

# Introducing the Loop for Circuit Access during Extracorporeal Membrane Oxygenation: Feasibility and Safety

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**Abstract:** In extracorporeal membrane oxygenation (ECMO), blood is drained from the patient, and pumped through a membrane oxygenator/lung (ML) for gas exchange and then back to the patient. For monitoring blood gases, samples may be sampled downstream from the ML. This exposes the patient for embolization risk (air/clot) when the stopcocks are flushed. For safe sampling procedures, the Loop was introduced. It is a constant low-flow arteriovenous shunt (AVS) used preferably in venoarterial ECMO. It is composed of three different length and diameter three-way stopcocks connected to the circuit just downstream the

ML with its return upstream the pump. It offers safe arterial blood sampling and a simultaneous access point to the venous side of the circuit. Since its introduction, no patient complications have been reported to be accounted for by the Loop. The Loop is an AVS permitting a safe access point for post membrane blood sampling and for injections in the venous pre-pump limb. It has a low cost and is easy to install and maintain. It may be used in any ECMO configuration. **Keywords:** extracorporeal membrane oxygenation, loop, bridge, gaseous emboli, access, shunt, venoarterial. *J Extra Corpor Technol. 2019;51:175–8*

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Extracorporeal membrane oxygenation (ECMO) is a lifesaving rescue therapy offered patients with refractory severe respiratory and/or cardiac failure (1). Deoxygenated blood is drained from the patient's greater veins/right atrium, pumped via a membrane lung (ML) for oxygenation and decarboxylation, and then returned to the patient's circulation. For lung support, blood is returned to the venous side (VV ECMO), and for cardiopulmonary support, the blood is reinfused to the patient's arterial side (VA ECMO).

A circuit component, called a *bridge*, was, and still is, used by some ECMO centers, especially in VA ECMO (1–3). This bridge is an arteriovenous shunt (AVS) between the arterial and venous limbs of the ECMO circuit,

often close to the patient. Its purpose is to maintain circuit flow in case of access problems or any other cause for separation from the patient (2). If the ECMO flow is interrupted for more than a few minutes, the blood in the circuit risks to clot because of stagnation of flow. This bridge has also been used as a tool during the weaning process, especially in the infants, because it allows for ultralow flows to the patient (4). This bridge is composed of the same tubing as the ECMO system and is connected to the main circuit via luered Y or T connectors. A bridge is as default clamped but because of stagnation of flow, the risk for clotting is evident, thus needs to be flushed at regular intervals. Although modifications have developed, the basic concept prevails (2). The shunt flow is as such intermittent and cannot be used for infusions, and it proposes a significant drop in treatment efficiency when open for flow.

Thus, we developed *the Loop*, which is a low-flow constantly open AVS with a different clinical purpose than the bridge. To our knowledge, the Loop was first briefly described in a recent overreaching work in extracorporeal life support by Conrad et al. (3). The Loop allows for a safer way to access the ML for blood sampling and for

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minimizing the risk for air or clot to enter the patient from repeated saline flushes on the arterial side of the circuit. The aim of this article was to describe the clinically evaluated circuit component called *the Loop*.

## MATERIAL AND METHODS

### Setting

Our ECMO center was established in 1987 as one of the first in Europe and is an Extracorporeal Life Support Organization (ELSO, Ann Arbor, MI) Center of Excellence in Life Support since 2007. The center is a high-volume respiratory ECMO center performing all treatments in all age groups, except post-cardiotomy. VA ECMO is commenced in 60% of the annual 80 to 90 patients treated. Approximately 80% of the patients are referred to us from other hospitals or centers. These are assessed, cannulated, and transported on ECMO by our mobile ECMO teams. We also perform 10–20 additional primary and secondary transports between other centers within Scandinavia and Europe.

*The Loop* is an add-on device to the prefabricated circuits that are the same for any ECMO mode. The Loop was developed to avoid the risk of flushing on the post-ML side. The Loop is exclusively used for VA ECMO in the authors' ECMO program and is an AVS attached to pressure measurement three-way stopcock approximately 10-cm downstream on the arterial limb distal to the ML. As shown in Figure 1, the Loop starts from this point, is composed of one 100-cm three-way stopcock (priming volume 5.50 mL), one male–male Luer-lock adapter (b), one 15-cm micro three-way stopcock (.30 mL, *resistance segment*), and one 10-cm three-way stopcock (.80 mL). Reentry to the circuit is via a Luer-lock connector (LLC) on the venous side, where a default three-way stopcock is always mounted. The Loop is primed with saline and then connected to the arterial and venous default stopcocks, respectively. Before establishment of flow, it is de-aired. In case of exchange, that procedure follows the same practice. For roller pumps, the reentry is in the circuit just before the bladder. For centrifugal pumps, reentry is before the head (Figure 2). As depicted in Figures 1 and 2, the Loop offers three access

points. The flow is continuous and measured with a Transonic HT110 (Transonic Systems Inc., Ithaca, NY). There is no preset interval for exchange of the constituents as they are exchanged as required. The exchange procedure is easily performed and safe to the patient. In our setting, pre-ML saturation is continuously measured non-invasively with the sensor (Spectrum Medical, Gloucester, UK) placed on the venous line before the reentry point of the Loop. Heparin is infused into the circuit downstream and blood samples are drawn upstream in relation to the reentry point.

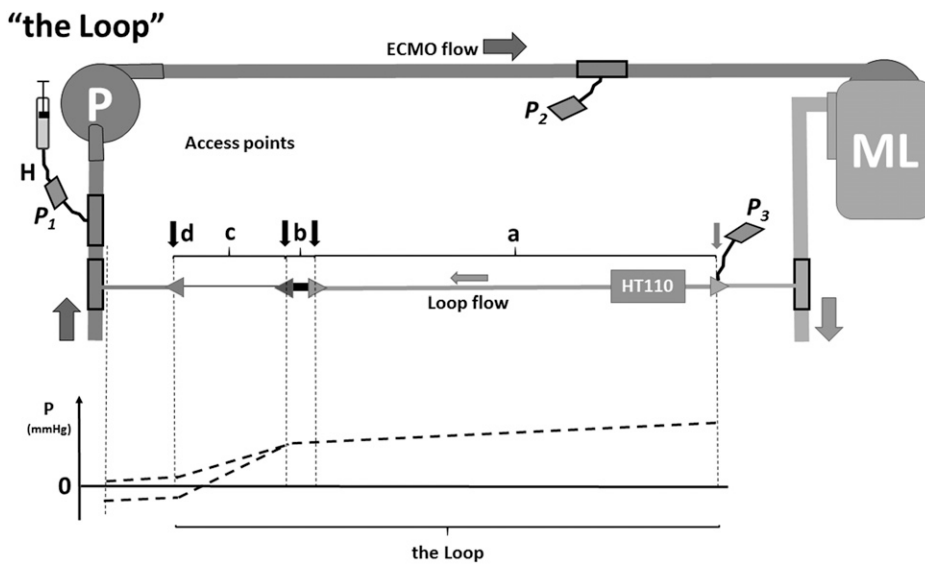
## RESULTS

A modification of the neonatal ECMO circuit for VA ECMO, the Loop, was introduced in 2008 and then for all VA patients from 2010. From 2017, all procedures regarding the ECMO circuit have been recorded in a quality assurance database in the unit and detailed information can be retrieved from this.

The Loop permits a continuous differential pressure-dependent flow of 40–250 mL/min between the post-ML tubing to the drainage side before the pump. It has three 3-way stopcocks that may be used for post membrane blood sampling, injections/infusions of pharmaceuticals, or as an access for continuous renal replacement therapy. The 100- and 10-cm stopcocks allow for the narrower 15-cm stopcock (resistance segment), susceptible for clotting, to be exchanged and de-aired without interruption of ECMO flow per se. The Loop before the resistance segment is part of the high-pressure side of the circuit and air cannot enter the system here. In case of accidental injection of air bubbles, those would get trapped by the ML. The adult ML used may capture 20-mL gas (Medos hilite 7000 LT; Medos Medizintechnik AG, Stolberg, Germany). It should be noted that not all ML designs may act as “air traps.” The top of the ML (by design) is used as default for sampling pre-ML blood gases. Heparin is infused via the luered connector where P1 is measured (Figure 2). At the infusion rate of .5–1.2 mL/h, the risk for falsely high monitoring values at the pre-ML sample point is not a problem.

**Figure 1.** The Loop as default constructed of (starting from the arterial side, right side in figure) one 100-cm three-way stopcock (a), one male–male Luer-lock (LLC) adapter (b), one 15-cm micro three-way stopcock (c). (d) A 10-cm three-way stopcock always attached to a straight LLC on the drainage side of the circuit and thus considered part of the drainage limb of the circuit (not the Loop). The “a” end is connected approximately 10-cm downstream the membrane lung (ML) and the “d” end is connected to the venous limb closely before the pump head.





**Figure 2.** The Loop that is connected to the default P3 pressure transducer/10-cm three-way stopcock on connector downstream the ML. The P3 pressure is measured post membrane in all modes of ECMO. The Loop is used in venoarterial configurations. The blood flow in the Loop is monitored by a Transonic HT110 (Transonic Systems Inc., Ithaca, NY), adapted outside of the “a” line. A typical flow would be 40–250 mL/min. Access points are shown in black. The gray arrow indicates the occupied access for pressure monitoring. The additional pressure monitoring points are on the venous limb (P1) before the centrifugal pump (P) and the P2 between the pump and ML, heparin (H), is infused via the P1 pressure line. The lower part of the panel displays the pressure gradient along the Loop. From the ML side, via a male–male adapter (b), to the resistance segment (c). Up to here, all access points are on the positive pressure side. After the resistance segment (from “d”), the pressure may be positive or negative depending on the pressure in the venous tubing.

The loop is strictly used inhospital, and not on inter-hospital ECMO transfers.

Our database shows that from the beginning of 2008 until October 2018, 186 neonatal patients, and from 2010, 104 pediatric and 204 adult patients were treated on VA ECMO. No patient adverse events attributable to the Loop have been experienced in over these 135,000 patient hours. However, clotting of the loop occurs on occasion, commonly of the narrow resistance segment. This has occurred once since 2017 of a total of 123 VA ECMO treatments. The clotted part was easily exchanged without clamping of the major circuit. If the whole Loop would have to be changed including the additional three-way stopcocks on the circuit luered connectors, it would mandate for a short (3–5 seconds) interruption of the ECMO flow. However, until today, we have never had to halt the ECMO flow for change of the Loop.

## DISCUSSION

Ten years ago, the Loop, a continuous low-flow AVS was introduced for VA ECMO patients at our department to allow for safe post membrane blood samplings without risk for accidental injection of air or emboli to the patient. It also offered a continuous “venous” positive pressure access point in the ECMO circuit during VA ECMO. The Loop may, however, be used in any ECMO mode. The cost is approximately US\$5. The bridge was abandoned in our organization at the turn of the decade 1990 because of risk and impracticality.

Both thrombotic and gaseous micro-emboli (GME) enter the patient from the ECMO circuit (5) and may lead to cerebral lesions and affect outcome (6). In our practice, post membrane samplings are assessed at least once daily

or when needed and are always taken in the Loop. Macro-bubbles or GME directly into the patient is thus avoided. Development of technology may reduce GME (7), or paradoxically using filters seems to add to the problem by fractioning microbubbles (8). There might be benefits also for use of the Loop in VV ECMO with respect to emboli because approximately 25% of the adult population has an unknown persistent foramen ovale (9).

Ultralow blood flow for weaning neonatal patients poses no challenge compared with using the bridge. However, this always carries an increased risk for flow stagnation and clot formation in the tubing, including the Loop. In our practice, total ECMO blood flow, flow to the patient, and the Loop flow are continuously measured at all time. Thus, the weaning procedure is performed in a controlled manner. The pressure in return tubing to the patient, P3, is measured in the Loop close to the return tubing. Because the pressure measuring point is in the Loop, the measured pressure will be approximately 5 mmHg lower than the true P3. It is the pressure trends that are followed, thus, this pressure discrepancy does not have an impact of clinical management. If the “true P3” is wished for, it is just to halt (turn a three-way stopcock) the Loop blood flow for approximately 10 seconds.

It may be suspected that red blood cells passing through narrow tubing would be exposed to increased shear stress, increasing the risk for hemolysis. However, we have not found the Loop to be causative for hemolysis at any time.

The Loop is a safe, low cost, easy to install and maintain AVS that permits access for arterial sampling and venous injection/infusion in the ECMO circuit. Because the major part of the Loop is part of the circuit’s high-pressure side, the risk for gas or thrombi/debris accidentally entering the patient is substantially reduced. A decade of development and experience shows its feasibility.

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