EXPERIMENTAL COMPARISON OF PRESSURE PERFORMANCES IN DIFFERENT CPAP DELIVERY TECHNIQUES.

Margherita De Luca (1,2), Andrea Formaggio (1,2), Giovanni Putame (1,2), Simone Borrelli (1,2), Alberto L. Audenino (1,2) and Mara Terzini (1,2)

1. Department of Mechanical and Aerospace Engineering, Politecnico di Torino, Torino (Italy)
2. Polito^BIO^Med Lab, Politecnico di Torino, Torino (Italy)

Introduction

CPAP (continuous positive airway pressure) therapy is widely used to treat patients with hypoxemic respiratory failure to avoid the necessity of intensive care. The traditional CPAP therapy is delivered by an open configuration with some disadvantages such as high daily oxygen consumption, viral air contamination and high noise [1]. An alternative solution lies in an innovative system able to deliver CPAP therapy with a closed-loop breathing circuit [2]. The aim of this study is to evaluate the pressure performance of commercial devices able to deliver CPAP therapy, and to compare them with the innovative closed-loop concept performances, eventually aiming at an optimization of the pressure control in the closed-loop breathing circuit.

Methods

Three devices were tested: (1) a double flowmeter (DF, StarVent2, StarMed srl) that delivers a mixture of ambient air and oxygen used in combination with a positive end expiratory pressure (PEEP) valve to adjust CPAP level, (2) a device (iSleep, Breas Medical) for treating obstructive sleep apnoea (OSA) patients used in its standard open configuration and (3) in the novel closed-loop (CL) configuration. The CPAP devices were connected via a circuit to a lung simulator (TestChest V3, Organis Gmbh) and a flow analyser (FlowAnalyser Pro, IMT Analytics), and the therapy was delivered to a head phantom through the patient interface under normal operating conditions (DF and CL with a helmet – A and B3 respectively – and OSA with a full-face mask – B1). As a control, the OSA was also tested with the helmet interface (B2). All tests were performed using CPAP levels at 5 and 10 cmH_2O, simulating two pathological conditions normally treated with CPAP therapy: a post-surgery patient and an acute respiratory distress syndrome (ARDS) patient. Thirty-two tests were performed in total, measuring the pressure at the patient connection port.

Results

DF pressure oscillations (ΔP) result smaller than the OSA ones when used in all configurations (B1, B2 and B3) (Fig. 1). This could be caused by OSA pressure closed-loop control, which is based on a pressure measurement located inside the device itself. The distance from the interface may indeed induce a delay in pressure adaptations. The introduction of the helmet in the open configuration (B2) slightly reduces the oscillations with all the tested patients and CPAP levels (maximum reduction of 19%). On the contrary, closing the breathing circuit produces a ΔP increase since the exhaled gas is restrained to a large extent within the circuit.

Table 1 shows the PEEP values computed from the pressure trends. Compared to the set CPAP pressures, the DF imposes a higher PEEP, while the OSA device reaches PEEP values under the set ones, with worse performances when using a helmet due to greater leakage. When the post-surgery patient is treated with CL the PEEP value resulted very close to the set one.

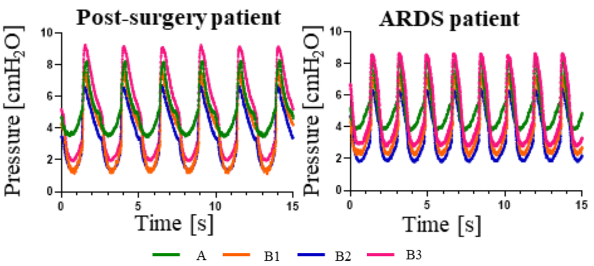

Figure 1: Comparison between pressure at the patient connection port in the four tested configurations during multiple breathing cycles.

CPAP level		Post-surgery A	B1	B2	B3	ARDS A	B1	B2	B3
5 cmH_2O	ΔP	4.9	6.8	5.5	7.4	4.5	5.4	4.7	5.9
	PEEP	5.3	3.8	2.4	5	5.6	4.3	3.7	4.4
10 cmH_2O	ΔP	4.9	7.2	6.5	7.4	4.7	6.9	5.8	6
	PEEP	10.4	9.4	8.4	10.1	10.2	9.1	7.5	8.7

Table 1: ΔP and PEEP obtained in the four tested configurations. ΔP is the difference between expiratory and inspiratory peaks.

Discussion

Preliminary results highlight the importance of the pressure control, with particular reference to the pressure measurement location. Getting closer to the interface would indeed better compensate for the pressure oscillations and the leakage. The helmet use helps in stabilizing the ΔP, also thanks to its greater internal volume, but induces a higher leakage. Finally, closing the breathing circuit may solve open issues in viral load dispersion and oxygen consumption, but it complicates the pressure stabilization, which must be considered a crucial aspect for future optimizations.

References

[1] Lucchini et al. Dimens Crit Care Nurs, 9(4):194-202,2020
[2] Cavaglià et al. Artif. Organs, 45(7):754-761, 2021

Acknowledgements

Research supported by DIVOC project (INFRA-P2).