Use of roller pump in venovenous extracorporeal membrane oxygenation as an emergency rescue procedure

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Abstract
A 41 years old male patient, having acute respiratory distress syndrome (ARDS) due to viral pneumonia, was put on veno-venous (VV) extracorporeal membrane oxygenation (ECMO). After 3 h of initiation, the ECMO pump malfunctioned. The patient was initially managed on a hand crank for 5 h. However, as another machine would be available after 12–24 h, we decided to use a roller pump with a conventional cardiopulmonary bypass (CPB) circuit. We successfully manage this crisis with this technique without any complications. This technique can be lifesaving in catastrophic situations such as ECMO console or pump failures when there are neither backup machines nor service engineers available.

Keywords Centrifugal pump · Roller pump · ECMO · ARDS

Introduction
Extracorporeal membrane oxygenation (ECMO) provides temporary cardio-respiratory support for patients until the recovery of organs or as a bridge to transplant. The first case of successful ECMO support in an adult patient was published by Hill et al. in 1972 [1, 2]. With the sudden surge in coronavirus disease (COVID-19) cases, there are large numbers of patients with respiratory failure requiring of more numbers of ECMO machines and manpower [3, 4]. In overburdened intensive care units, there is a need for an alternative tool in times of crisis when an ECMO machine malfunctions, and there is no immediate replacement available, especially at peripheral centres. We are reporting a successful use of a roller pump with a conventional cardiopulmonary bypass (CPB) circuit as an emergency stop-gap, rescue veno-venous extracorporeal membrane oxygenation (VV-ECMO) due to mechanical ECMO console failure at All India Institute of Medical Sciences (AIIMS), Jodhpur.

Case report
A 41 years old male patient, having acute respiratory distress syndrome (ARDS) due to viral pneumonia (non-COVID-19), was put on VV-ECMO (Maquet cardiopulmonary GmbH, Model-Rotaflow, PLS 2050 Maquet adult circuit). After 3 h of initiation, the ECMO pump had a technical failure and we immediately put the patient on a hand crank for temporary support. The ECMO console showed the error “ERR OR!!” (Fig. 1). After consultation with the service engineer, it was found that the flow measuring and power supply board in the console had malfunctioned and could not be repaired immediately as it required major repair or replacement of the machine. Our institute is situated in a rather remote area, and there was only one machine at our institute and no other machine was available in the vicinity.

The patient was initially managed on a hand crank for 5 h and we were able to maintain adequate flows. However, as another machine would be available only after 12–24 h and it was impractical to continue on hand crank for prolonged periods, we decided to use a roller pump (Maquet HL 20) with a conventional CPB circuit (Sorin INSPIRE 6 oxygenator, Dr Surgical custom tubing pack (adult) with arterial filter 3/8–3/8).

The challenges pertaining to roller pump for VV-ECMO were increased risk of hemolysis, the requirement of a higher level of activated clotting time (ACT) (more than 480 s in roller pump in contrast to 180–200 s in centrifugal pump),
increased risk of bleeding complications due to higher ACT, and maintaining adequate venous drainage and flow rate. Before switching to a roller pump, we heparinized the patient to achieve an ACT of more than 480 s and primed the reservoir with a crystalloid solution. We put the patient on maximal ventilatory support and clamped the drainage and return cannula. At the time of initiation of the roller pump, we checked the occlusion by falling in fluid level in the return line by 1 inch per minute, to prevent haemolysis.

The ECMO circuit was disconnected from the cannula and the tubing of the roller pump was connected after complete de-airing and venovenous bypass was re-established. The circuit included a femoral venous cannula draining into the reservoir with adequate priming volume as a safety measure, followed by the roller pump pushing blood across the oxygenator (Fig. 2, green arrow), into the patient via a return cannula in the right internal jugular vein (IJV). We had to use intermittent, partial clamping of venous lines for adequate drainage, to maintain the flow rate of 4L/min and target arterial oxygen saturation (Spo2) of 85%. On Day 1 morning, around 13 h post machine malfunction, the Service Engineer from Delhi arrived with a new console. Although the service engineer brought a new console, he just wanted to check the cause of the fault in the console for that he exchange the motherboard and in the process, the new motherboard also malfunctioned. If he would have just exchanged the console which he brought, definitely, we could save at least 6 h. This decision was proved erroneous as, soon after the exchange of motherboard from the new console, our console again started to show the same error! If service engineer would have just exchanged the console which he has brought, definitely we could have saved at least 6 h. Now, we were in deep trouble as it was already more than 8 h on the roller pump and we have no replacement machine nearby. After contacting multiple centres, we were able to arrange another machine from Jaipur, which reached us by road, around 20 h post machine malfunction. On arrival of a new machine, we put the patient on maximal ventilatory support for a while and clamped the cannula, conventional CPB circuit lines were disconnected and centrifugal pump lines were connected and VV-ECMO was re-established. The total duration of conventional CPB with a roller pump was 15 h and 20 min. During this period, we were able to maintain an adequate flow rate and target saturation without any complications like bleeding, hemolysis or air embolism. Also, during this period, we kept circulating the previously used ECMO tubing in the roller pump slowly at a rate of 100 ml/min to prevent damage to the expensive ECMO oxygenator due to stasis (Fig. 2, blue arrow). We used the same circuit again when the replacement ECMO machine arrived.

**Discussion**

The centrifugal pump and the roller pump are the two basic types of blood pumps used for cardiopulmonary bypass. Each has its own advantages and disadvantages. For routine
cardiac surgery, which lasts for a few hours, a roller pump is routinely used. The centrifugal pump can be used for long durations (days to weeks) due to its differences in design, and working mechanism which prevents mechanical shear force. Hence, centrifugal pumps have become a standard for ECMO circuits worldwide [5].

1. Our concept to use a roller pump in a VV-ECMO circuit in emergency situations is supported by the fact that the roller pump is being used in neonatal Ven-Arterial ECMO (VA-ECMO) circuits in some centres [6]. A survey was conducted in the USA in 2011 among active Extracorporeal Life Support Organization (ELSO) centres, by electronic mail regarding neonatal VA-ECMO equipment and professional staff. Of the 67% of responding centres, 53% routinely used roller pumps for neonatal ECMO, 15% reported using centrifugal pumps and 32% reported using a combination of both. Although, they concluded that in comparison to 2002, the use of the centrifugal pump for neonatal ECMO increases eightfold (5 centres to 39 centres) in the year 2011 [6]. However, on literature search, we have not found reports on the “use of roller pump in VV-ECMO”. The conventional CPB circuit with a reservoir usually functions good for about 8 h, we monitored the oxygenation by doing regular blood gas analysis of post membrane sample at 30-min intervals and kept observation on urine for possible haemolysis. As post membrane oxygenation was good and there was no sign of haemolysis, so we continued the roller pump after 8 h and successfully used it for more than 15 h.

**The challenges for use of roller pump in ECMO circuit**

**Negative pressure and suction**

Due to increased negative pressure and suction, the right atrium walls may stick to the cannula and venous return hampers. To overcome this, we used a reservoir in the circuit and we also applied clamps, intermittently and partially, on the venous line to get adequate drainage and able to maintain adequate flows, while preventing venous drain chatter. The use of a collapsible bladder pre-pump helps in avoiding reservoir usage and also reduces the high ACT requirements. At our centre, the collapsible bladder was not available and hence not used in that emergency situation.

**Mechanical shear forces on tubing**

This causes damage to tubing and increased haemolysis. Peek et al. assessed the durability of three different types of tubing in a roller pump and demonstrated that tubing rupture occurred after an average of 7 to 244 h [7]. Although the silicone tubing withstands higher shear forces than poly vinyl chloride (PVC) tubing [8], we used PVC tubing due to the non-availability of silicone tubing. Our total duration on the roller pump with PVC tubing (Dr Surgical custom tubing pack adult with arterial filter 3/8–3/8) was 15 h and 20 min without any evidence of damage to tubing or haemolysis.

**Overheating of roller pump and pump failure on prolonged use**

Kaluza et al. in their study concluded that the circuit heating and substantial limitations in flow detection should be taken into account if clinical use in situations of crisis is considered [8].

**The large size of the roller pump machine**

This can decrease the mobility of the patient on ECMO, in comparison to the small size of the centrifugal pump.

**The increased need for heparinisation**

In a roller pump with reservoir and oxygenator, we have to maintain ACT for more than 480 s, in comparison to the ACT of 180–200 in a centrifugal pump. We maintained ACT for more than 480 s without any evidence of bleeding.

AIIMS, Jodhpur, is a tertiary care centre situated in western Rajasthan, India, which is around 650 km away from major cities like Delhi where facilities of ECMO service engineers or spare machines are available immediately. At our centre, this was our first case of ECMO support and we had only one ECMO machine and none was available in the vicinity for immediate replacement. During the crisis situation, we initially manage on the hand crank and then decided to put on a roller pump till the new machine arrived. We are reporting this case as a successfully managed catastrophic complication of ECMO console failure with the use of a conventional roller pump as a stop-gap VV-ECMO circuit, without any other complications. We have been able to successfully wean off our patient from VV-ECMO 43 days later.

**Conclusion**

We believe that this technique can be lifesaving in a catastrophic situation such as an ECMO pump or console failure, especially at peripheral centres which lack backup machines, and or service engineers for immediate repair or replacement. We also propose to use this technique as a bridge to VV-ECMO in cases where ECMO machines or any consumable spares are not available immediately.
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Declarations

Ethics approval  Not required.

Consent to participate  The informed consent was obtained from the patient for the publication.

Conflict of interest  The study was presented as a free paper by Suren德拉 Patel at the “68th Annual conference of the Indian association of cardiothoracic and vascular surgeons (IACTSCON 2022)” held in Jaipur, on 7–10th April 2022. All the authors declare no other conflict of interest.

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