx.jpg

Fig. 8: Portrait of Galen. (September 129 AD – c. AD 216). His teachings were uncontested in the Western Medicine for the next millennium. By Georg Paul Busch (engraver) – The Lancet, public domain, https://commons.wikimedia.org/w/index.php?curid=40855568In

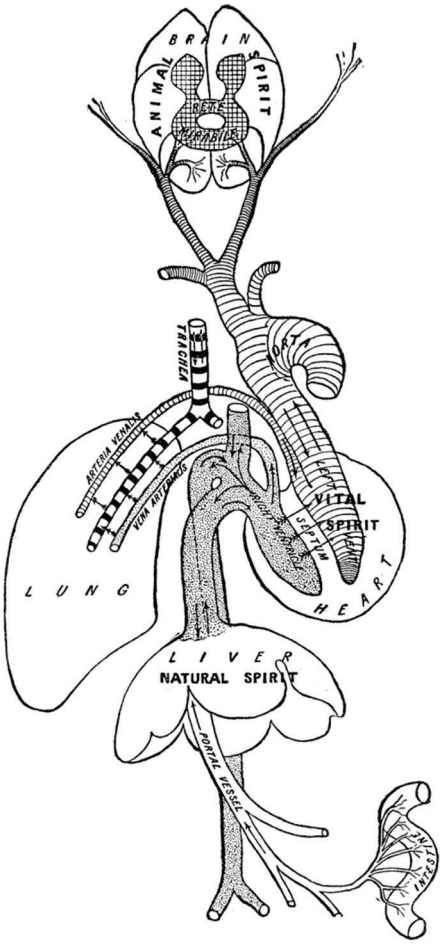

Fig. 9: Interpretation of Galen's understanding of human physiology by https://wellcomeimages.org/indexplus/obf_images/e4/ea/3b3191a5df9013f3a607cf06a756.jpgGallery: https://wellcomeimages.org/indexplus/image/M0000376.htmlWellcome Collection gallery (2018-03-29): https://wellcomecollection.org/works/sa2dbj78 CC-BY-4.0, CC BY 4.0, https://commons.wikimedia.org/w/index.php?curid=36308717

Fig. 10: Illustration showing the teachings of Andreas Vesalius, from the title page of the first edition of De humani corporis fabrica libri septem (AD 1543). https://www.britannica.com/biography/Andreas-Vesalius#/media/1/626818/198189

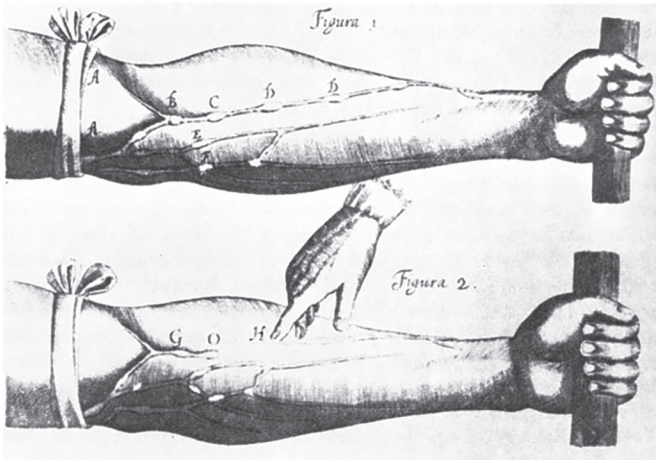

Fig. 11: An illustration showing the blood circulation in Harvey's "*de Motu Cordis*"

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Continues as Evolution of ECMO-Part 2 in next issue

REVIEW ARTICLE

Sedation Management on ECMO

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Abstract

Sedation, analgesia, and muscle relaxants are an integral part of critical care unit, which works like a double-edge sword, and hence judicious use of each agent remains the matter of primary concern. These get more compounded, especially when the patient is on extracorporeal therapy. The patient who needs extracorporeal therapies besides being critically ill also has altered pharmacokinetics for varied reasons and usually has longer ICU stay. Recently, there is a paradigm shift in practice of sedation in critical care unit from deep and prolonged sedation to short and minimal sedation. The basic goal of sedation therapy in a critical care unit is to keep the patient comfortable with minimal possible sedation, avoid muscle relaxants as far as possible, and try to give sedation break.

The commonly used drugs are opioids, benzodiazepines, major tranquilizers, and anesthetic agents like barbiturates, propofol, etc. Ideal sedative agents during ECLS should be short-acting as daily sedation break is mandatory to assess CNS status, should not be reacting to the circuit (like fentanyl and propofol), and cardiostable.

Extracorporeal circuits alter the pharmacokinetics of sedative agents by increase in the volume of distribution, circuit adsorption, and hypoproteinemia secondary to systemic inflammatory response syndrome (SIRS).

The need for sedation in cardiac ECMO is very limited, provided there is no associated lung pathology (like pulmonary edema). Cardiac patient can well be kept off the ventilator, or if already intubated, can be extubated at the earliest so that the sedation requirement is minimized.

In respiratory ECMO, invariable sedation is required, especially in the first few days till the time the patient stabilizes. Sedation requirement after 48 hours of ECMO is mostly because of patient-ventilator asynchrony and the air hunger. This can be to some extent managed by maintaining low PCO_2 (less than 30), which can be achieved by keeping high-sweep gas.

The different scoring systems that can be followed are modified motor activity assessment scale (MMAAS) and Richmond agitation-sedation scale and comfort score. The monitoring scale is as per the institutional protocol.

In contrast to the sedated patient, the awake patient has multiple advantages on medical, psychological, and social front.

Keywords: Awake ECMO, Pharmacokinetics in ECMO, Sedation during ECMO.

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Introduction

Sedation, analgesia, and muscle relaxants are an integral part of critical care unit, which works like a double-edge sword. These get more compounded, especially when the patient is on extracorporeal therapy. The patient who needs extracorporeal therapies, besides being critically ill, also has altered pharmacokinetics for a varied reason and usually has longer ICU stay. Recently, there is a paradigm shift in the practice of sedation in critical care unit from deep and prolonged sedation to short and minimal sedation. Sedation practices vary with different critical care units. However, the basic principle of minimizing the use of sedation with safety in mind remains universal. Each unit follows some kind of assessment tools and has its own sedation protocols for when, which, and how to use sedation.[1–3]

Now, it has been established beyond doubt that use of sedation is associated with both short-term and long-term adverse effects, but at the same time, it is an essential tool in critical care units. The reason we need sedation is to give comfort and pain relief to the patient to relieve anxiety and delirium. It induces amnesia so that the patient does not have psychological effect from the event. It decreases the metabolic rate and thereby decreases oxygen consumption and cardiac output. In noncooperative and agitated patient, it decreases the risk of catheter malposition and decannulation. It helps to improve patient ventilatory asynchrony and thereby oxygenation.

The immediate adverse effect of use of sedation and muscle relaxant is hemodynamic instability and loss of spontaneous drive, which leads to atelectasis and delays lung recovery leading to prolonged ventilation. [3,4] Also, that makes the patient more prone for ventilator-associated lung injuries especially pneumonia.[5,6] The prolonged use of sedation and especially muscle relaxants is associated with critical care myopathy, which ultimately increases the ventilatory days and ICU stay days. Deep sedation also makes the neurological assessment difficult.

Decreased sedation and spontaneous breathing will increase lymphatic drainage and are associated with reduced length of stay and reduced mechanical ventilation.[7–9] Early mobilization of the patient on ECMO gives comfort to the patient, it counteracts muscle atrophy, and reduces the risk of bed sores, venous thrombosis, and

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Table 1: Goal of sedation

- Keep the patient comfortable with minimal sedation.
- Daily interruption – give awake cycle.
- Minimal adverse events related to sedation.
- Avoid muscle relaxant as far as possible.

Table 2: Indication for sedation

Indications for sedation
- To relieve pain and anxiety
- To improvise gas exchange
- In a restless and agitated patient to prevent patients from removing lines
- For patient-ventilator asynchrony
- To give a normal sleep pattern in night
- Before any procedure, cannulation, and decannulation

Indications for muscle relaxants
- Patient-ventilator asynchrony
- When patient movement interferes with venous return
- In the rare situation when excessive patient movement threatens accidental decannulation

ICU-acquired myoneuropathy.[7,10] While withdrawing sedation, psychotic stage is usually seen as a withdrawal phenomenon that can be treated with antipsychotics or with half the dose of muscle relaxants. Usually within 2 days, the patient wakes up normally and then we can stop muscle relaxant.

Indications of Sedation

Sedation and muscle relaxants should be used judiciously. One should have a clear idea about why and when the sedation should be used. The basic goal of sedation therapy (Table 1) in a critical care unit is to keep the patient comfortable with minimal possible sedation, avoid muscle relaxants as far as possible, and try to give sedation break.

Minimum sedation and daily interruption help us to assess patients neurologically, which will help us to diagnose neurological complications at the earliest. It has been found to have shortened the length of mechanical ventilation and also has reduced the complication [8,11] like ventilator-associated pneumonia (VAP). This strategy of sedation break helps the patient to be aware about the surrounding and also some interaction with the staff and relatives. This also helps at the social front to keep relatives motivated and satisfied. Lighter sedation is associated with less drug accumulation that may reduce ICU length of stay, duration of ventilation, reduced ventilator-induced diaphragmatic dysfunction, and risk of delirium, which is associated with risk of mortality. [9,12]

Sedation should be used with specific indications (Table 2). Sedation should be used to relieve pain and anxiety. It is used to calm down the violent patient and to prevent those removing lines. It should be given to maintain the normal sleep pattern in the night so that they wake fresh in the morning and they are oriented to time. In case when there is patient-ventilator asynchrony, sedation is indicated after ruling out all other causes of asynchrony. In severe cases of respiratory failure, when the patient requires a high ventilator and ECMO support to maintain saturations, sedation should be used to decrease the metabolic activity and thereby decrease the oxygen (O_2) consumption and carbon dioxide (CO_2) production. As mentioned earlier, muscle relaxants should be avoided as far as possible and should be given only when sedation fails to relax the patient completely and he still shows patient-ventilator asynchrony. During ECMO, at times, we require to use muscle relaxants to avoid any kind of movements as the movement interferes with venous return (thereby ECMO flow) or it leads to excessive recirculation in VV ECMO. It should be used in the rare situation when excessive patient movement threatens accidental decannulation.

Table 3: Range of drugs available

Sedatives	*Analgesics*	*Hypnotics and others*
Benzodiazepines	Morphine	Quetiapine
Clonidine	Fentanyl	Risperidone
Dexmedetomidine	Meperidine	Olanzapine
Propofol	Remifentanil	Haloperidol
Thiopentone	Oxycodone	Fluoxetine
Ketamine		Inhalational
Etomidate		
Chloral hydrate		

Pharmacological Agents

Various sedatives and muscle relaxants are used in critical care. The commonly used drugs are opioids, benzodiazepines, major tranquilizers, and anesthetic agents like barbiturates, propofol, etc. Ideal sedative agents during ECLS should be short-acting as daily sedation break is mandatory to assess CNS status. It should not be reacting to circuits like fentanyl and propofol. It should be cardio stable (Table 3).

Opioids are usually the preferred agents in critical care units for analgesia and sedation. The agents that are available are morphine, buprenorphine, fentanyl, and remifentanil. The problems with opioid derivatives are they can cause respiratory depression, hypotension, gastric hypomotility, and constipation. Rarely, they can cause hallucinations and agitation.

Benzodiazepines are the drug of choice for sedation but do not have any of analgesic effects. Usually, they are used in combination with some analgesics. The agent that is commonly used in the critical care unit is midazolam. Barbiturate pentobarbital has not much been used in critical care units. Propofol has been used in the critical care unit, but the problem is the lipid base and can cause hypotension. It requires a separate line as it is lipid-based and also the chances of infection increase. During the ECMO run, it is not used as it gets adsorbed to the membrane and can decrease the membrane function. However, it is more known with silicon oxygenator than hollow fiber or polymethyl pentene (PMP) oxygenator. So, some centers still use propofol even during ECMO run (Table 4).

Ketamine due to its sympathomimetic property and dexmedetomidine due to its awake analgesia are getting popularity in the critical care unit. Ketamine is safe to be used in hypotensive patients, and also it relieves severe bronchospasm, hence it is a drug of choice for sedation in status asthmaticus. The problem with ketamine is hallucination and nightmares, and also it increases secretion. Usually, it is used in combination with midazolam. Dexmedetomidine is relatively safe, short-acting, and does not cause respiratory depression. It has a better analgesic effect. It is popular for awake analgesia, but usually not preferred to be used for more than 48 hours. The details of the few commonly used agents are given in Table 4.

The pharmacokinetics of these various agents has some variation in critically ill patients due to altered metabolism. This is more exaggerated when the patient is on extracorporeal therapy.

Table 4: Dosage of commonly used sedative agents in ICU

Name	*Dosage*	*Features*
Fentanyl	Bolus – 0.1–0.3 µg/kg Infusion – 0.1 µg/kg/hour	Synthetic opioid, 50–100 times more potent for pain relief compared with morphine. It is the shortest and quickest-acting analgesic.
Remifentanil	Infusion – 0.6–15 µg/kg/hour	Even quicker and shorter-acting than Fentanyl
Morphine	Bolus – 5 mg Infusion – 0.07–0.5 mg/kg/hour	Causes respiratory depression, hypotension, and reversal – Naloxone
Buprenorphine	Bolus – 0.1–0.3 mg Infusion – 0.01 mg/kg/hour	Potent synthetic opioid analgesic and anesthetic
Ketamine	Bolus – 0.25–1 mg/kg Infusion – 0.25–1 mg/kg/hour	Remains as a drug of choice for hemodynamically unstable patients. Can cause hallucinations and nightmares, increased secretions
Lorazepam	Bolus – 0.04 mg/kg	Duration of action is 6–10 hours. It is to be used as intermittent bolus
Midazolam	Bolus – 0.1 mg/kg Infusion – 0.5–5 µg/kg/minute	Short-acting benzodiazepine, three times potent than diazepam. Can cause respiratory depression, hypotension, myocardial depression, and antidote – flumazenil
Pentobarbital	2–6 mg/kg/dose IV over 3–5 minutes as intermittent boluses can be given 4–6 hourly	Barbiturates should not be used as a routine drug
Propofol	Bolus – 0.5–1 mg/kg, Infusion – 25–70 µg/kg/hour	Lipid emulsion. It is both intravenous sedative and anesthetic agent. It is a potent sedative – hypnotic drug. Adverse – hypotension and vasodilatation, hypertriglyceridemia, bacterial contamination, and propofol infusion syndrome (myocardial depression, shock, profound metabolic acidosis, rhabdomyolysis, and renal failure)
Dexmedetomidine	Bolus – 1 µg/kg Infusion – 0.2 – 0.7 µg/kg/hour	Selective a_2 receptor agonist. It is safe and as effective as benzodiazepines. Hypotension and bradycardia, easily arousable
Pancuronium	Bolus – 0.1 mg/kg IV Infusion – 0.02 – 0.1 mg/kg/hour	Long-acting neuromuscular blocking agent
Vecuronium	Bolus – 0.1 mg/kg IV Infusion – 0.06 – 0.15 mg/kg/hour	Short-acting neuromuscular blocking agent, cardiostable agent excreted mainly by the liver
Atracurium	Bolus – 0.4 mg/kg IV Infusion – 0.6 – 1.2 mg/kg/hour	Safe to be used in renal and hepatic failure, histamine release, and causes hypotension
Cisatracurium	Bolus – 0.15 mg/kg IV Infusion – 0.06 – 0.24 mg/kg/hour	Curare derivative and is independent of both hepatic and renal metabolism

The patient on ECLS has an altered physiology due to the extracorporeal circuit. This extracorporeal circuit adds into circulating blood volume, which leads to an increase in the volume of distribution and even has dilutional effect. Second, when blood comes in contact with this foreign circuit, it leads to activation of chemical mediators resulting in a cascade of reactions termed as SIRS (Table 5).

Moreover, the patients are critically ill with compromised organ functioning and some of them are in multiorgan failure. All these will alter the pharmacokinetics and pharmacodynamics of the drug in terms of blood level, tissue penetration, and elimination of drugs. Also, when the patient is on ECMO, there is a decrease in plasma protein as it gets adhered to the circuit, so those drugs requiring protein binding will be a problem. Many drugs like propofol and fentanyl get adsorbed in the circuit and they are required in high dose for the desired effect to come. In VA ECMO, as there is a nonpulsatile flow, the cerebral circulation is altered and even the blood–brain barrier function is also altered that might exaggerate the effect of sedative dose.

There are few *in vitro* and *in vivo* studies done regarding the sequestration of various sedative agents in ECMO circuits and pharmacokinetics of various agents while on ECMO. The few studies have been given in Table 6. The final conclusions derived from the different studies for commonly used sedative agent are given in Table 7. Drug sequestration in ECMO circuits also depends on the circuit used[10,13] and the surface area of the circuit. Sequestration is found more in silicon oxygenator and less in hollow fiber oxygenator (Fig. 1), drug sequestration in Quadrox oxygenator (see Fig. 2). Again, it will also depend on whether the circuit is coated or uncoated circuit. Patients on ECMO often have increased sedation requirements.[11,14]

Table 5: Factors affecting sedation during ECMO

Circuit-related factors	*Patient-related factors*
• Increased volume of distribution	• Changes in serum protein concentrations and protein binding
• Sequestration of sedative drugs[13,14]	• Altered hepatic, renal, and cerebral blood flow leading to impaired elimination
• Age of the circuit	• Organ dysfunction

Sedation Strategy in ECLS

Sedation strategy will differ as per the institutional policy and every institute needs to modify their sedation policy for the patient on

Table 6: Case studies on sedation and ECMO

Study	*Investigators*	*Outcome*
Sequestration of drug in the circuit may lead to therapeutic failure during extracorporeal membrane oxygenation	Shekar et al., Critical Care, 2012	Significant drug loss after 24 hours in Jostra Rotaflow / Quadrox D
Population pharmacokinetics of intravenous clonidine for sedation during pediatric ECMO and CVVH	Niina Kleiber et al., British Journal of Clinical Pharmacology, 2017	Increased CL and Vd need higher dose on ECMO
Phenobarbital dosing and pharmacokinetics in a neonate receiving extracorporeal membrane oxygenation	Elliott and ML Buck	Neonates on ECMO require larger phenobarbital doses to achieve desired serum concentrations due to the presence of large exogenous blood volumes for priming, as well as loss of drug during circuit changes, extraction by the circuit, or hemofiltration.
In vitro study sedative clearance during extracorporeal membrane oxygenation	Varsha Bhatt - Mehta, Gail Annich et al.	Up to 50% of a dose of lorazepam and 40% of a dose of morphine may be extracted by PVC and MO during bypass, depending on the age of the circuit. As the circuits become older, this amount could increase.
In vitro evaluation of sedative drug losses during extracorporeal membrane oxygenation	Mulla, Lawson et al., 2000	Results revealed significant uptake of drugs with losses in the range 40–98% and in the order propofol • diazepam • midazolam • lorazepam. When albumin was used, additional 10% increase in uptake
In vitro adsorption of analgosedative drugs in new Extracorporeal membrane oxygenation circuits	Raffaeli et al., PCCM Journal, 2018	Significant loss of lipophilic drugs (at 24 hours), different adsorption of midazolam, and adsorption varies with different ECMO circuits

Table 7: Sedative agents during ECLS

Sedative agents	*Study conclusion*
Propofol	High sequestration in ECMO circuit hence are not the ideal agents to be used. If used, there blood level will not be achieved till the circuits get fully saturated, so it requires initially high dose to saturate the circuit. Also, whenever the circuit is being changed, the same thing will follow.
Fentanyl	*In vitro* studies show 70% irreversibly bound to the circuit. Tenfold higher dosing in a case series. Almost 97% drug loss after 24 hours in Maquet system.[11,14]
Morphine	Data are conflicting, but show high interpatient variability in clearance, increasing fivefold after 10 days in one case series. Clearance appears to increase after decannulation that could precipitate withdrawal. Binding may increase to 40% as the circuit ages. Minimal drug loss after 24 hours in Maquet circuit.[11,14]
Opiates and benzodiazepine	Gets adsorbed in the circuit but to a lesser degree so they are the drug of choice for sedation. Probably they are to be used in higher dosage, but the exact dosage is not recommended due to paucity of studies and recommendation is to use the dosage as per clinical response.
Lorazepam	Data are limited to *in vitro* studies. Sedation requirements appear to increase over time due to either adsorption in the circuit or tolerance.
Phenobarbital	Case reports show increased requirements particularly after circuit change. *In vitro* data are conflicting, which ranges from no effect to 17% of drug lost to the circuit.
Midazolam	Significant drug loss after 24 hours on extracorporeal membrane oxygenation.

ECLS. Again, the sedation policy for the ECLS will be different for cannulation, for ECLS run, and for decannulation.

Sedation in ECMO is required for cannulation and decannulation. Sedation policy during cannulation can be the same as the routine critical care policy. The sedation policy during cannulation will depend on the condition of the patient at the time of cannulation, e.g., cannulation while resuscitating (for ECPR) does not require sedation. Propofol can be used for cannulation but not for ECMO run. The patient should be given a full anesthetic dose of sedation during cannulation to alleviate the pain and anxiety. Even muscle relaxants should be used to prevent the movement and possible chances of air embolism, especially while cannulating the jugular vein. Decannulation should be done under local anesthesia with mild bolus dose of sedation like fentanyl or benzodiazepine. Muscle relaxants are usually avoided post decannulation, especially in prolonged VV ECMO as that will decrease the spontaneous drive which is essential for carbon dioxide elimination. Post decannulation, the sedation policy remains like a routine critical care policy.

During the ECMO run, the sedation requirement is not mandatory, it depends on various factors like the mode of ECMO, the patient's condition, flow requirements, etc. Also, the strategy for sedation during the ECMO run definitely requires modification and is as per compatibility with the ECMO circuit. The basic plan is to use minimum sedation as far as possible. A policy and tradition of minimal sedation has evolved at the Karolinska Institute, Sweden. Initially for few days, the patient is sedated with the infusion

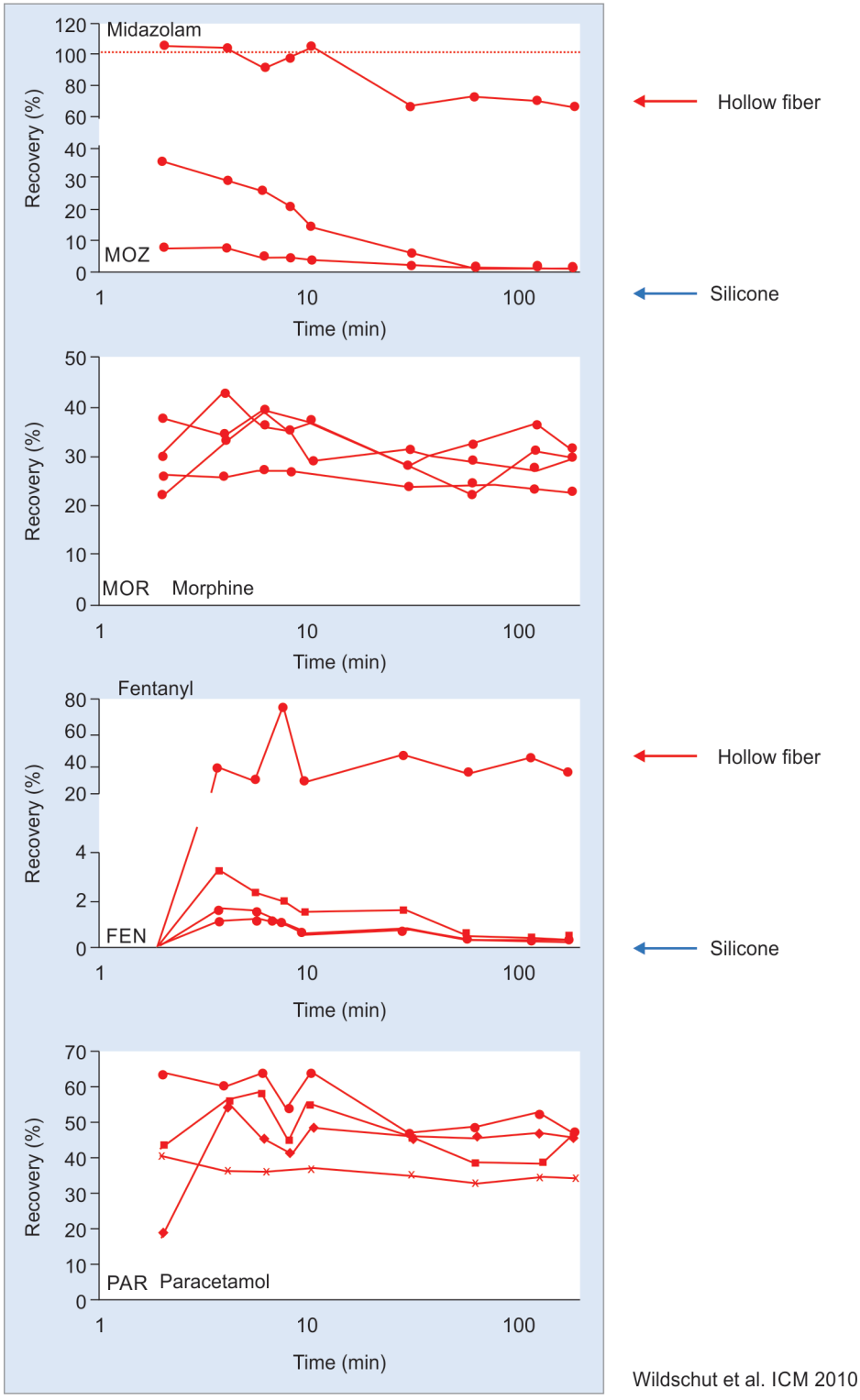
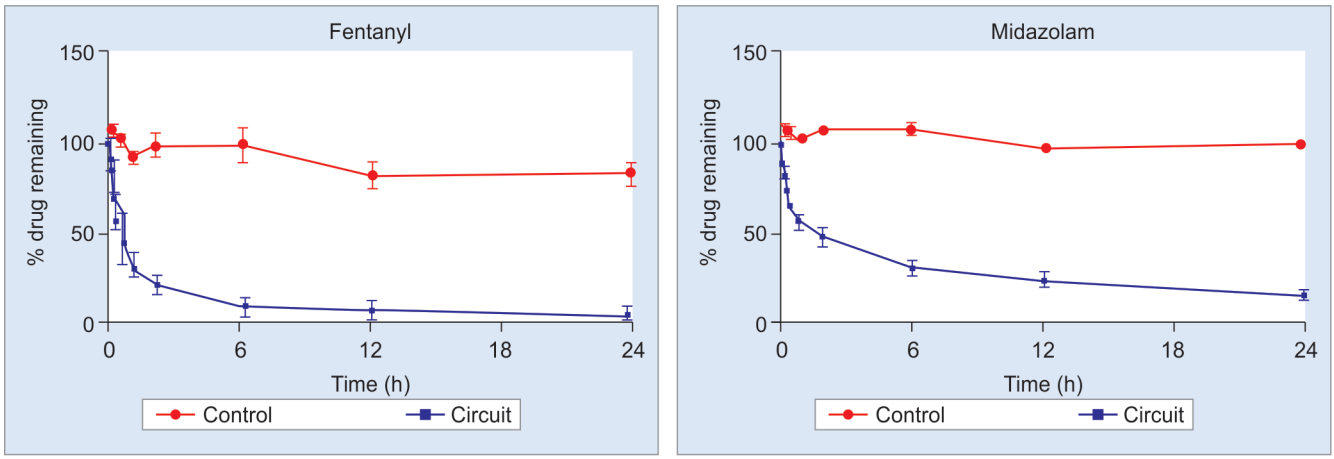


Fig. 1: Drug sequestration with different oxygenator

of opiates or benzodiazepine with daily interruption. Sedation should be stopped as soon as the patient stops fighting and gets acquainted.

The need for sedation in cardiac ECMO is very limited, provided there is no associated lung pathology (like pulmonary edema). Cardiac patient can well be kept off the ventilator or, if already intubated, can be extubated at the earliest, so that the sedation requirement is minimized.

In respiratory ECMO, invariable sedation is required, especially in the first few days till the time the patient stabilizes. Sedation



Drug loss after 24 hr in Jostra rotaflow/quadrox D ECMO

Fentanyl	97%
Morphine	0%
Midazolam	90%
Meropenem	80%
Vancomycin	10%

Fig. 2: Drug sequestration in ECMO circuit

requirement after 48 hours of ECMO is mostly because of patient-ventilator asynchrony and air hunger. This can be to some extent managed by maintaining low PCO_2 (less than 30), which can be achieved by keeping high-sweep gas and maintaining pH around 7.45. Another reason is patient's anxiety, pain, and agitation. The other treatable causes like mucus plug or excess secretion in the endotracheal tube and hypoxia, should be ruled out and, if present, should be addressed immediately.

In long-term respiratory ECMO and ECMO in chronic lung diseases, the sedation requirement is not very high. In these cases, one should try for awake ECMO, and only mild sedation should be used, especially during the night, to facilitate sleeping. Analgesics to be given always prior to minor procedures such as line or chest drain placement or other patient care. For the patient who has received long-term opiates, clonidine can be used to facilitate weaning off opiates. As mentioned earlier about the drug adsorption to the circuit, whenever there is a change of circuit, we might require some bolus dose of sedation.

Manytimes in prolonged respiratory ECMO, sedation may be required for a long time, and some patients do develop tachyphylaxis. They even do not get sedated with high doses of sedative agents, and you might require to use other sedative agents. So, in such cases, alternate groups of sedative agents are used for few days to break this cycle of habituation and drug tolerance.

It is essential to have daily team discussions about the phase of the disease, targeted sedation as per phase of the disease, arousal assessment, sedation weaning plan, and daily extubation readiness testing.

ELSO Guidelines

The patient should be thoroughly sedated to the point of light anesthesia during cannulation and management for the first 12–24 hours.[12,15]

After 24–48 hours: moderate-to-minimal sedation.

After 48 hours: minimal to no sedation.[13,16]

For adult patients, the RASS score is a good way to manage sedation.

Table 8: Modified Ramsay Score

0 – Unresponsive
1 – Responsive to noxious stimuli
2 – Responsive to touch or name
3 – Calm and cooperative
4 – Restless and cooperative
5 – Agitated
6 – Dangerously agitated and uncooperative

Conversion to tracheostomy should be considered early in the course in patients over 5 years of age to allow decreasing sedation.

Holding sedation and analgesia long enough to do a neurologic exam should be done daily (a daily drug holiday).

Monitoring of Patient

Analgosedative dosing should be guided by clinical monitoring and validated sedation and pain scales. A clinical sedation score is to be obtained every 4 hours and sedation is to be titrated accordingly. The different scoring systems that can be followed to guide overall sedation practice are the Modified Ramsay Score (Table 8) or RASS[1–3] (Table 9). The monitoring scale is as per the institutional protocol. Usually, target Modified Ramsay score to 3 or RASS score of –1 to 0.[14,17]

Assessment Tools

Bispectral Index (Bis)[15,18] measures the level of consciousness by algorithmic analysis of EEG. It has Scale 0 (silent EEG) to 100 (fully awake). It is a good tool to use for deep sedation/anesthesia, does not differentiate the level of consciousness for moderate-to-deep sedation.

Awake ECMO

In contrast to the sedated patient, awake patient has multiple advantages on the medical, psychological, and social front. The awake patient has better lymphatic fluid drainage from the lungs with spontaneous breathing as compared with positive-pressure ventilation. They generate better tidal volume due to forced

Table 9: Richmond agitation-sedation scale (RASS)

STAGE I – Observe the patient	If restless or agitated score from +1 to +4. If alter or calm score 0. If not alter progress to stage II	+4	Combative	Overtly combative or violent, immediate danger to the staff
		+3	Very agitated	Pulls on or removes tubes or catheters, aggressive
		+2	Agitated	Frequent nonpurposeful movement, patient-ventilator dysynchrony
		+1	Restless	Anxious but movements not vigorous or aggressive
		0	Alert and Calm	
STAGE II – Assess response from verbal stimulation – state patient name & ask to open eyes and look at the speaker. Repeat if necessary	If response from voice, then assess from -1 to -3. If no response, move to stage III	–1	Drowsy	Not fully alert, awakens and sustains eye-opening, and contact for more than 10 secs
		–2	Light sedation	Awakens and briefly sustains eye-opening, and contact for less than 10 seconds
		–3	Moderate sedation	Any movement in response to voice but no eye contact
Stage III – Physical stimulation by shoulder shake or sternal rub (if safe)	Assess response to physical stimuli	–4	Deep sedation	Movement or eye-opening to physical stimulation
		–5	Unrousable	No response to physical stimulation

Table 10: Advantages of awake patient[17,20]

- Better lymphatic fluid drainage from the lungs
- Better tidal volume due to forced expiration
- Better clinical control in terms of lesser hemodynamic effect, lesser ventilator requirements, and peak pressures
- Better infection control
- Psychological reasons – Patient can communicate with the relatives
  - The patient is able to communicate with the staff about:
    - Changes in body position
    - Body temperature (fever and shivering)
    - Thirst, hunger, and nausea
    - Pain and anguish
    - Outputs (urine and bowel)
    - Neurological control
- Social reasons –
  - Decreases the relative's anxiety
  - Develops some positive attitude

expiration, better infection control, and decreased ventilatory requirement with better hemodynamic controls. The psychological benefit is patients can communicate with the relatives and staff. The patient remains aware about the surroundings and can also actively communicate regarding his problems and dilemmas. Patient participation aids recovery, increased transplant recovery, and decreased postoperative hospital length of stay.[16,19] The social benefit is it decreases the relative's anxiety and helps to develop some positive attitude.

Many times, when the patient is awake, he or she is likely to have some drop in saturation due to increased metabolism. If the patient remains hemodynamically stable, maintaining good urine output, awake, and lactates are acceptable, then we accept lower saturation and prefer to keep the patient awake. One can even increase the ECMO flow (if required) to improve saturation (Table 10).

Extra care is required to maintain adequate flow and prevent accidental decannulation. Also, one should keep a watch on respiratory rate and breathing patterns in order to avoid self-induced lung injury (SILI). Active and passive limb physiotherapy and chest physiotherapy should be encouraged, and if the patient is not able to bring out expectoration, then periodic bronchoscopy is advocated. Communication with the patient should be done by the staff and relatives with respect to his comfort and complaints. For children, it is important to have one of the parents at the bedside most of the time to keep them calm and cooperative. Reading books and telling stories are highly effective in keeping children calm. Let them use all sorts of entertainment like computers, movies, and television to divert their mind.

Summary

ECMO is not painful by itself. Continuous heavy sedation should not be used as sedation does not come without a price.[21] However, achieving optimal levels of sedation to promote comfort, relieve stress, maximise ECMO flows and minimise oxygen consumption, while preventing accidental dislodgement of life-sustaining equipment, can be a difficult balancing act in the setting of altered pharmacokinetics during ECMO. Although the use of minimal sedation and early tracheotomy and ambulation in selected patients has been reported,[22] this is not always possible. Fentanyl and propofol gets coated to circuit hence to be avoided. Muscle relaxant to be avoided as far as possible. It is not just the matter of which sedative agents to use but it is equally important to know do patient needs sedation? Why does he/she need sedation? Can we go without sedation? All these questions need to be answered before giving sedation to the patient.[20] Remember Gentle patient care, friendly talking to the patient and warm assurance to the patient are potent sedatives.

So in short, Sedation Management on ECMO is a risk benefit balance, deep Sedation has risks that appear to outweigh its benefits. Maintaining less to no sedation appears to have benefits but is not without risks. Management of the awake patient is challenging, more resource intensive & requires a dedicated team approach

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CASE REPORT

Primary Hybrid Extracorporeal Membrane Oxygenation in Septic Shock with Acute Respiratory Distress Syndrome: A Case Report

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Abstract

Septic shock with acute respiratory distress syndrome (ARDS) comes with extremely high mortality. In this case report, we are presenting a case of septic shock with biventricular dysfunction rescued by primary hybrid VAV ECMO and de-escalated the support as the organs started improving.

Keywords: Acute respiratory distress syndrome, Hybrid extracorporeal membrane oxygenation, Septic shock.

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Introduction

Sepsis is a clinical syndrome characterized by systemic inflammation due to infection. The mortality rate estimated is wide-ranging and is more than or equal to 40%[1] when presented with shock. This study discusses a case of septic shock with ARDS rescued with primary hybrid veno-arterial-venous extracorporeal membrane oxygenation (VAV-ECMO).

Case History

A 65-year-old male was admitted with fever and respiratory distress for the last 3 days. After admission, his SpO_2 was 82% with a non-rebreather mask (NRBM) and he was drowsy, so he was taken on invasive ventilation. However, he remained hypoxic with SpO_2 of 80%, FiO_2 of 1%, and positive end expiratory pressure (PEEP) of 14. Chest X-ray revealed bilateral infiltrates with basal consolidation with cardiomegaly. Bedside echocardiography revealed he has an ejection fraction (EF) of 25% with severe biventricular dysfunction. Meanwhile, he became hemodynamically unstable and required vasopressors in the form of noradrenaline, vasopressin, and adrenaline after fluid resuscitation as per the surviving sepsis guidelines.[2] Laboratory results revealed procalcitonin of 16, Total leucocyte count of 1890, and serum creatinine of 3.4. Endotracheal BioFire and subsequent culture analyses revealed methicillin-sensitive *Staphylococcus aureus* for which we started injection flucloxacillin.

In view of rapidly progressing pneumonia with ARDS and hemodynamic instability due to the severe biventricular dysfunction with severe lactic acidosis, the patient's relatives were counseled to rescue him on ECMO support. After informed consent, we cannulated his femoral artery (16 Fr) and vein (24 Fr) with a distal perfusion cannula of 7 Fr and started on veno-arterial ECMO with a flow of 3.2 L. As his right-hand saturation remained lower than 70% with a pulse pressure of 15, another right internal jugular venous cannula (18 Fr) was inserted and he had been taken on a hybrid VAV configuration of ECMO. Vasopressors were tapered off slowly as the mean arterial pressure, lactate level, and urine output improved over 24 hours keeping a touch of adrenaline @0.05 µg/kg/minute dosage to maintain a pulse pressure of more than 10. Blood culture did not show any growth of the organism with slowly normalizing procalcitonin and total leucocyte count for the next 3 days.

Serial echocardiographic measurements showed gradual improvement in EF with aortic VTI and we came off arterial support on day 6 and continued on VV ECMO in the femoro–jugular configuration as ARDS remained a concern. After 14 days, both the compliance and the chest X-ray improved significantly, so we could decannulate him after 24 hours of trial-off. The next day, we did a tracheostomy and slow ventilator weaning commenced. Ultimately, tracheostomy decannulation was done on day 23 and discharged the patient on day 27.

Discussion

Adult septic shock remained a controversial indication for ECMO for decades.[3] Furthermore, VA-ECMO has been successfully applied as a rescue strategy in pediatric and neonatal sepsis even with a central cannulation strategy. The comparison survival in both groups shown by Yang et al. is 18% in adults and 53% in children.[4] In adults, its role is limited due to ongoing capillary leak and third-spacing and inadequately achieved flow, especially by peripheral cannulation. The recent meta-analysis by Ling et al. showed that if the adult septic shock is associated with low EF (less than 20%), the VA-ECMO is beneficial but with normal EF with hyperdynamic sepsis, its role

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is very limited.[5] Moreover, ECMO should be considered a valuable therapeutic option for patients with refractory cardiovascular dysfunction in the context of septic shock.[6] The hemodynamics, we experienced herein (low cardiac index, elevated filling pressure, profound myocardial depression, and elevated systemic vascular resistance) is certainly a rare but treatable entity in the spectrum of septic shock with VA-ECMO, which resembles almost cardiogenic shock.

In our case, a rapid progressive ARDS with septic shock with low EF compels us to think about VA-ECMO initially. However, in the patient's poor lung condition, a primary hybrid VAV strategy proved better to improve overall oxygenation of both ECMO and the native cardiac output. We de-escalated the support sequentially according to which organ improved first and continued respiratory ECMO till ARDS improved.

Conclusion

In adult patients, we suggest addressing rapidly progressing septic shock with ARDS with low EF with primary VAV hybrid ECMO strategy and slowly de-escalating according to the sequential organ improvement.

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CASE REPORT

Venovenous Extracorporeal Membrane Oxygenation Elective Therapy Time to Rethink: A Case Report and Review of Literature

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Abstract

Acute airway obstruction poses a therapeutic challenge to treating physicians. There can situations where one is unable to secure the airway along with complete airway obstruction. In such conditions, ECMO can be considered as one of method that can protect from hypoxic damage simultaneously by giving time for adequate surgical access to airway. We present a case of complete airway obstruction where time for adequate surgical access was provided by use of VV-ECMO without any hypoxic damage.

Keywords: Acute airway obstruction, Difficult airway, Extracorporeal membrane oxygenation, Tracheostomy.

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Introduction

Acute airway obstruction can be life-threatening condition, which requires emergent airway access. Management of a difficult airway is a critical element of emergency practice. Difficulty can be in form of difficult intubation, supraglottic device placement, or surgical access. Tumors causing extrinsic airway compression, especially of the trachea pose a therapeutic challenge. Airway management of such patients needs the development of a strategy keeping in mind the relevant anatomy as well as the physiology of such patients. There are situations though not very frequently encountered, where one is unable to secure the airway along with complete airway obstruction. Such situations are nightmares for the physicians as they can be fatal. Extracorporeal membrane oxygenation (ECMO) can be an answer to such desperate situations by providing time window till adequate surgical access can be obtained. We describe a case of life-threatening, malignant tracheal obstruction managed successfully with ECMO rescue. The objective of reporting this case is to highlight the importance of ECMO in acute airway emergencies where other measures of securing airway might fail.

Case Report

A 48-year-old male underwent radical surgery followed by local radiotherapy for squamous cell carcinoma of the right buccal mucosa in 2012. He had a local recurrence in June 2015 and underwent right commando resection with free fibula graft surgery with a tracheostomy. He was decannulated one month after the surgery. Five months later, follow-up positron emission tomography–computed tomography (PET–CT) scan revealed a recurrence of the disease for which he was started on palliative chemotherapy. After three cycles of chemotherapy, he started having difficulty in breathing and presented to our emergency with severe respiratory distress. His pulse rate was 204/minute; blood pressure was 144/66 mm Hg; respiratory rate was 45/minute, oxygen saturation was 85–86% on O_2 by high flow Venturi mask. On auscultation, bilateral air entry was reduced in intensity with wheezing. He was managed with non-invasive mask ventilation, nebulized with bronchodilators, intravenous steroids, and antibiotics.

Computed tomography scan of the neck revealed tracheal obstruction due to tumor recurrence at the tracheostomy site with a vertical length of 2 cm and over 90% luminal compromise (Figs 1 and 2). The patient was admitted to the intensive care unit (ICU). He needed immediate relief from obstruction. Both distorted anatomy and a very small tracheal lumen were predictors of anticipated difficulties with bag–mask ventilation, supraglottic airway placement and tracheal intubation. Therefore, all these were dismissed as viable options. Cricothyroidotomy and cervical tracheostomy were not possible due to tumor recurrence with severe tracheal obstruction at the previous tracheostomy site. Mediastinal tracheostomy needed general anesthesia, which was not possible. Rigid bronchoscopy to core out the tumor, was not possible as his neck could not be extended due to recurrence and previous radiotherapy. Fiberoptic bronchoscopic debulking of the tumor to relieve tracheal obstruction was considered an option. However, the same could have led to complete obstruction and choking during the procedure, and the absence of any surgical access to the trachea in the neck would have led to immediate arrest due to hypoxia. To avoid this eventuality and provide

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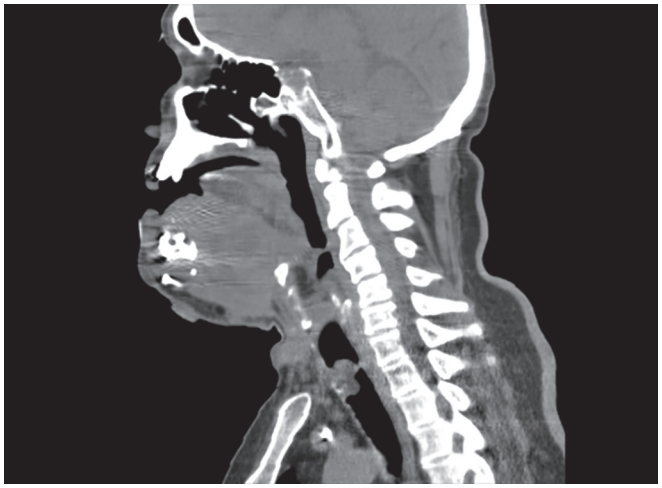

Fig. 1: The CT scan of sagittal section showing near a complete tracheal obstruction

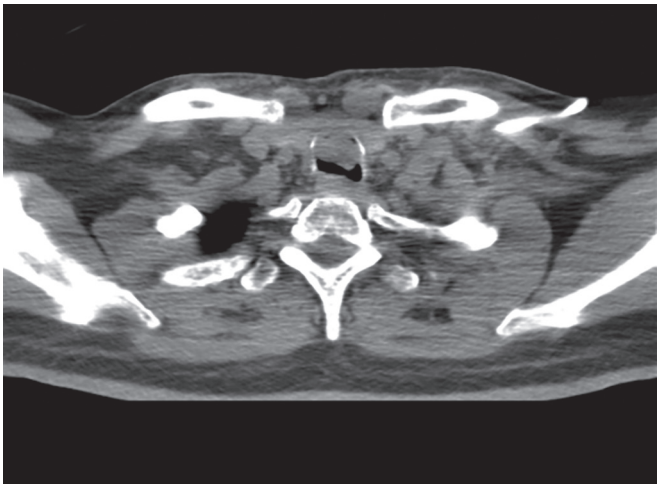

Fig. 2: The CT scan showing the low location of the tumor in the trachea at the level of the suprasternal notch

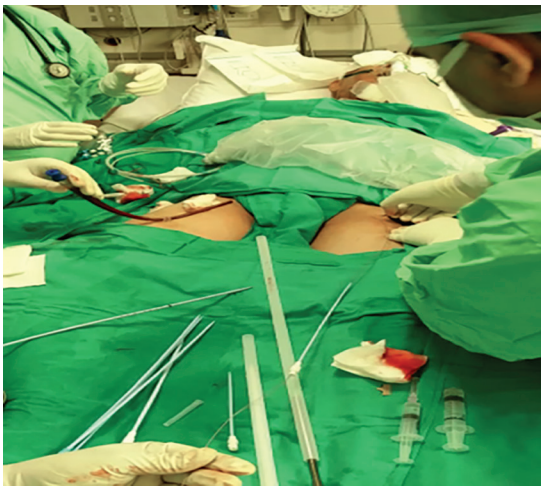

Fig. 3: V.V. ECMO Canulation

sufficient time for to pulmonologist to debulking, we planned the procedure to be done under venovenous (VV) ECMO support (Fig. 3).

Bedside bifemoral VV ECMO was instituted immediately. The ECMO team cannulated the right femoral vein with a 23-Fr catheter and the left femoral vein with a 20-Fr catheter (Edward) under local anesthesia. Quadrox PLS oxygenator with RotaFlow was used. An unfractionated heparin bolus of 5,000 IU was given at the time of cannulation without the requirement of additional heparinization. Oxygen saturation of 98% was achieved with a blood flow rate of 3 L/minute, FiO_2 of 1.0, and sweep gas flow of 3.0 L/ minute. Once ECMO flow was established, the patient was deeply sedated with intravenous fentanyl and midazolam.

After initiating ECMO, a bronchoscopy was done *via* the nasal route. Oropharyngeal and vocal cord anatomy were completely distorted. The tumor was visualized 2 cm away from the vocal cords almost completely occluding the tracheal lumen. Access to the bronchoscope was convoluted and it was very difficult due to the distorted anatomy of the epiglottis, vocal cords, and pharynx. As a result of which neither the electrocautery nor the cryoprobe could be passed through the channel of the bronchoscope. During the procedure, despite ECMO support he started desaturating and developed hypotension. The ECMO flow was increased, and ionotropic support was started, with which he stabilized. The decision for low tracheotomy was made as the procedure of bronchoscopic debulking could not be successfully performed, while continuing to maintain his oxygenation on ECMO. At this stage, he received vecuronium along with sedation and analgesia.

An incision was given below the previous tracheostomy site, the strap muscles were quickly separated in the midline to reach up to the trachea, and quick blunt (finger) dissection was done anterior and lateral to trachea in a retrosternal manner (as we do while performing cervical mediastinoscopy), which allowed trachea below the previous tracheostomy site to be pulled up. With the left index finger on the trachea as a guide, a wide tracheotomy was done, and a No. 7 endotracheal tube was passed into the trachea distally under finger guidance to establish ventilation. The patient now could be easily ventilated, and the endotracheal tube was later changed with a 7.5-Fr tracheostomy tube using Cook's airway bougie. The position of the tracheostomy tube was confirmed by bronchoscopy and adequate suctioning was done.

The ECMO support was removed after one hour and the inotropes and ventilator were weaned off over the next 4 hours. The patient was spontaneously breathing on oxygen mask, and was comfortable with a respiratory rate of 20/minute 4 hours after the procedure. He was continued on intravenous antibiotics, corticosteroids, and aggressive chest physiotherapy. One week later, he was discharged in a comfortable condition for further chemotherapy. The patient survived the entire procedure only due to the oxygenation provided by venovenous ECMO, which provided the time window to perform a difficult emergency tracheostomy.

Discussion

Establishing a secure and patent airway is the most important goal in the management of acute airway obstruction. Total tracheal obstruction represents a therapeutic challenge for physicians, experienced anesthesiologists, and thoracic surgeons.

Patients with critical airway disease present with a range of airway pathology, including tracheal tumors (31%), tracheal stenosis (20%), and head and neck cancers (20%).[1] Successful use of ECMO for the management of airway obstruction was first reported in

Table 1: Reported literature experience on the use of VV ECMO in acute tracheal obstruction

Authors	*Year*	*Age (years)*	*Obstruction*	*Obstruction site*	*ECMO mode*	*ECMO duration*	*Definitive procedure*	*Result*
Higashi et al.[5]	1989	17	Saw dust	Trachea, bronchi	VV	1.5 days	Fiberoptic bronchoscopy	Survived
Rosa et al.[7]	1996	51	Thyroid lymphoma	Upper trachea	VA	Operative case	Tracheostomy, resection	Survived
Shiraishi et al.[8]	1997	3	Fibrosarcoma	Distal trachea	VA	Operative case	Surgery	Survived
Bond et al.[9]	1998	19	Mediastinal tumor	Distal trachea	VA	2 days	Chemotherapy, radiotherapy	Survived
Belmont et al.[10]	1998	73	Thyroid Lymphoma	Supraglottic	VA	Operative case	Tracheostomy	Survived
Chao et al.[11]	2006	21	Mediastinal tumor	Distal trachea	VV	3 days	Chemotherapy	Survived
Hong et al.[6]	2013	19	Malignant tumors	Tracheal obstruction	VV	20.9 hours		Survived
Tian et al.[12]	2017	65	Tracheal tumor	Trachea, Bronchus	VV	2.2 hours	Surgery	Survived
Tian et al.[12]	2017	60	Tracheal tumor	Trachea	VV	1.61 hours	Surgery	Survived
Malpas et al.[1]	2019	77	Papillary thyroid carcinoma	Glottis	VA	Not known	Surgery	Survived
Jeong et al.[13]	2019	67	Intrathoracic goiter	Trachea	VV	4.55 hours	Surgery	Survived

1999 by Onozawa et al. in adults.[2] The cause of airway obstruction was due to thyroid carcinoma. Since then, ECMO has been utilized for variety of surgical procedures involving the respiratory tract for different purposes such as intubation to provide gas exchange and hemodynamic support during stenting and tracheotomy. Patients with upper tracheal tumors, obstructing tracheal lesions, and inappropriate intubation attempts may not result in successful oxygenation and ventilation and may result in cardiopulmonary arrest. Furthermore, ECMO is an excellent tool to maintain oxygenation in critical situations and provide a time window to secure access to the airway.

Moreover, "ECMO or extracorporeal life support (ECLS)" provides both cardiac and respiratory supports enabling an adequate amount of gas exchange. There are several forms of ECMO, the most common are the venoarterial (VA) and VV. In both modalities, blood drained from the venous system is oxygenated outside the body. In VA ECMO, this blood is returned to the arterial system and in VV ECMO the blood is returned to the venous system. Furthermore, ECMO provides time for intrinsic recovery of the lungs as well as of the heart while a standard cardiopulmonary bypass will provide support during various types of cardiac surgical procedures. Extracorporeal Life Support Organization (ELSO) publishes the guidelines describing the indications and practice of ECMO. Clinical situations that may prompt the initiation of ECMO include hypoxemic or hypercapnic respiratory failure, refractory cardiogenic shock, cardiac arrest, failure to wean from cardiopulmonary bypass after cardiac surgery, and as a bridge to either heart or lung transplantation or placement of a device. There is emerging evidence for the use of ECMO in these clinical settings. The conventional ventilatory support vs ECMO for severe adult respiratory failure (CESAR) trial reported the use of VV ECMO in adults with severe acute respiratory distress syndrome.[3] A recent case series have provided evidence for use of ECMO in cardiopulmonary resuscitation (CPR).[4] The application of ECMO in the management of life-threatening airway obstruction has been limited. Higashi et al. were the first to report the use of ECMO in the management of acute tracheal obstruction in 1989.[5] Since then, there have been case reports and a recent case series of 19 patients by Hong et al. using VV ECMO for managing central airway obstruction.[6] (Table 1).

When endotracheal intubation is deemed too risky, ECMO can be used for gas exchange as seen in our case.

Major reason limiting the use of ECMO in cases of acute, life-threatening airway obstruction is the time required for initiation. In centers where ECMO is not being routinely used, the decision to initiation time is minimum of 1–2 hours and the patient with life-threatening compromised airway may not survive this time without severe hypoxia and brain injury. The severity and the exact duration of hypoxia that can be tolerated without neurological injury varies considerably among various individuals. The efforts should be to somehow maintain ventilation and oxygenation as far as possible while the ECMO is being set up, as was the case with our patient.

Conclusion

Today, VV ECMO is an effective method of oxygenation in cases of life-threatening acute airway obstruction where conventional methods of airway access are not immediately possible without completely jeopardizing the airway. It provides that critical time window, with the patient adequately oxygenated, to be able to plan and secure airway access, as we did in our case successfully.

The application of ECMO for advanced cancer patients is debatable. However, Invasive intervention as a life-saving measure provides only a chance to get definitive and palliative treatment for such patients.

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Association of Pre-intubation Non-invasive Mechanical Ventilation and the Hospital Mortality of Critically Ill COVID-19 Patients Received Extracorporeal Membrane Oxygenation (ECMO) Support: A Retrospective Cohort Study

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Keywords: COVID-19, ECMO, Mechanical ventilation, Non-invasive, Pre-intubation.

Introduction: Decision-making is crucial for optimal patient management, particularly for individuals with life-threatening respiratory failure. This includes an appropriate selection for patients requiring ECMO support with a favorable outcome. The length of noninvasive mechanical ventilation (NIV) duration prior to the commencement of ECMO therapy may influence patient outcomes. The overwhelmed institutions during the COVID-19 pandemic and the associated limited mechanical ventilator capacity obligate healthcare providers to overuse the NIV with maximum settings for a longer course before intubation than we used to do before the pandemic. Uncertainly, NIV duration is thought to be associated with mortality risk in those with life-threatening respiratory failure. A clinically relevant threshold exists for estimating the maximal time for NIV that indicates poor outcome; therefore, there is an urgent need for more high-quality research to understand the risk of antecedent NIV time pre-ECMO on patient outcome. **Objective:** This study aims to determine the association between the length of pre-intubation non-invasive mechanical ventilation and hospital mortality following ECMO support. **Methodology:** A retrospective, observational study of patients who received ECMO in King Saud Medical City between 1 January 2020 and 1 October 2022. The cohort includes all patients who received ECMO and were admitted to the ICU. Patients were divided according to the use of NIV before ECMO into two groups: patients who received NIV before intubation and those who never received it before intubation. **Outcomes:** The primary outcome is hospital mortality, while the secondary outcomes include ICU length of stay and ventilator-free days (VFD). Additionally, we explored hospital mortality if NIV was used for three or less days compared to more than 3 days. **Results:** 61 patients were included, the mean age was 39.7 ± 12.6, and 43 (70.5%) males. 37 patients received NIV before ECMO for a different course duration, while 24 were immediately intubated upon hospitalization. Both groups were comparable demographically presented in Table 1. In the NIV group, 20 patients died (54.1%) compared to 14 (58.3%) in the immediate intubation group. No statistically significant difference in mortality (95% CI: –20% to 30%; $p = 0.7$). ICU LOS for the NIV and Intubation groups were 36.5 ± 25.5 and 35.7 ± 27.6, respectively, with no significant difference (95% CI: –14.5 to 13; 0.7). The NIV group had a longer VFD of 10.9 ± 17.3 compared to 7 ± 15.1 for the intubation group with no statistical significance (95% CI: –12.7 to 4.8; 0.4). (Table 2). In a subgroup analysis of the NIV group, 27 patients received NIV for 3 or less days, out of which 15 patients died (56%), whereas 10 patients received NIV for more than 3 days, out of which 5 patients died (50%). No statistical significance was observed (95% CI: –31% to 42%; $p = 0.8$). (Table 3). **Conclusion:** Days on NIMV prior to endotracheal intubation should be cautiously discussed on selecting COVID-19 patients for ECMO support until high-quality research exists enough to have a solid conclusion.

Table 1: Characteristics of patients receiving NIV compared to those who did not

Variable	*All (n = 61)*	*NIV (n = 37)*	*Immediate Intubation (n = 24)*	*95% CI of difference; p-value*
Age (years) mean ± SD	39.7 ± 12.6	41.1 ± 12.2	37.5 ± 13.1	–10.1 to 3.1; 0.3
NIV Duration (days) mean ± SD	2.7 ± 5.3	4.5 ± 6.3	0	
Males: *n* (%)	43 (70.5)	26 (70.3)	17 (70.8)	–0.2 to 0.2; 0.9
DM: *n* (%)	37 (60.7)	26 (70.3)	11 (45.8)	–0.5 to 0; 0.05
HTN: *n* (%)	30 (49.2)	23 (62.2)	7 (29.2)	–0.5 to –0.1;0.007
APACHE (ICU Admission) mean ± SD	55.5 ± 27.4	51.8 ± 27.3	61.2 ± 27.1	–5 to 23.7; 0.2

Table 2: Outcomes of patients receiving NIV compared to those who did not

Variables	*All (n = 61)*	*NIV (n = 37)*	*Immediate Intubation (n = 24)*	*95% CI of difference; p-value*
Tracheostomy: *n* (%)	17 (27.9)	9 (24.3)	8 (33.3)	–0.1 to 0.3; 0.5
Hospital Mortality (n, %)	34 (55.7)	20 (54.1)	14 (58.3)	–0.2 to 0.3; 0.7
ICU LOS mean ± SD	36.1 ± 26.1	36.5 ± 25.5	35.7 ± 27.6	–14.5 to 13; 0.7
Hospital LOS mean ± SD	43 ± 29	44.5 ± 25.8	40.7 ± 33.8	–19.2 to 11.4; 0.2
Ventilator free days mean ± SD	9.4 ± 16.5	10.9 ± 17.3	7 ± 15.1	–12.7 to 4.8; 0.4

Table 3: Subgroup analysis of patients who receive NIV with different outcomes related to NIV days

	One day	*Three days*	*Five days*
Equal or less	19/34 (56%)	29/51 (57%)	30/55 (55%)
More than	15/27 (56%)	5/10 (50%)	4/6 (67%)
p-value	–20 to 30%; 0.9	–27 to 41%; 0.7	–52 to 28%; 0.5

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Severe ARDS in a Kyphoscoliosis Patient and Application of VV – V ECMO – A Case Report

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Keywords: ARDS, ECMO, Kyphoscoliosis.

Introduction: VV ECMO established itself as one of the final therapeutic options in cases of severe ARDS, where conventional therapies fail. The Pandemic of Swine flu and COVID-19 allowed ICU physicians worldwide to be familiar with the benefits of extracorporeal Life Support ECLS. Despite acquaintance with ECMO, its usage and literature are scarce in patients of kyphoscoliosis who have altered anatomy and compromised pulmonary reserves, which poses unique challenges during ECMO run. **Case presentation:** We present a case report of 35 yr old male with kyphoscoliosis since birth with no other comorbidities presented with severe ARDS secondary to H1N1 pneumonia requiring extracorporeal therapy for severe hypoxemia despite three days of conventional mechanical ventilation and prone position. Initially, he was started on VV ECMO, which required him to convert to VV-V ECMO to overcome flow disturbances, cannula malposition, and proper drainage. During the course of therapy, to overcome bleeding from the tracheostomy site, ECMO was managed without anticoagulation, reintubation of the patient, and requiring circuit change in view of oxygenator failure were other challenges faced. We were able to prone patients even on ECMO with all precautions taken. After 23 days of ECMO run patient was successfully weaned, with an overall stay of 29 days in the ICU. **Conclusion:** Overall, there is a limited experience and literature on challenges faced during extracorporeal therapy in patients with spine deformities. In our case, anatomical challenges were surpassed by placing properly sized cannulas with the help of fluoroscopy guidance and ultrasonography. Physiological challenges because of reduced pulmonary reserves, like difficult weaning, are known, which was not a big hurdle in our case. Overall, the experience is not as scary as we were at the beginning of ECMO.

A Novel Approach to ECMO Troubleshooting (Hypoxia) Management Utilizing Two ECMO Circuits in Parallel, A Case Report

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DOI: 10.5005/jaypee-journals-11011-0003.3

Keywords: Anticoagulation, ECMO, Point of care anticoagulation.

Introduction: The improvements in ECMO management last decade were in response to the innovation and breakthrough of ECMO material biocompatibility and miniaturization; however, there is a lack of high-quality ECMO research to support and look for the best management approaches. Troubleshooting, particularly patient hypoxia while on ECMO, the most common one that algorithmically necessitated management escalation till reaching to insertion of another cannula to increase the pump flow, which, if failed, probably may lose the patient if he did not tolerate hypoxia or develop brain insult from prolonged hypoxia herein, we present a challenging case that failed to be managed with all previously mentioned approaches and how.

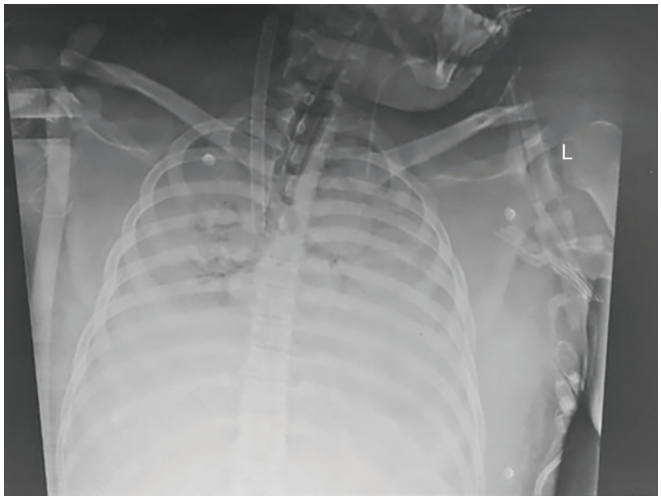

Fig. 1: C-Xray post initiation of the two ECMO circuits

Case presentation: 25-year-old male, morbid obese male, weight 130 kg, height 170 cm (Body Mass Index [BMI] 45 kg/m^2, known epilepsy, presented to the emergency department due to burn 30% of involved upper limbs, head, and neck, with inhalation injury and worsening respiratory distress On initial aggressive fluid resuscitation, developed hypoxia on oxygen and non-invasive positive pressure ventilation with a decrease of the level of conscience. He was endotracheally intubated, placed on lung protective mechanical ventilation with a fraction of inspired oxygen [FiO2] of 100%, and admitted to the intensive care unit (ICU) on 25/08/2021. He was on a high ventilator setting and had severe refractory hypoxia saturation of 60%, partial pressure of oxygen to fraction inspired oxygen ratio (Pao2:Fio2 52mmhg)), so the team decided to support the patient on V-V ECMO. Successful ECMO cannulation on 29/08/2021 with access cannula on left femoral vein (23fr) and return on IJV (21fr). Unfortunately, hypoxia improved; however, Oxygen saturation remained low and the best Pao2:FIO2 on the maximum setting and excluding all possible causes of hypoxia on ECMO and membrane oxygenator efficiently worked, and pump flow reached 6L/min and controlled cardiac output, Hemoglobin Hb optimized to 11.4 d/l adding another oxygenator to the circuit was ignored due to possible hemolysis and patient condition cannot tolerate and planned to add new another ECMO circuit with new pump and console to run concurrently with the old. Eventually, a triple venous closed circuit (V-V-V ECMO) setup initiated with two different venous site access (left and (right femoral 21fr. cannula) veins) drained blood by two different pumps and passing it into the right Internal Jugular vein cannulate with 25 fr. Cannula called dual or parallel ECMO run. Both pumps' RPM (round per minute) adjusted equally to the two circuits. Patient hypoxia improved, and oxygen saturation picked up above 90% while lowered mechanical ventilator setting was adjusted to the lowest. (ABG: Ph 7.43, PcO2 39.8 Po2 70.2, SPO2 93%). Eight days later, we succeeded in weaning one of the ECMO circuits and explant one of the access cannulas with preserving patient oxygen saturation. During ICU post-weaning of one of the circuits, the patient course was further challenged with severe recurrent, hardly controlled, ventilator-associated pneumonia VAP with MDRO infection and severe septic shock required vasopressors; a blood culture showed candida Auris covered with antifungal treatment, Also, the patient developed AKI and require multiple

sessions of dialysis. The oxygenator was changed 5 times during the run, and the patient eventually tolerated the weaning trial of sweep gas, and hemodynamics improved on low mechanical ventilator support. The patient completed an 80-day ECMO run and successfully decannulated; a few days later discharged from the ICU and eventually from the hospital in good general condition. **Conclusion:** We reported a rare successful feasible approach to ECMO troubleshooting management with very few reported cases or case series in the literature; however, further high-quality research is required to support this finding.

Combined VV-ECMO and Independent Lung Ventilation for Hydatid Cyst – Case Report

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DOI: 10.5005/jaypee-journals-11011-0003.4

Keywords: ECMO, Hydatid cyst, Independent lung ventilation, One-lung ventilation.

Background: Independent lung ventilation is an infrequently used ventilation strategy in an intensive care unit. It can benefit unique, selective patients, such as those with unilateral pulmonary pathology. Independent lung ventilation allows for the individual separation of each lung and isolates each lung content, thus preventing lung content from reaching the other lung. Theoretically, it may help avoid spilling of content in the non-diseased lung and thus maintaining healthy lungs and providing adequate oxygenation. In addition, it allows for targeted interventions. Here in, we report a case of an adult female with a unilateral hydatid cyst requiring venovenous extracorporeal membrane oxygenation ECMO who showed improvement in the non-diseased lung after the application of independent lung ventilation. **Case presentation:** 21 years old female patient of Arabic origin who is known as asthmatic. Presented with complaints of shortness of breath and cough for 10 days. Her initial chest x-ray was highly suspicious of a hydatid cyst. (Fig. 1)

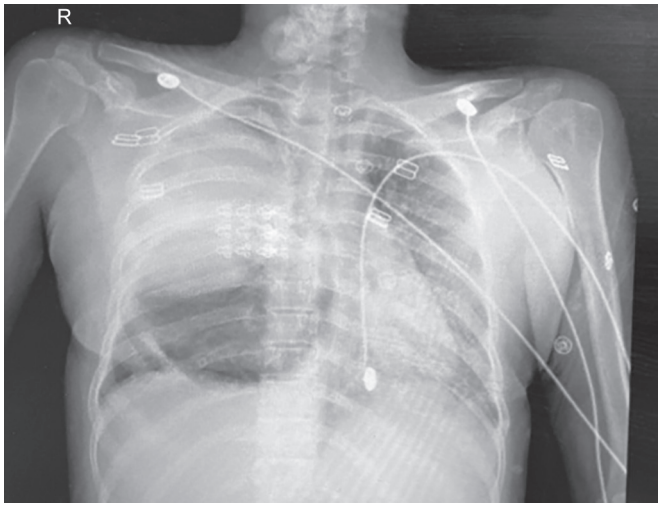

Fig. 1: Chest x-ray on admission

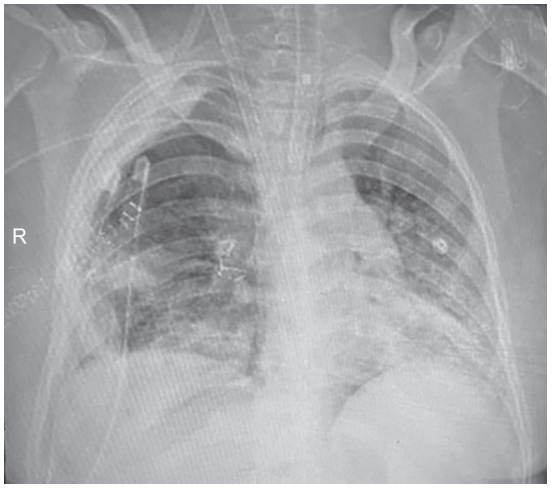

Fig. 2: Chest x-ray 4th postoperative

Due to rapid deterioration respiratory-wise, she was intubated and mechanically ventilated four days following her ICU admission, then supported by VV ECMO a day later. Chest surgeons were involved in her management and confirmed the diagnosis of the Hydatid cyst. On the second day of ECMO, we proceeded to independent lung ventilation in order to protect the left lung. She underwent a right middle lobectomy while on ECMO and gradually showed substantial improvement in ventilator parameters and chest x-ray (Fig. 2). Unfortunately, as we planned her weaning and extubation, she started to deteriorate again, and the bronchoscopy showed accumulated blood clots in the right lung and leakage of pathological tissue to the left lung. Eventually, she succumbed to her illness and died 45 days postoperatively. **Discussion:** Hydatid cysts can present in a single lung. Thus, intensivists aim toward preventing further spilling of content to the other lung to maintain adequate oxygenation and ventilation and prevent secondary damage until definitive surgical management can be provided, including pneumonectomy/lobectomy; this strategy presents a challenge to intensivists as different lungs has different compliance and driving pressure requiring different ventilator settings. ECMO can overcome this issue by directly delivering oxygen to the circulation bypassing the capillary-alveolar membrane. This was the case in our patient, who initially improved by applying an independent lung ventilation strategy. However, this strategy can be used as a bridge until definitive management of the pathological lung is achieved. **Conclusion:** Independent lung ventilation and ECMO may temporarily be beneficial in managing single lung pathology until definitive management of the pathology is achieved.

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Fulminant Myocarditis

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Keywords: Fulminant Myocarditis, IV.Ig, Inotropes, Milrinone, VA ECMO.

Introduction: Fulminant myocarditis occurs as an inflammatory response to an initial myocardial insult. Its rapid and deadly progression calls for prompt diagnosis with aggressive treatment measures. Demonstrating its excellent recovery potential has led to the increasing use of mechanical circulatory support. ECMO should be considered earlier in these patients as it can lead to rapid hemodynamic collapse.

Case presentation: A 5-year-old Kid brought a fever, cold & cough for three days, followed by difficulty breathing; shown to an outside physician who found gallop & referred them for management of myocarditis. In our facility Patient had signs suggestive of cardiogenic shock. Chest x-ray showed cardiomegaly, Abnormal ST waves; ECHO showed EF 40% with left ventricular dysfunction, very high troponin T (>900), Rising lactate, low Scvo2, CRP 0.5mg/dl, COVID PCR, H1N1PCR, tropical infection workup & blood culture-negative s/o fulminant Myocarditis. The patient was treated with fluids, HFNC support, IVIG, IV methylprednisolone, Dobutamine, adrenaline, calcium, vitamin D & other supplements (Thiamine, carnitine & B12). Despite maximum medical management in the first 48 hr, lactate kept rising, scvo2<60%, MAP<45, oliguria with rising creatinine, inotropic score >20, EF<20, VTi<7. Peripheral bifemoral VA ECMO has been done, right femoral venous cannulation size 18F & left femoral arterial cannulation size 12 F, DPS 5F. Euroset pediatric circuit size with a pediatric oxygenator. The patient started on VA ECMO with the partial flow, titrated with scvo2 & lactates. Heparin is used for anticoagulation. After five days of the ECMO run, as markers for cardiac recovery were seen, the patient was weaned, trialed off & decannulated on day 6th of the ECMO run. ECMO run done for six days. The patient was successfully extubated on day 9th of ventilation & discharged on 21 days of hospital stay. **Conclusion:** Prompt diagnosis & timely ECMO support in fulminant myocarditis, along with medical treatment, could prevent lethal outcomes.

Adenovirus Organizing Pneumonia Responding to Pulse Steroids and V-V ECMO Therapy – A Case Report

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DOI: 10.5005/jaypee-journals-11011-0003.6

Keywords: Adenovirus, Organizing pneumonia, Steroids, V-V ECMO.

Background: Adenovirus pneumonia in children may lead to severe lung damage, bronchiectasis, fibrosing organizing pneumonia and severe ARDS. We present ECMO for a child as lifesaving and a bridge to the healing of his severe organizing pneumonia on pulse steroid therapy. **Purpose:** To report the use of V-V ECMO and pulse steroids therapy in a child with adeno viral organizing pneumonia. **Case presentation:** A 4-year-old boy presented with severe respiratory distress secondary to adenovirus pneumonia and was admitted to the PICU treated with conventional ventilation, then HFVO and NO, complicated with bilateral pneumothoraxes and because of persistent hypoxemia was commenced on VV ECMO for three days, in addition to pulse steroids 30 mg/kg methylprednisolone. The right internal jugular vein was cannulated by an adult intensivist with a Dual-lumen Avalon cannula size 23 Fr. He showed a dramatic response and decannulated and extubated to HFNC without respiratory or neurological sequelae. **Conclusion:** Veno-venous ECMO should be started early in the course of the disease before more lung damage from mechanical ventilation or HFVO and give the lungs a chance to heal as soon as possible.

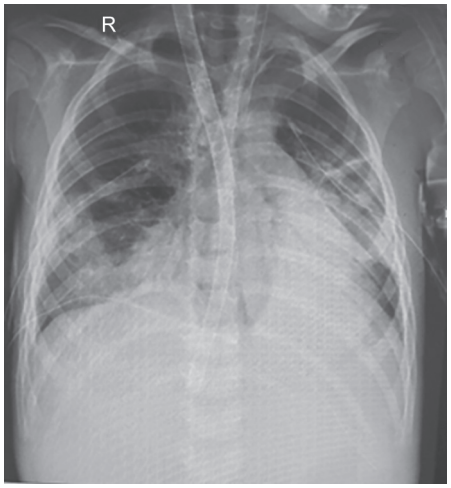

Fig. 1: Dual-lumen cannula in RIJ vein

The Use of HFVO in VV ECMO in Infants with ARDS to Overcome Femoral Cannula Shattering

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Background: VV ECMO in pediatrics is a lifesaving procedure that is being more recently used, especially in cases of respiratory failure with persistent hypoxemia and failure of conventional and high-frequency ventilation. Complications such as bleeding, clot formation, infection and mechanical obstruction of the ECMO circuit may happen. **Objective:** To describe the benefit of high-frequency ventilation oscillation (HFVO) use with VV ECMO in a case of shattering and low ECMO flow. **Case presentation:** A 5-month-old, 5 kg weight baby developed ARDS secondary to human metapneumovirus. He was treated with mechanical ventilation and then HFVO with iNO, but his hypoxemia persisted. Then he was started on VV ECMO with a right femoral vein cannula for drainage and a right internal jugular vein cannula for return (Fig.1). He developed shattering phenomena and reduction in the ECMO flow, after which he was converted from conventional MV to HFVO and noticed the disappearance of shattering and improvement of the drainage of ECMO flow. **Conclusions:** The use of HFVO with VV ECMO helps to solve the problem of shattering and improvement in the drainage flow in VV ECMO.

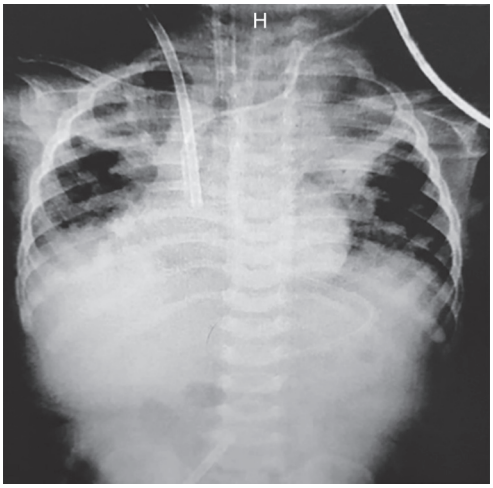

Fig. 1: Right femoral cannula(drainage), right internal jugular cannula for return

Neurodevelopmental Outcome in Children Undergoing Extracorporeal Membrane Oxygenation ECMO

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DOI: 10.5005/jaypee-journals-11011-0003.8

Introduction: Extracorporeal membrane oxygenation (ECMO) is a well-established life support technique for cardiopulmonary failure. But the procedure is not without complications. As many as 15–36% of ECMO patients suffer neurologic injury surrounding their ECMO course, including hypoxic-ischemic injury, thromboembolic stroke, and intracranial hemorrhage. Acute neurologic injury during ECMO is associated with an 89% increase in the risk of mortality, and neurologic disability among survivors has been reported at a rate of 10–60%. **Objective:** We aimed to study the neurodevelopmental outcomes in pediatric patients undergoing extracorporeal membrane oxygenation (ECMO). **Methodology:** This is a 7-year of a retrospective study from 2015–2022 in KIMS Health, Trivandrum which is a Quaternary care center in south Kerala. Data including patient demographics, indication for ECMO, type and days of ECMO support, complications and neurodevelopmental status at discharge and latest follow-up was recorded from the electronic medical record. Neurodevelopmental status was determined through the Pediatric Overall Performance Category (PCPC). **Results:** Total 14 children were included in the study. Among 14 children, 9 survived. Among the 5 children who died, one child had massive intra-cerebral bleeding. Another 14-year-old boy who was on VA ECMO developed critical illness polyneuropathy. Among the 9 patients who survived 8 patients had GCS 15/15 on discharge, and One child had myopathy. We did a follow and found that among the 7 school-going children, 6 were back to school at 6 months follow-up. One child had a learning disability. Two toddlers' development assessment was appropriate for age at 3 months follow-up. **Conclusion:** Neurological complications are not uncommon during ECMO therapy. Even though the literature shows neurological complications can be very high, our data shows that with timely intervention and multidisciplinary care, children can have excellent neurological outcomes.

Extracorporeal Membrane Oxygenation in Pregnant Women: Case Series

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DOI: 10.5005/jaypee-journals-11011-0003.9

Keywords: ARDS, COVID-19, ECMO, Peripartum, Pregnancy.

Introduction: Extracorporeal membrane oxygenation (ECMO) is a supportive treatment that provides circulatory and ventilatory support as a bridge to organ recovery. Extracorporeal life support (ECLS) has expanded to include unique populations such as peripartum women. Extracorporeal membrane oxygenation (ECMO) has seen increasing use for critically ill pregnant and postpartum patients over the past decade. Increasing evidence supports the ECMO use as a bridge to babies throughout pregnancy and attests to its favorable outcomes. These case series aim to report maternal and fetal complications and outcomes associated with peripartum ECMO. **Methodology:** A descriptive analysis of 7 patients as a case series who required ECMO support in pregnancy and postpartum at KSMC, Riyadh, Saudi Arabia, between January 2020 and January 2022. **Result:** Our case series includes seven patients with a median age of 35 years (24–42 years), five of them are pregnant at the time of ECMO, and two are postpartum. Two were in the second trimester, and three were in the third trimester. All patients were COVID-19 positive, and all patients had ARDS. In addition, six patients received venovenous ECMO support, and one required VA ECMO due to cardiogenic shock.

Table 1: descriptive analysis of COVID-19 pregnant ladies during ECMO

	Age	*Gestational age*	*ICU LOS*	*Hospital LOS*	*ECMO days*	*NIV Before Intubation*	*MV days*	*Mother's Outcome*	*Baby's Outcome*	*DM*	*HTN*
Case 1	28	30 weeks	28	103	10	yes	17	Alive	Alive	No	No
Case 2	36	27 weeks	17	21	12	yes	17	Alive	Alive	No	No
Case 3	24	27 weeks	55	73	11	yes	12	Alive	Alive	No	No
Case 4	42	23 weeks	23	23	6	no	11	Alive	Alive	No	No
Case 5	41	23 weeks	53	60	8	no	19	Alive	Alive	Yes	Yes
Case 6	32	Post CS	15	43	11	yes	13	Alive	Died 27w	Yes	Yes
Case 7	35	Post CS	16	25	48	no	51	Alive	Alive	No	No

All patients were successfully decannulated from ECMO; however, the required days of ECMO range from 6–48 days. Two of the five pregnant patients delivered usually, and three underwent cesarean sections. All newborns are alive post-delivery. All mothers survived home discharge with their babies except one who developed Intra uterine fetal death and spontaneously aborted in ICU. **Conclusion:** Our case series demonstrates a promising outcome for pregnant ladies with severe ARDS and preserving pregnancy in experienced ECMO centers.

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Successful Venovenous ECMO in a Post-CPR Pediatric Patient with ARDS and Bilateral Pneumothorax

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DOI: 10.5005/jaypee-journals-11011-0003.10

Keywords: ARDS, CPR, Venovenous ECMO.

Case presentation: A 12years boy was admitted with fever, dry cough for three days and breathlessness; the 1st day was managed in pediatric IPD and discharged on the 7th day. On the next day, the patient was readmitted with breathlessness and shifted to ICU in view of hypoxic with arterial oxygen tension (PaO2) of 58mm Hg on 15L/min of oxygen via mask with a reservoir, requiring non-invasive positive pressure mode of ventilation to maintain arterial oxygen saturation. HRCT thorax showed diffuse bilateral ground glass opacities with extensive consolidation, RT-PCR for COVID-19 positive. The patient received empirical antibiotics and steroids for two days, but there was no improvement in respiratory status, and he was hooked to mechanical ventilator support with intubation. Unfortunately, he developed bilateral pneumothorax on the 5th day, managed with bilateral intercostal drains. On the 7th day, the patient developed refractory hypoxemia with high settings mechanical ventilation; ABG analysis showed persistent hypoxemia (PaO2 of 48mm Hg, PaCO2 79, Ph7.1, lactate 3) on 100% fraction of inspired oxygen (FiO2) with positive end-expiratory pressure (PEEP) of 12 cm H2O on prone position. On the 8th day, the patient had a cardiac arrest (ROSC was achieved after 3 minutes of CPR) due to hemodynamically stable and refractory hypoxemia with respiratory acidosis (Pao2–33, Paco2 98, Ph 7, lactate 7) decision was made to treat the patient with venous-venous ECMO. He was subsequently initiated with a circuit flow of 1.2L/min and sweep gas of 4.0L/min of oxygen (FiO2 of 100%, 3000RPM) with lung protective ventilation and antibiotics based on the cultures' result. On day 13th, the patient was shifted to KIMS Hospitals Secunderabad on ECMO by aviation for a lung transplant. The patient was weaned successfully after 2 months from ECMO and discharged after 80 days of admission without lung transplantation. **Conclusion:** To the best of our knowledge, this is the first pediatric case report in the country with the successful use of VV-ECMO for bilateral pneumothorax with post-CPR survivor from refractory ARDS.

ECMO Oxygenator Changeout During the COVID-19 Pandemic

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Keywords: COVID-19, ECMO, Oxygenator.

Background: This retrospective study focuses on the critical issue of ECMO oxygenator change-out during the COVID-19 pandemic. The study also presented the single institution's experience and protocol for managing ECMO patients during the pandemic. **Objectives:** We aimed to emphasize the team's effort, along with other healthcare service providers, to run 29 ECMO simultaneously. **Results:** The study involved a robust large cohort of 180 ECMO patients. The oxygenator was changed once in 23 patients and multiple times in 6 patients. We analyzed the reasons for the oxygenator and circuit change and evaluated the health criteria used to assess the performance of the oxygenator. **Discussion:** The results of this research provide a better understanding of the challenges faced in managing ECMO during the pandemic and the importance of monitoring oxygenator health and following established protocols for optimal patient care. **Conclusion:** The findings are significant for the healthcare industry, as they provide valuable insights into managing ECMO during the COVID-19 pandemic and highlight the importance of continuous monitoring and improvement of oxygenator criteria and protocols.

Problems Faced During VV ECMO of Dengue Patient with Severe ARDS: A Case Report

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Keywords: ARDS, Dengue, ECMO.

Case presentation: A 21-year-old male patient with no history of chronic illness presented with chief complaints of High-grade fever with chills and rigor for 10 days, Breathlessness for 1 day, and altered behavior for 1 day. On examination, BP –120/70, PR –128/min, CVS - S1S2 present, chest - B/L crepts, GCS E3M5V3, Pupil B/L constricted, RR 35/min SpO2 70% without oxygen. The patient was diagnosed case of dengue fever and presented with severe ARDS. The patient was intubated and lung protective ventilation was initiated. Initial investigations suggest abnormal liver functions and raised Ferritin (40,000). The patient received immunoglobulin and steroids, keeping Hemophagocytic lymphohistiocytosis as the cause. Liver enzymes improved and the patient showed some signs of improvement. On day 4 patient started de-saturating and did not improve even after proning for 3 hours. A call for VV-ECMO was taken. After starting VV ECMO, ventilatory paraments were decreased to rest lung settings. Heparin was an anticoagulant used and the dose was titrated to maintain an activated clotting time

of 180 to 220. up till Day 8 on ECMO, the patient was doing good in terms of clinical and laboratory parameters. After day 8 serum bilirubin started increasing at 17 mg/dl (direct bilirubin 11 mg/dl). At presentation total bilirubin was 3 mg/dl (direct bilirubin 1.7mg/dl). Although the bilirubin was raised, the SGOP/SGPT and ALP were not that raised, and INR was also normal. Screening for other hepatotropic viruses was negative. The drainage cannula position was not obstructing hepatic veins. The patient was not accepting enteral nutrition because of paralytic ileus, so intravenous amino acids were given. The patient developed hypertensive episodes, which were treated by intravenous labetalol. Till day 8 patient's GCS after giving a sedation break was E2 M5 VT, but pupils were pinpoint bilaterally. On day 8, pupils became dilated & fixed bilaterally and GCS became E1M1VT. Heparin was stopped, and ECMO flow was increased, keeping Intracranial haemorrhage as the possible cause. EEG was done, suggesting a deep comatose state with prominent delta wave activity. Post tracheostomy, there was deterioration in lung parameters also bleeding from the tracheostomy site, so a bronchoscopy was done and blood clots were removed. Ventilatory parameters improved post-bronchoscopy. The patient was gradually weaning from VV- ECMO and decannulated. MRI brain with contrast was suggestive of global cerebral ischemia, acute infarct in pons and medulla, and bilateral anterior cerebral and posterior cerebral arteries did not show post-contrast opacification. An apnea test was done, which was positive. The patient developed 2nd sepsis and septic shock on day four post-decannulation, after which the patient deteriorated and expired on day 28. **Discussion:** Possible reasons for the patient's deterioration. We could not do imaging prior to ECMO due to the unstable condition of the patient. Was the dose of anticoagulation inappropriate, leading to thrombosis of cerebral vessels? The liver that was already compromised may further deteriorate during ECMO. Coagulopathy can lead to pulmonary haemorrhage which can further lead to delayed weaning. Persistent paralytic ileus was unexplainable. **Conclusion:** The case of Dengue fever represents a challenge of ECMO management.

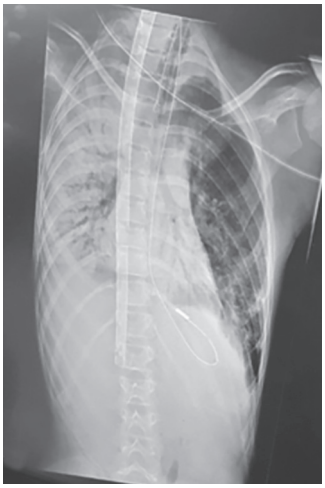

Fig. 1: Double lumen Avalon cannula in right internal jagula vein

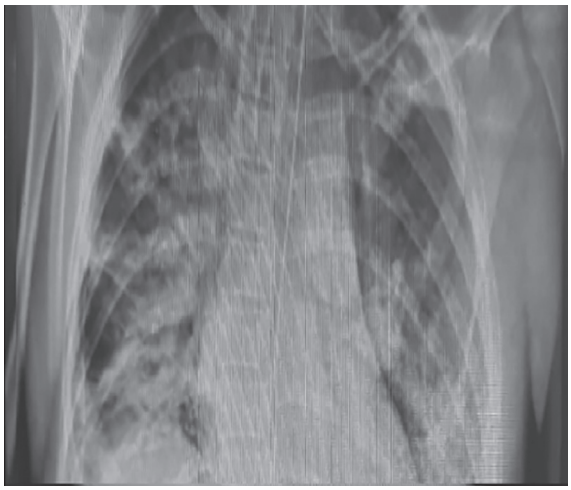

Fig. 2: Post decannulation CXR with right pneumothorax

Venovenous ECMO in a 10-year-old Girl with ARDS, Cannulation with Double Lumen Cannula Inserted by Pediatric Intensivist

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Background: Extracorporeal membrane oxygenation (ECMO) is increasingly used as a rescue therapy for refractory hypoxemia in ARDS patients. Extracorporeal membrane oxygenation (ECMO) support for severe adenoviral infection has been reported since the early days of ECMO use. This is a description of a successful double-lumen cannulation in a child done by a pediatric intensivist. **Purpose:** To describe vv ECMO experience and double lumen cannulation in a young girl done in our PICU. **Case presentation:** This is a case report of a 10-year-old girl with Marfan's syndrome, ARDS secondary to Adeno viral pneumonia received MV, then HFO for 6 days, after which she was started on vv ECMO because of persistent hypoxemia. A double Lumen cannula size 31 Fr. (Figs. 1 and 2) Was inserted by a pediatric intensivist under ultrasound and ECHO heart guidance using percutaneous Seldinger's technique. She was decannulated after ten days of ECMO. She underwent a tracheostomy due to muscle weakness. She developed right internal jugular vein thrombus after decannulation and was started on low molecular weight heparin. **Conclusion:** The study opened the door for using the percutaneous cannulation technique in PICU by pediatric intensivists with low complications.

The Use of V-V ECMO in an Infant with Human Metapneumovirus Pneumonia and ARDS

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DOI: 10.5005/jaypee-journals-11011-0003.14

Keywords: ARDS, Metapneumovirus, Pneumonia, V-V ECMO.

Background: Extracorporeal membrane oxygenation (ECMO) is a life-saving modality to support respiratory and cardiac failure patients. Recently noticed the emergence of aggressive human metapneumovirus in infants. The use of ECMO was life-saving and successful via bilateral internal jugular vein cannulation. We reported a case of V-V ECMO use in infants below 1 year of age. **Purpose:** To describe the successful use of both internal jugular veins for cannulation.

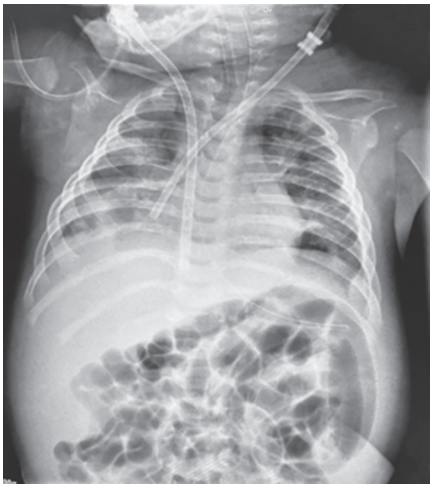

Fig. 1: RIJ vein a drainage cannula & LIJ vein as a return one

Case presentation: Ex pre-term infant 27 weeks' gestation age and corrected age 6 months with bronchopulmonary dysplasia. Admitted to PICU with acute bronchiolitis secondary to human metapneumovirus. He developed ARDS and persistent hypoxemia despite maximum ventilator support with HFVO and NiO; he was commenced on ECMO with cannulation of Rt. Internal Jugular vein for drainage and Lt. internal Jugular vein for return. After four days of ECMO support, he was extubated and then decannulated successfully to High Flow Nasal Cannula HFNC and lung healing from the primary disease was noted. He was discharged home without respiratory or neurological sequelae. **Discussion:** Veno-venous ECMO use in this infant was lifesaving, and de-cannulation after four days was successful. The use of V-V ECMO on these small infants needs a special cannula and expertise in cannulation technique, which was successfully done with the percutaneous technique by the pediatric intensivist (Fig.1), which opened the door for more cases to be treated with ECMO. There is a need for a pediatric ECMO center in Kuwait where babies with respiratory failure not responding to conventional therapy and reaching maximum support will benefit from this technology to survive the respiratory illness and give the lungs a chance to heal and normalize pulmonary function. **Conclusions:** Successful ECMO for the first infant with human metapneumovirus respiratory failure to be treated with ECMO in Kuwait.

ECMO – The Saviour of Reversible Toxic Myocarditis – A Case Report

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Introduction: VA ECMO has become the saviour for severe myocarditis when the underlying cause is reversible, such as viral or toxin. We reported a case of toxic myocarditis secondary to aluminium phosphide poisoning, which recovered with the support of VA ECMO. Interestingly, we initiated ECMO while the patient was awake. **Case description:** A 52-year-old lady was brought to us with cardiogenic shock and metabolic acidosis after consuming two tablets of aluminum phosphide. VA ECMO was initiated for the patient while he was on room air within 6 hours of poison intake. Within the next few hours, the patient had malignant arrhythmias. Simultaneously, ECMO support maintained tissue perfusion and lactate levels decreased within 3 hours of ECMO initiation. 48 hours, she developed pulmonary edema due to severe myocardial depression. She was put on invasive positive-pressure ventilation. 72 hours, the myocardium showed signs of recovery. She was gradually weaned off and decannulated successfully after 84 hours of ECMO support and extubated the next day. The patient was discharged on day seven without any complications. **Discussion:** Aluminium phosphide ingestion is associated with high mortality. This compound is frequently used as a rodenticide and fumigant for grain storage. The phosphine gas released after ingestion of this compound inhibits cytochrome oxidase, interferes with cellular respiration, and causes oxidative stress. It causes myocardial toxicity, metabolic acidosis, shock, and multiorgan dysfunction syndrome (MODS). No specific antidote is available for this compound; VA ECMO has become the mainstay of supportive care in managing aluminum phosphide poisoning. The key to recovery is the early initiation of ECLS before the onset of MODS. In recent years, initiating VA ECMO in awake patients has become widely accepted, which might, theoretically, reduce the rate of hospital-acquired infections, the burden on healthcare personnel and patient comfort. **Conclusion:** VA ECMO is a feasible lifesaving modality for severe myocarditis when the underlying cause is reversible, such as viral or toxins.

Extracorporeal Membrane Oxygenation in COVID-19 – Indian Scenario

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Keywords: COVID-19, ECMO.

Introduction: Extracorporeal membrane oxygenation (ECMO) is used as rescue therapy when lung-protective ventilation fails to achieve adequate gas exchange in severe acute respiratory distress syndrome (ARDS). Initial reports during the first wave of the COVID-19 pandemic suggested a high mortality rate of patients on ECMO. However, later evidence suggested that the clinical efficacy, outcome and complications were comparable in the patients treated with ECMO in COVID-19-related ARDS and non-COVID-19 ARDS. We intend to study the clinical characteristics and outcome of ECMO in COVID-19 ARDS in the Indian scenario. **Methods:** It was a single-center retrospective cohort study done at Medica Superspeciality Hospital, Kolkata, from June 2020 to May 2021. Data from patients treated with ECMO for COVID-19 ARDS were compiled and analyzed. **Results:** Total cases of COVID-19 treated with ECMO were 79 (M:F–71:8). Mean age of the male was 45 ± 2.5 years, while the female was 41 ± 3.8 years, with 15% of cases morbidly obese. The mean duration of intubation to ECMO initiation was 54 ± 18 hours. Twenty-five percent of cases were prone, and 2 cases received awake ECMO. Prolonged ECMO (more than 14 days) was observed in 60% of cases. The mean duration of the patient on ECMO was 17 ± 5.2 days. Sepsis (65%) was the commonest complication. Fifty percent of patients were discharged home, while 5% were still on ECMO. **Limitations:** The study was retrospective, so patient selection criteria for ECMO were not stringent. Also, 38% of patients were retrieved from

different centers for ECMO therapy to our hospital. Hence, the duration of intubation to ECMO support initiation could not be protocolized. As a single-center study of a functional ECMO unit with 7 years of experience, it cannot be generalized to the pan-India scenario. **Conclusions:** Our study showed better survival of COVID-19 patients on ECMO than those reported during the first wave. However, the survival rate reported in western literature (37%) is better than our study (50%), which might be because the major bulk of patients (38%) were retrieved from various centers for ECMO, the probable bias of delay in initiation of therapy could not be denied.

ECMO for Polytrauma Patients: A Blessing in Disguise or a Trail of Fiction?

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Keywords: ADRS, ECMO, Polytrauma.

Background: Venovenous extracorporeal membrane oxygenation (VV ECMO) for polytrauma patients has widely increased in the last decade. Earlier, polytrauma and ECMO did not mix; it was one of the main contraindications to patient selection, owing to the risk of bleeding and the therapeutic anticoagulation used during the ECMO run. However, the renascence on ECMO material became more compatible with patient blood, allowing ECMO run-off heparin. This pushes the boundaries of ECMO use, opens new frontiers, and increases the pool of patients who may benefit from this super-advanced form of life support. We aimed to evaluate the outcomes of a group of polytrauma patients who received ECMO in a tertiary hospital. **Methods:** All patients were admitted to King Saud Medical City ECMO center from 1 June 2020 to 01 January 2022. We stratified patients according to primary diagnosis into 2 groups Non-trauma ECMO and trauma ECMO groups. Propensity score matching (1:2) was done between the two groups; then we compared the matched groups for the primary outcome of in-hospital mortality. **Results:** The total number of patients included in this study was 61 unmatched trauma and non-trauma, 53 to 8 patients, respectively. Post-matching trauma to non-trauma 8 to 16 patients. The mean age 37.5(±16.7) to 62.5 (±16.7), p-value 0.6. No significant difference between in-hospital mortality of matched trauma to non-trauma patients (3, (37.5%): 10, (62.5%), *p*-value 0.2), matched trauma patients, mean ECMO days 24.6 (±25.4) to 36.7 (±32.3) respectively, Trauma patients stayed at the hospital, ICU much more days than non-trauma patients and higher ventilator-free days VFD. (Table 1). **Conclusion:** ECMO use in trauma patients was previously thought to be harmful; however, our study is underpowered and suggests that ECMO may play a role in reducing hospital mortality comparable to ECMO use in non-trauma patients of the same severity with no adverse effects. More high-quality research is needed for a larger number of patients.

Table 1: Demographics and outcomes of matched trauma and non-trauma patients.

Variable	*Trauma (n = 8)*	*Non-Trauma (n = 16)*	*95% CI of difference; p-value*
Age (years) Mean ± SD	37.5 ± 16.7	41.2 ± 14	–11.3 to 18.7; 0.6
Sex: Males *n* (%)	7 (87.5%)	15 (93.75%)	–32 to 20; 0.6
DM: *n* (%)	2 (25%)	6 (37.5%)	–25.7 to 50.7; 0.5
HTN: *n* (%)	2 (25%)	6 (37.5%)	–25.7 to 50.7; 0.5
BMI (kg/m^2) Mean ± SD	34 ± 8	33 ± 7	–8.2 to 6.3; 0.8
Hospital Mortality: *n* (%)	3 (37.5%)	10 (62.5%)	–16.1 to 66.1; 0.2
Hospital LOS (day) Mean ± SD	67.6 ± 43.4	43.4 ± 29.4	–62.1 to 13.8; 0.2
ICU LOS (days) Mean ± SD	53.8 ± 31	39.8 ± 29.6	–42.5 to 14.7; 0.3
VFD (days) Mean ± SD	12.3 ± 15.8	5.75 ± 9.6	–21.4 to 8.3; 0.3
ECMO Days Mean ± SD	24.6 ± 25.4	36.7 ± 32.3	–15 to 39; 0.4

Combined Use of VA-ECMO and Impella (ECpella) in Patients with Acute Coronary Syndrome and Cardiogenic Shock (ACS-CS)

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Keywords: ACS, CS, ECpella, Impella, VA ECMO.

Introduction: In a patient with cardiogenic shock (CS), VA-ECMO maintains end-organ perfusion; however, it may increase left ventricle (LV) afterload, increasing wall stress and oxygen demand of the LV, leading to myocardial ischemia and, ultimately, impairing CS recovery. The term "ECpella" refers to Impella and VA-ECMO support in cardiopulmonary resuscitation (CS) to provide optimal hemodynamic support while reducing LV afterload and unloading the LV. In this case, we will describe how ECpella was used to successfully manage a patient who presented with CS during percutaneous coronary intervention PCI due to Acute Coronary Syndrome ACS. **Case presentation:** The patient was a 33-year-old Filipino male with known HTN who presented to the emergency department with late presentation anterior ST-segment elevation myocardial infarction STEMI; the patient was conscious, oriented, and HD hemodynamically stable; the ECG revealed anterior ST-segment elevation and positive troponin results; and the transthoracic/cardiac ECHO revealed left ventricular hypertrophy, mitral regurgitation (MR), and EFs of 40–45%. A coronary angiogram showed triple vascular disease. Cardiac MRI showed MI involving the right coronary artery (RCA), left anterior descending LAD, and left circumflex LCX (EF 26%). Percutaneous coronary intervention PCI was performed on the RCA, LAD, and LCX; inotropes (noradrenaline,

adrenaline, and dopamine) were started at the maximum dose, and the decision was made to support him on VA ECMO in addition to Impella. Day 1 HD unstable on 3 inotropes, patient intubated on Fio2:80% PEEP: 8mmHg, troponin 4.1, developed AKI, DIC, liver dysfunction, radiological chest X-ray: bilateral infiltration. On day 3, showed improvement, patient on 3 inotropes decreased adrenaline dose to 0.07mcg/Kg/min with HD stable, Fio_2: 40% PEEP: 8 mmHg, troponin 2.1, showed little improvement in coagulation profile and lactate 3.4 mmol/L. On day 4, there was a significant improvement; the patient was on 2 inotropes, normal lactate 1.1 mmol/L, improved liver function, then decided to remove Impella. On day 6, patient HD was stable without inotropes, low setting mechanical ventilation MV, chest X-ray normal, normal lactate, liver function, and coagulation profile. ECHO showed LV moderate dilatation, EF: 20–25%, VTI:13.4 cm, and stroke volume: 39 ml; compared to the previous study, there was an improvement in LV EF, and eventually, the decision was taken to remove VA ECMO. On day 10 patient extubated on dexmedetomidine for agitation, he was HD stable on nasal canula 2L. On day 13, discharged from ICU to the ward. On day 16 patient was discharged home. **Conclusion:** Combined VA ECMO and Impella (ECpella) in patients with CS were associated may improve survival and patient outcome. We advocate early unloading guided by echocardiographic and hemodynamic monitoring.

Rapid Establishment of ECMO Program During the COVID-19 Pandemic

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Introduction: Extracorporeal membrane oxygenation (ECMO) is a modality used in the management of patients with refractory cardiogenic shock or acute respiratory failure. During 2020, the world suffering from Covid 19 pandemic, so a number of cases and centers offering adult extracorporeal membrane oxygenation (ECMO) has risen. **Objective:** Analysis of our experience. **Methodology:** We rapidly develop and implement an organized ECMO program at King Khalid hospital as an Adhoc support. The program provided care for patients within the ICU from March 2020 till now. It started with preparing policies and strategies followed by training of a multidisciplinary team of doctors, nurses, RT specialists and perfusionists then starting the service with continuous training and improvement including workshops, hands-on training and lectures. Also, we had great support from the MOH ECMO team for training and supervision. Finally, we became an ELSO center being the 4th center in Saudi Arabia and designated this year as a silver-level center by ELSO. **Results:** Eighty-five patients were treated with venovenous and veno arterial ECMO with survival to decannulation of 75% and survival to intensive care unit discharge of 55%. All these patients are initiated and managed by our ECMO team; we have 20 cases of retrieval, in which we used air, ground, or both. Complications: included hemothorax in 6 patients, heparin-induced thrombocytopenia in three patients, oxygenator failure in 3 cases, oozing from cannulation sites in 10 cases, oral cavity bleeding in 4 cases, from tracheostomy site in another four and renal impairment or failure represented in 39% of cases. **Conclusion:** The results suggest that a rapidly developed ECMO program can provide safe services and provide outcomes similar to those in the existing literature. Key components are an institutional commitment, a physician champion, dedicated leadership, a multidisciplinary team and organized training.

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Extracorporeal Membrane Oxygenation for Severe Viral Myocarditis: A Bridge to Recovery and Decision

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DOI: 10.5005/jaypee-journals-11011-0003.20

Introduction: Myocarditis is a rare complication of viral respiratory infections with very high short-term mortality. We report a previously healthy young patient who presented with severe, rapidly progressive viral myocarditis, which improved after five days of support with VA-ECMO without mechanical ventilation. **Case report:** A 48-year lady presented with fever and hypoxia with cardiogenic shock (LVEF 18–20%), for which she was initiated on inotropes and IABP support, despite which she had clinical and metabolic worsening. On presenting to us, she was in shock (Systolic BP 60 mmHg) on Norepinephrine at 0.2 ug/kg/min and Vasopressin at 1 U/hour. Echocardiography showed global hypokinesia (LVEF 10–12%). She had severe metabolic acidosis (pH 7.28, Lac 5.2, BE –11.6) with troponin-T of 1.65 ng/ml and BNP of 3240 pg/ml. Renal/hepatic functions were normal. A possible acute coronary event was ruled out with normal coronary angiography. In view of refractory shock, she was initiated on VA ECMO with left femoral vascular access under local anesthesia. After initiation of ECMO, norepinephrine was tapered to a target SBP of 90 mmHg. Gradual improvement in LVEF was noted to 45 % by the fifth day. ECMO support was gradually tapered and decannulation was done on day 6. She maintained normal blood pressure and oxygenation and was successfully discharged. **Discussion:** Severe viral myocarditis is associated with a fatality rate of 25% with a median of 9.9 days to spontaneous recovery. Mortality is due to refractory cardiogenic shock and multiorgan dysfunction and ECMO provides support during this period and prevents end organ damage. **Conclusions:** ECMO provides a valuable bridge to recovery in diseases with reversible myocardial dysfunction and allows time to recover before the onset of irreversible organ damage. Increasing awareness of the use of ECMO will enable more patients to receive this valuable treatment modality.

ECMO as a Lifesaving Modality in Near-Fatal Asthma, Najran Experience

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Introduction: The use of extracorporeal membrane oxygenation (ECMO) in cases of near-fatal asthma has increased, but the benefits

of this therapy have yet to be fully investigated. However, its use in severe asthma is limited to case reports or a case series. **Objective:** To analyze our experience implementing VV ECMO as a lifesaving modality in near-fatal asthma. **Methodology:** A retrospective study of near-fatal asthma patients who received VV ECMO in the emergency department, King Khalid hospital, Najran between 1st January 2022 and 1st December 2022. **Results:** In this study, we analyze five cases of patients with bronchial asthma who were presented to the emergency department with severe fatal asthma. Three patients presented with severe hypercapnia and severe respiratory acidosis and intubation was done in ER; two developed cardiac arrest while managing asthma. The time of arrest was between 2 and 4 min. While the other two patients were arrested in the emergency department and CPR was done, ROSC was obtained in 5 and 18 min, respectively. Vigorous asthma management in the form of muscle relaxant, sedation, PRVC ventilation and aggressive therapy for bronchial asthma was started for all five patients, but their condition was worsening, and no improvement was obtained. ECMO consultation was done in the emergency department and VV ECMO was started for those patients. Fem-jag configuration was used with gradual correction of hypercapnia, and normalization of ABG was obtained later with continuity of conventional asthma treatment. The mean time of the ECMO run was 128.3 hours. Four patients were extubated before ECMO decannulation while one patient decannulated while on a ventilator. Ventilator settings were significantly improved after ECMO initiation in all patients. Weaning of ECMO was successful in all five patients and four patients were discharged home. One patient with prolonged cardiac arrest before initiation developed irreversible brain damage and died later in ICU. **Conclusion:** ECMO is lifesaving in patients with severe fatal bronchial asthma for whom conventional therapy failed, and it is associated with a good outcome, however, bigger studies should be performed.

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Lifesaving Starts with BLS and Ends with ECPR

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Introduction: The incidence of unexpected cardiac arrest is high, in-hospital and out-of-hospital, respectively. ECPR is emerging as a modality to improve prognosis by augmenting perfusion to vital end-organs by utilizing extracorporeal membrane oxygenation (ECMO) during conventional CPR and stabilizing the patient. **Objective:** Case report analysis. **Methodology:** Case report of a patient who survived after 45 minutes of cardiac arrest with whom all modalities of life support were used in King Khalid hospital, Najran, Saudi Arabia. **Results:** 24 years old male developed cardiac arrest after choking while sitting with his friends. Immediately they started CPR using BLS protocol while the ambulance was called. The patient was transferred to a primary health care center where he was intubated and ACLS started while transporting him to our hospital. The patient was received in the emergency department after 15 min with a systole. CPR was continued for another 10 min, during which he developed VT, to which DC shock was used twice. ROSC was obtained with instability in hemodynamics and severe hypotension in spite use of maximum inotropes. ECMO consultation was done, and VA ECMO was started within 30 minutes of ROSC. Patients' hemodynamics were improved in the next hours with gradual withdrawal of inotropes. After 24 hours, the patient was of inotropes, and full investigations were done, which revealed frequent PVCS, post-cardiac arrest stunning and moderate brain edema. Within the next three days, the patient's condition improved, ejection fraction was improved, brain edema subsided, and he regained full consciousness. Extubation was done and on the fourth day and a day later, the patient was decannulated. The patient was discharged home on the 10th day in good general condition and referred to EPS clinic for follow-up. **Conclusion:** ECPR can improve survival and decrease hospital mortality, but this should be proceeded by good CPR started from BLS and ACLS.

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Incidence and Outcome of Neurological Complications in H1N1 Respiratory Failure Patients on ECMO: A Retrospective Study

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Introduction: H1N1 respiratory failure is a severe condition that can lead to acute respiratory distress syndrome (ARDS). Extracorporeal membrane oxygenation (ECMO) is a life-saving therapy for patients with severe ARDS. However, ECMO can also cause neurological complications, impacting patient outcomes. Respiratory extracorporeal membrane oxygenation (ECMO) is well established, and its popularity has increased during the coronavirus disease 2019 (COVID-19) time. The efficacy of ECMO has been proved in refractory respiratory failure with varied etiology. More than 85,000 respiratory ECMO cases (neonatal, pediatric, adult) registered as per Extracorporeal Life support Organization (ELSO) statistics April 2022 report, with survived to discharge or transfer ranging from 58 to 73%. Early initiation of ECMO is usually associated with shorter ECMO runs and better outcomes. Many patient factors have been associated with mortality while on ECMO. **Objective:** The aim of this study is to investigate the incidence and types of neurological complications in H1N1 respiratory failure patients receiving ECMO and to evaluate the impact of these complications on patient outcomes. **Methodology:** We conducted a retrospective chart review of all H1N1 respiratory failure patients who received ECMO at our institution between January 2010 and December 2021. Patients with pre-existing neurological conditions were excluded from the study. We collected data on patient demographics, comorbidities, ECMO parameters, and neurological complications. We also evaluated the impact of neurological complications on patient outcomes, including mortality, length

of stay, and functional status at discharge. The primary outcome goal was a survivor and discharged home versus non-survivor, while the secondary goal was the number of ECMO days and incidence of neurological complications. The statistical analysis was done for the primary outcome, and incidences of neurological complications and the p-value were obtained using the chi-squared method. **Results:** A total of 256 patients with respiratory failure were treated with ECMO during the specified period by the Riddhi Vinayak Multispecialty Hospital ECMO team. Data analysis of 251 patients (5 patients were transferred for a lung transplant, hence not included n the study) was done. Out of which 36 patients were from H1N1 respiratory failure cases, out of which nine patients had neurological complications. As anticipated, neurological complications were relatively common in H1N1 respiratory failure patients receiving ECMO. As also expected, these complications had a negative impact on patient outcomes, including increased mortality, longer length of stay, and worse functional status at discharge. **Conclusion:** This study provides important insights into the incidence and impact of neurological complications in H1N1 respiratory failure patients receiving ECMO. Healthcare providers should be aware of these complications and implement strategies to minimize their occurrence. Further studies are needed to identify effective prevention and treatment strategies for ECMO-related neurological complications in H1N1 respiratory failure patients. Authors recommend early initiation of ECMO for mortality and morbidity benefits.

ECMO as a Life Saving Modality in Near Fatal Asthma, Najran Experience

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Introduction: The use of extracorporeal membrane oxygenation (ECMO) in cases of near-fatal asthma has increased, but the benefits of this therapy have yet to be fully investigated. (1) However, its use in severe asthma is limited to case reports or a case series. **Objective:** To analyze our experience of implementing VV ECMO as a life saving modality in near fatal asthma. **Methodology:** A retrospective study of near fatal asthma patients received VV ECMO in emergency department, King Khalid hospital, Najran between 1st January 2022 and 1st December 2022. **Results:** In this study we analyze five cases of patients of bronchial asthma were presented to emergency department in sever fatal asthma. Three patients were presented with sever hypercapnia and sever respiratory acidosis and intubation was done in ER, two of them developed cardiac arrest during their management of asthma. time of arrest was between 2 and 4 min. While other 2 patients were brought arrested to the emergency department and CPR was done for them ROSC was obtained in 5 and 18 min respectively. Vigorous asthma management in the form of muscle relaxant, sedation, PRVC ventilation and aggressive therapy for bronchial asthma was started for all 5 patients, but their condition was worsening, and no improvement obtained. ECMO consultation was done in emergency department and VV ECMO was started for those patients. Fem-jag configuration was used with gradual correction gradual correction of hypercapnia, normalization of ABG obtained later with continuity of conventional asthma treatment. Mean time of ECMO run was 128.3 hours. 4 patients extubated before ECMO decannulation while one patient decannulated while on ventilator. Ventilator settings were significantly improved after ECMO initiation in all patients. Weaning of ECMO was successful in all 5 patients and 4 patients were discharged home. One patient with prolonged cardiac arrest before initiation developed irreversible brain damage and died later in ICU. **Conclusion:** ECMO a life saving in patients with severe fatal bronchial asthma whom conventional therapy failed, and it is associated with good outcome, however bigger studies should be performed.

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Life Saving Starts with BLS and Ends with ECPR

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Introduction: The incidence of unexpected cardiac arrest is high, with in-hospital and out-of-hospital respectively. (ECPR) is emerging as a modality to improve prognosis by augmenting perfusion to vital end-organs by utilizing extracorporeal membrane oxygenation (ECMO) during conventional CPR and stabilizing the patient. **Objective:** Case report analysis. **Methodology:** Case report of a one patient survived after 45 minutes of cardiac arrest with whom all modalities of life support were used in King Khalid hospital, Najran, Saudi Arabia. **Results:** 24 years old male developed cardiac arrest after choking while sitting with his friends. Immediately they started CPR using BLS protocol while ambulance was called. Patient was transferred to primary health care center in which he was intubate and ACLS started while transporting the patient to our hospital. Patient received in emergency department after 15 min with a systole. CPR was continued for another 10 min in which he developed VT to which DC shock was used twice then ROSC was obtained with instability in hemodynamics and sever hypotension in spite use of maximum inotropes. ECMO consultation was done, and VA ECMO was started within 30 minutes of ROSC. Patients hemodynamics were improved in the next hours with gradual withdrawal of inotropes. After 24 hours patient was of inotropes, full investigations were done which revealed frequent PVCS, post cardiac arrest stunning and moderate brain oedema. Within the next 3 days, patient condition was improved, ejection fraction was improved, brain oedema subside and he regain full consciousness. Extubation was done and on the fourth day and day later patient was decannulated. Patient was discharged home in the 10th day with good general condition and referred to EPS clinic for follow up. **Conclusion:** ECPR can improve survival and decrease hospital mortality, but this should be proceeded by good CPR started from BLS and ACLS.

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Rapid Establishment of ECMO Program During the COVID-19 Pandemic

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Introduction: Extracorporeal membrane oxygenation (ECMO) is modality used in the management of patients with refractory cardiogenic shock or acute respiratory failure. During 2020, the world suffers from Covid 19 pandemic so number of cases and centers offering adult extracorporeal membrane oxygenation (ECMO) has risen. **Objective:** Analysis of our experience. **Methodology:** We rapidly develop and implement an organized ECMO program at King Khalid hospital as an adhoc support. The program provided care for patients within the ICU from March 2020 till now. It started with preparing policies and strategies followed by training of multidisplinary team of doctors, nurses, RT specialists and perfusionist then starting the service with continuous training and improvement including workshops, hands on training and lectures. Also, we had a great support from MOH ECMO team for training and supervision. Finally, we became an ELSO center being the 4th center in saudia arabia and designated this year as a silver level center by ELSO. **Results:** 85 patients were treated with both veno-venous and veno arterial ECMO with a survival to decannulation of 75% and survival to intensive care unit discharge of 55%. All these patients are initiated and managed by our ECMO team, we have 20 cases of retrieval, in which we used air, ground or both. Complications: included hemothorax in 6 patients, heparin induced thrompcytopenia in three patients, oxygenator failure in 3 cases, oozing from cannulation sites in 10 cases, oral cavity bleeding in 4 cases, from tracheostomy site in another four and renal impairment or failure represented in 39% of cases. **Conclusion:** The results suggest that a rapidly developed ECMO program can provide safe services and provide outcomes similar to those in the existing literature. Key components are an institutional commitment, a physician champion, dedicated leadership, multidisplinary team and organized training.

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Never Lose Hope, The Battle Will Be Won: Two Consecutive Runs of Veno Venous ECMO in a Young Female with Severe COVID-19 ARDS

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We report case of 31 years old previously healthy lady, referred to our tertiary care center with severe covid 19 infection and rapidly progressive respiratory failure. Despite adequate mechanical ventilation, she kept on deteriorating (PF RATIO 55, PCO2 60), VV ECMO was initiated with 19th F right IJV – return cannula and 25 F right femoral - drainage cannula. Initiation and first month of ECMO run were smooth. In the 2nd month, she developed prolonged ECMO run complications like hospital-acquired multidrug-resistant pneumonia and bacteremia (Acinetobacter, stenotrophomonas maltophilia), managed by higher antibiotics. Minimal cannula site and peri tracheostomy oozing occurred, managed with compressive dressings and reduction in ACT targets. Gradually she was generating around 300 ml Tidal volume with satisfactory ABGs on minimal ECMO support (flow - 1.5-liter, SWEEP gas - 1 liter). On 54th day, after a successful 24-hour trial off, she was decannulated. Unfortunately, next day she become tachypneic, hypoxic, and ABG suggestive of hypercarbia of 110, a PF ratio of 60 on the control mode of ventilation. After expert ECMO stalwart opinion, VV ECMO was reintroduced. During 2nd run, we faced difficult challenges like critical illness neuropathy, managed with IVIG and ECMO circuit-related hemolysis, managed with multiple blood transfusions, and changed of entire circuit with its components. On 22nd day, ECMO was gradually weaned off. Finally, patient was discharged on 130th day of hospital stay with big smile on her face with minimal 0_2 support. We conclude case of two consecutive runs of VV ECMO and the complications dealt with a long-run ECMO.