Supplementary Information

Pressure drop modeling

Numerical modelling (using COMSOL Multiphysics software, COMSOL Inc., Burlington, MA) was done to investigate pressure drop over different flow rates to find an optimum channel height.

In this simulation, it was assumed that the blood has a density of 1060 kg m^{-3} and a dynamic viscosity of 0.0035 Pa.s. The pressure drop over different flow rates is shown in Fig. S1a. The simulation showed that the pressure drops increases by reducing the channel height as expected due to the fact that irreversible relationship between pressure drop and channel height. As operating pressure drop is from 20 – 60 mm Hg, 130 μm would be the best option because its pressure drop fits in a wide range of flow rate from 1 – 6 mL min^{-1}.

Characterizing PDMS thickness for the bottom membrane

PDMS was spin-coated on the mold with different RPM to optimze this layer thickness. Later, the pressure drop of each device was measured by flowing water through channels under different flow rates. Lower pressure drop means that the membrane underwent higher deflection which increase the height of blood channel and would reduce the gas exchange. However, higher RPM would decrease the membrane thickness and increase the gas exchnage. Therefore, the best RPM was selected based on these parameters.

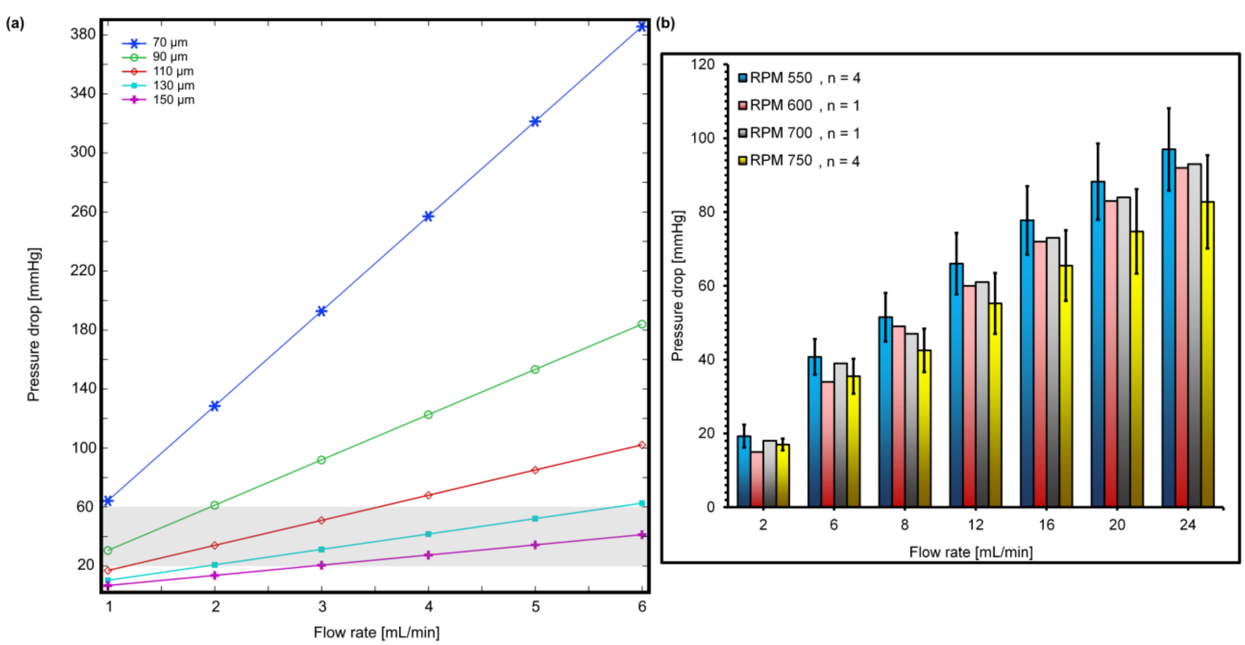

Figure s1: (a) numerical simulated pressure drops at different flow rates for different channel heights (gray box shows the operating pressure drop range) and (b) pressure drop versus flow rates for devices made of different RPMs with a channel height of 130 μm.

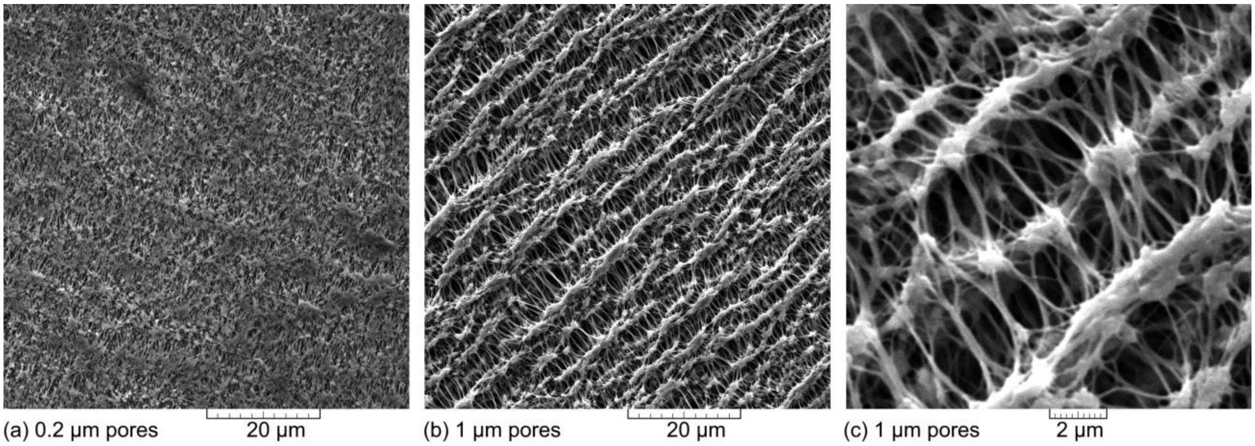

Figure s2: SEM images of PTFE membranes

Tensile Test for composite and PDMS membrane

A tensile testing machine (Shimadzu, Inc) was used to measure the mechanical properties of our new composite membrane (PTFE and PDMS) and make a comparison with PDMS membranes. Composite and PDMS membranes for tensile testing were spin-coated at a thickness of ~ 300 μm and cut into smaller pieces with rectangular sections measuring 1 cm in width and 6 cm in length as seen in Figure. 4a. Then, these samples were mounted in the grips of the machine at a gauge length of 1 cm.

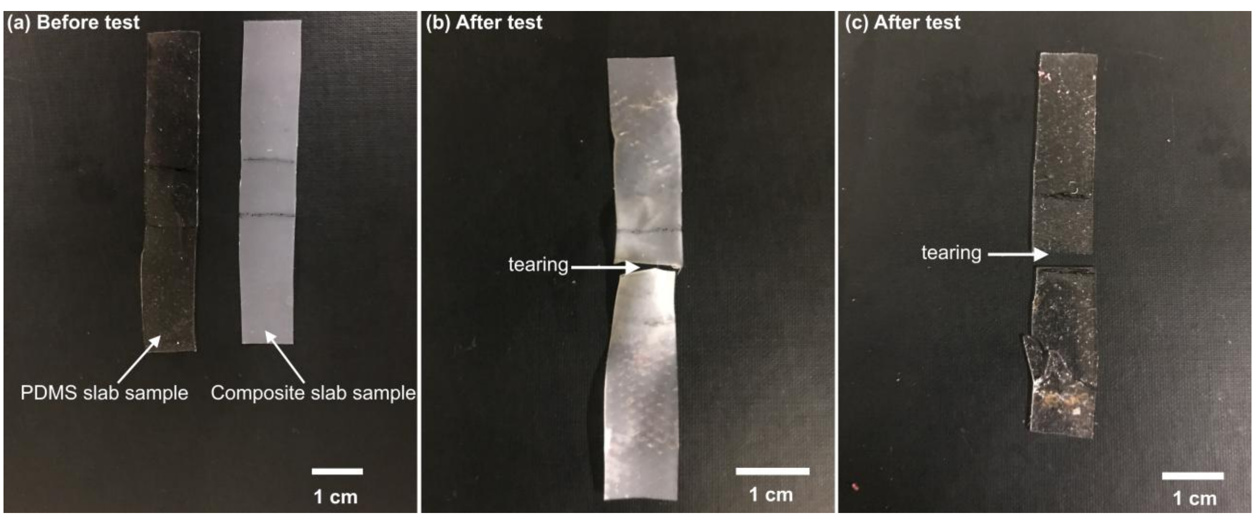

Figure s3: PDMS and composite samples for tensile testing: (a) before test, (b) a composite sample after testing, and (c) a PDMS sample after testing.

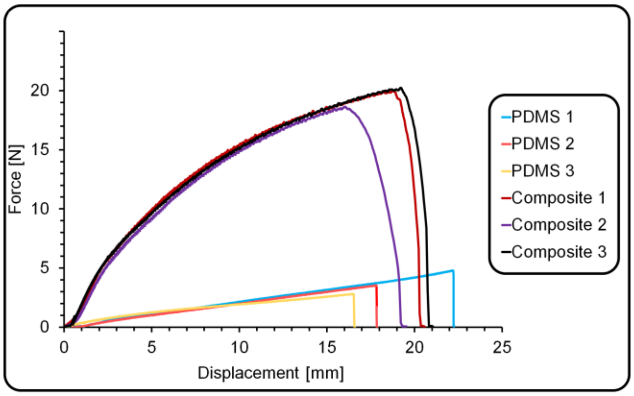

Figure s4: Sample force-displacement curve for composite and PDMS membranes. The slope for Composite samples is greater than PDMS ones which shows a higher Young's modulus for composite membranes meaning that reinforcing PDMS with porous PTFE membranes improved mechanical prosperities while maintaining the flexibility prosperities of PDMS.

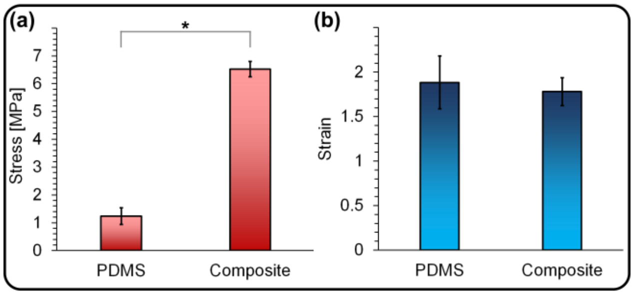

Figure s5: Tensile tests of PDMS and composite samples: (a) stress at failure point and (b) strain at failure point. Embedding porous PTFE membrane in PDMS appeared to reinforce PDMS and increase the mechanical properties.

Bending Test

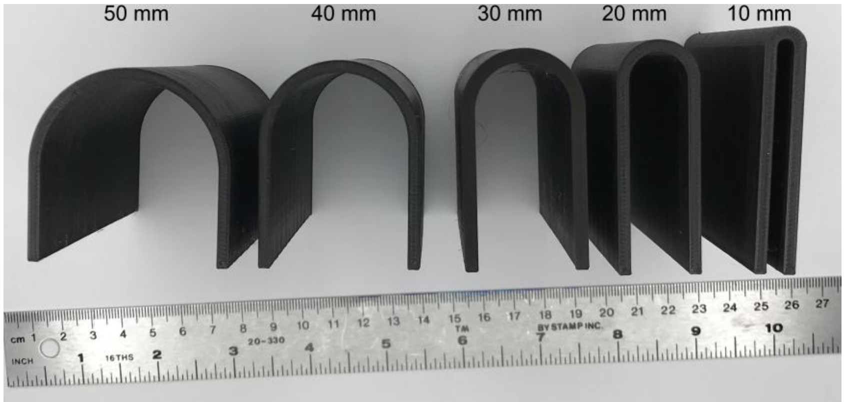

Figure s6: 3D-printed holders for bending APMBOs at different curvatures.

The Origami-shaped Compact LAD Preparation

As shown in the below figure, the LAD was made first and cut to be assembled.

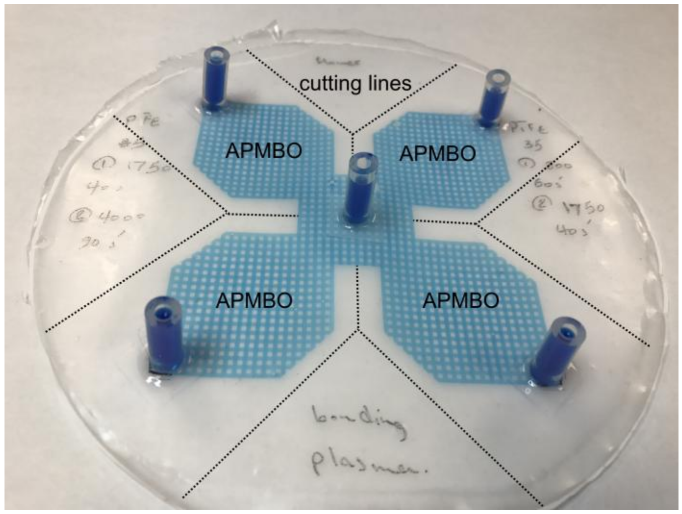

Figure s7: the origami-shaped compact LAD before being fully assembled.

Extracorporeal circuit

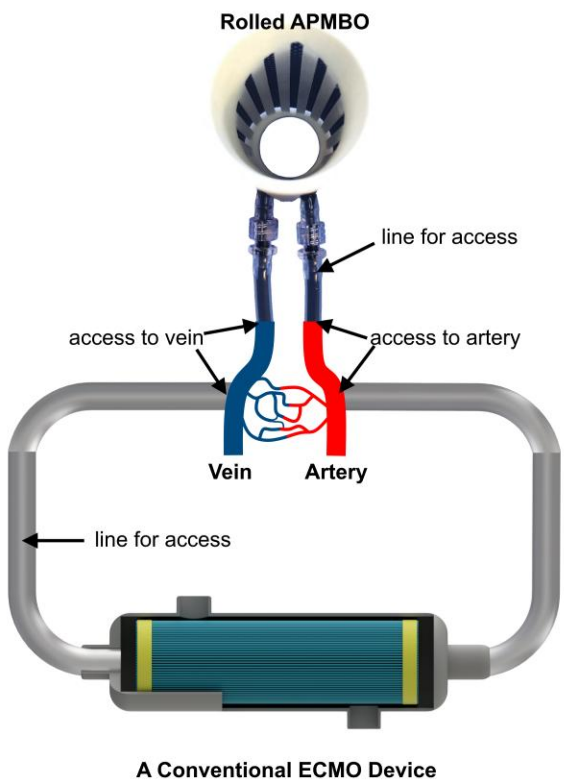

Figure s8: the required extracorporeal circuit for connecting a blood oxygenator to the vessels: comparison between Rolled APMBO and a conventional ECMO device.