Use of a Continuous Non-Invasive Respiratory Volume Monitor in Postoperative Cardiac Surgery Patients Before and After Endotracheal Extubation

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Introduction

Over half a million cardiac surgeries are performed in the United States annually. Despite the considerable amount of improvements made in postoperative care and monitoring, respiratory problems following extubation are the most significant cause of postoperative comorbidity in cardiac patients. While measurements of respiratory rate and volume, heart rate, mean arterial pressure (MAP), and TV (as well as other invasive monitoring systems) have been used to guide anesthetic and ventilatory interventions, both are inaccurate and many times unreliable. Patients undergoing median sternotomy surgery are generally mechanically ventilated postoperatively. However, due to the risk of postoperative respiratory compromise, early extubation may be desirable. Patients at an increased risk of respiratory compromise before extubation events occurred could markedly improve patient care and safety. Furthermore, while useful in intensive care settings, there are limitations to the invasive monitoring devices, such as the risk of complications associated with invasive monitoring, length of hospitalization, and cost. Therefore, a non-invasive Respiratory Volume Monitoring (RVM) system would be valuable.

Results

During mechanical ventilation, TV measured by the RVM strongly correlated with TV reported by the ventilator (r=0.79, Figure 2). This correlation was maintained during both mandatory ventilation (SVH) and spontaneous breathing with pressure support (SPS) modes. During episodes of spontaneous breathing, the relative accuracy of the ventilation data time points (only available at 15 second averages) introduced additional measurement variability when comparing the average TV and TVCP over a 30-second window. This variability persisted to be less than 15% of the measured TV. The intra-patient variability was found to be <15% of TVCP. In the first 30 minutes post-extubation compared to pre-extubation values (p<0.05), while RVM could not determine post-extubation status, it was highly accurate in identifying patients unable to support spontaneous breathing. The RVM system was able to accurately determine the patients who were able to support respiratory efforts (TV<20cm3) and those patients who required ventilatory support (TV>20cm3) during the first 30 minutes post-extubation, demonstrating the potential of the RVM system for assessing respiratory effort. This was observed in the bottom panel of Figure 4. Note that ROC levels by ABB accurately a 1 hour post-extubation were essentially the same as the pre-extubation (C-statistic range 0.81-0.84, p<0.05, Figure 4, Table).

Discussion

While intubated, RVM based TV and TVCP correlated well with CTO ventilator measurements in patients after median sternotomy. After extubation, RVM continuously reported TVmeasurements, which provided a non-invasive, quantitative assessment of respiratory competence. A pattern of MV and TV decrease during the first 15 minutes after extubation was noted in all patients. Subsequent recovery to pre-extubation levels within one hour as confirmed by POC, from arterial blood gas was noted in all patients. RVM showed distinct changes in TV and TV post-extubation while RRV showed no significant variations. Although no patients in this study required re-intubation, based on data from other studies and our own experience, we believe that RVM could be used to accurately screen patients who may need post-extubation support. While the RVM system was not specifically designed for neonates, it was able to accurately identify patients who were able to support respiratory efforts. Future studies are underway for neonatal cardiac surgical patients for early detection of respiratory failure for development of re-intubation protocols are ongoing.

Conclusions

- RVM can be used on patient’s post-median sternotomy using the modified position of the electrode
- RVM provides useful data on patients who are being paced with temporary pacing wires
- RVM provides a means to continuously and quantitatively monitor respiratory status in non-ventilated patients with the potential for improving postoperative outcomes. RVM is currently being studied for use in patients undergoing non-invasive ventilation or to trigger reintubation and improve patient safety.

Methods

Twelve patientsAge 69 ± 3.5 years, BMI 29 ± 5.8 kg/m2) were enrolled in an IRB approved protocol for monitoring respiratory status in the Tufts cardiosurgical unit (CTU). Invasive tracings were recorded from thoracic electrodes using an impedance-based RVM system (ResMed, Respiratory, Boston, MA). Invasive measurements were recorded in the CTU after cardiac surgery (6 coronary artery bypass, 4 valve replacements, 2 myocardectomies). All procedures were performed under general anesthesia and all patients arrived intubated and sedated. Ventilator (Puritan-Bennett BIPAP, CareFusion, MA) settings were determined based on both patient weight and initial to target SWR mode. The vertical portion of the RVM electrode assembly was positioned to the right of the sternum, approximately the right mid-axillary line, instead of the standard mediastinal placement (Figure 3). The system was capable of measuring tidal volume and minute ventilation for each breath, resulting in raw data from each breath onto the RVM system database. The Puritan-Bennett BIPAP ventilator did not support continuous respiratory tracking and as a result, respiratory data (MV, TV, and RR) were acquired only every 5 seconds from the ventilator. The RVM system based MV, TV, RR were calculated from continuous 15-second segments. Simultaneous recordings were collected from the ventilator prior to extubation. RVM data monitoring was continued until at least one post-extubation data was obtained.

Figure 2: Comparison of tidal volumes between RVM and the ventilator in this group the measurement is based on the RVM and the ventilator (defined as the number of measurements/second) our r=0.79, the precision (measured by the standard error) was 0.13, and the correlation accuracy (defined as the square of the correlation error) was 0.52, that the average time interval over which ventilation was compared was 0.65 minutes.

Figure 3: Example of sample ventilations from a representative patient (no in-slice, no epoch). Both TV and MV measurements increased over time after successful extubation (r=0.49).