DIAPHRAGM PACING DURING CONTROLLED MECHANICAL VENTILATION: PRE-CLINICAL OBSERVATIONS REVEAL A SUBSTANTIAL IMPROVEMENT IN RESPIRATORY MECHANICS

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INTRODUCTION
Positive Pressure Mechanical Ventilation (MV) is the standard modality of life support for critically ill patients in Intensive Care Units (ICU). However, delivering the required amounts of air using positive pressure can damage the lungs (ventilator-induced lung injury, VILI; ventilator-associated pneumonia, VAP) and causes rapid atrophy of the disused diaphragm muscle (ventilator-induced diaphragmatic dysfunction, VIDD; [1]). We hypothesized that electrically pacing the diaphragm to assist MV with more physiological Negative Pressure should lead to improved respiratory mechanics, reduce complications and help patients wean faster from MV.

METHODS
We conducted experiments on anesthetized pigs, mechanically ventilated in Volume Control Mode. Lungpacer™ prototype transvascular phrenic nerve stimulating electrodes were percutaneously inserted via the external jugular vein [2] and a proprietary system controlled the timing and intensity of diaphragm contractions.

Initially, with the animal fully supported on MV, airway flow, airway pressure, esophageal pressure and gastric pressure data were acquired in real time, stored and analyzed off-line to derive the basic respiratory mechanics parameters.

Subsequently, transvascular phrenic nerve pacing was started. Stimulation was delivered during the inspiratory phase of the ventilatory cycle with operator set stimulation amplitude, pulse width and frequency parameters. The signals specified above were acquired for analysis of the respiratory mechanics.

RESULTS
For every breath in which the diaphragm was paced during the MV inspiratory phase, a large reduction in the peak airway pressure was observed, when compared to every breath that was produced with MV alone. In the example shown in Fig. 1, pacing reduced the ventilator pressure by about 50%, while the tidal volume and airway flow remained largely unchanged.

The signals were analyzed to quantify changes in respiratory mechanics like Work of Breathing and Pressure-Time product.

Figure 1: Data from 3 breaths during MV only, followed by 3 breaths during MV + Pacing. A substantial reduction in peak airway pressure occurred immediately upon pacing (arrow); the airway flow and tidal volume remained largely unchanged.

DISCUSSION & CONCLUSIONS
We show here preliminary results of combining two opposite ventilatory modalities with beneficial effects in the respiratory mechanics of breathing. In critically-ill patients subjected to positive pressure mechanical ventilation, the respiratory mechanics can be optimized depending upon the condition of the patient’s respiratory neuromuscular system. Such a therapeutic intervention will not only reduce the risk of ventilator induced lung injury, but also protect the diaphragm from rapid disuse atrophy in patients subjected to mechanical ventilation and sedation. An additional benefit of pacing is in improving cardiovascular mechanics through the pumping action of the diaphragm in assisting venous return [3].

REFERENCES

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