**Smart ECLA - Closed loop control of O2 and CO2 for management of extracorporeal lung assist**

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**Objectives:**
The management and operation of extracorporeal lung support systems requires skilled and specifically trained personnel at the bedside during the whole time of operation. While this is routine in the operating theatre, when applied in the intensive care unit, the operating scheme changes. Here we see a reduced level of interaction between operator and machine in intermittent or event driven intervals. In order to maintain the same safety and operating standard, the machine should be capable of higher levels of autonomous operation. This applies both for security features as well as for optimal adjustment of machine operation.

**Methods:**
In order to address the mentioned issues the “Smart ECLA” system was designed. Addressing veno-venous extracorporeal lung support, oxygenator and cannulae were taken from a standard extracorporeal circuit. As hemolysis is a key feature in long term extracorporeal circulation we chose a Medos Deltastream rotational blood-pump. An own motor console based on a Maxon motor controller was designed. A remote controllable gas supply was designed based on gas flow controllers for Air and O2, so both mass flow and Oxygen concentration of the fresh gas can be set electronically. Blood flow and pressure before and after pump and oxygenator as well as blood parameters (partial pressures of CO2 and O2, K, ph) are continuously measured and transmitted via a distributed CAN bus network. Related Safety critical tasks (e.g. sensor supervision) are performed in these distributed sensor/actuator nodes. Additional to the ECLA Sensors a full patient monitoring including continuous cardiac output monitoring was used.

All signals are processed in a central dSpace control unit, where higher control algorithms are implemented. In a hierarchical control scheme the inner control loop consists of controllers for CO2 and O2 partial pressures at the output of the oxygenator. So these can now be set independently of each other and of external factors (e.g. oxygenator wear, input concentrations). Based on a simplified physiological model several control algorithms for optimal setting of the ECLA parameters have been implemented. Among others we implemented a robust control for arterial oxygen saturation and venous CO2 partial pressure. These control loops were specifically designed to account for the large process parameter variation. The overlying blood flow optimizer sets the extracorporeal blood flow as low as possible for the desired target values.

**Results:**
System development, safety features and control performance have been evaluated in 15 animal experiments. After full instrumentation of the anaesthetised 45-60 kg pigs, two cannulae were placed in both femoral veins. The return cannula was placed in the jugular vein. Ventilatory insufficiency was simulated by using a hypoxic gas mixture for ventilation. Subsequently a test program for system identification (different operating points), control evaluation (set value changes, control disturbances) and specific safety critical situations (e.g. bubbles, cannulae suction) was performed.

Conclusions:
We could show that an ECLA system with enhanced capabilities is able to provide safe and reliable operation. Control targets could be met and safety features provide assistance and reliable alarms in critical situations.

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