Introduction:
Extracorporeal membrane oxygenation (ECMO) is used increasingly in critically ill patients suffering from acute respiratory failure, cardiogenic shock or cardiac arrest. However, this therapy can have deleterious side effects such as bleeding or clotting complications and hemolysis. These complications are particularly caused by physical stress acting upon the blood components while passing through the ECMO system, especially within the rotary pump. We here present a novel approach to simulate blood flows through rotary blood pumps used in current ECMO systems in order to better understand the genesis of these complications.

Methods:
Geometries of the Xenios DP3 (Xenios AG, Heilbronn, Germany) rotary pump were reconstructed by CT-scans and manual measurements using computer-aided design (CAD). The Computational Fluid Dynamics (CFD) simulation was performed using the software PreonLab (FIFTY2 Technology GmbH, Freiburg, Germany), which implements a mesh-free Lagrangian method requiring minimal preprocessing of the CAD data. The geometries are introduced to the simulation model as tessellated surfaces. Five operating points have been specified by the rotation of the centrifugal fan and the corresponding inflow and outflow of blood. The blood is approximatively modelled as a Newtonian fluid with a density of 1040 kg/m³.

Results:
PreonLab allows detailed assessment of the blood flow while passing through the rotary pump including analysis of local flow rates, pressure gradients and shear stress acting upon the blood. Dead zones in the fluid flow can be detected which gives reference points for optimizations of the pump design.

Conclusion:
For the first time, we demonstrate a novel approach for flow simulation in an ECMO rotary pump. This approach may help better understand hemodynamics within the extracorporeal system to define optimal operating points or re-design components aiming to limit hemolysis, coagulation disorders and bleeding in seriously ill patients.
Visualization of fluid velocity (in m/s) within the rotary pump (cross-section).