

Optimizing the Triggering of Abdominal Neuromuscular Stimulation During Exhalation to Support Ventilation

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Rationale: VentFree™ is an investigational muscle stimulator (Liberate Medical) that applies neuromuscular electrical stimulation (NMES) to the abdominal wall muscles during exhalation (Te). The long-term goal of the device is to promote extubation in difficult-to-wean patients (McCaughey. Critical Care 2019;23:261). The trigger in the prototype (Trigger from Inhalation) fixes duration of stimulation to 70% of the duration of each preceding inhalation (Ti). In patients with small Ti:Te ratios or during bradypnea, we observed delays between end of stimulation and end of Te with the Trigger from Inhalation. To overcome this limitation, we have now tested a trigger based on expiratory flow (Trigger from Exhalation). Specifically, we hypothesized that compared to the Trigger from Inhalation, the Trigger from Exhalation would ensue a longer duration of stimulation during exhalation, irrespective of respiratory pattern. **Methods:** We developed the Trigger from Exhalation to turn on NMES 100 ms after the start of exhalation and turn it off when exhalation flow decreased to 20% of its peak value. Then, we compared the performance of the activation signal of Trigger from Exhalation against that of the Trigger from Inhalation using a flow simulator. The latter was set to deliver six different flow patterns (slow and fast decelerating, slow and fast sine, square, concave) with respiratory rates ranging from 4 to 40 BPM, and tidal volumes ranging from 0.25 to 1.50 L. The sensitivity (correctly triggered stimulations over total breaths), error rate (stimulations delivered at the wrong time (during inhalation) over total breaths), and delays between end of stimulation and end of exhalation of the two triggers were calculated. **Results:** Across all flows, respiratory rates and tidal volumes, the median sensitivity of the Trigger from Exhalation was greater than the Trigger from Inhalation: 100% (IQR 1%) vs. 92% (IQR 14%); $p < 0.001$. The median error rate of the Trigger from Exhalation was similar to the error rate of the Trigger from Inhalation: 0% (IQR 6%) vs. 0% (IQR 0%); $p < 0.001$. The median delays between end of stimulation and end of exhalation were smaller with the Trigger from Exhalation than with the Trigger from Inhalation: 0.020 s (IQR 0.038 s) vs. 0.776 s (IQR 0.449 s); $p < 0.001$. **Conclusion:** Trigger from Exhalation produced an activation signal that lasted for a longer portion of exhalation than the Trigger from Inhalation. The performance of the Trigger from Exhalation needs to be validated in human subjects. **Support:** VA Research, Liberate Medical LLC, NSF(#1632402)

This abstract is funded by: NSF

