Outcomes Associated with Implementing the Respiratory Knowledge Portal (RKP) into Daily ICU Rounds: a Retrospective Observational Trial

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Introduction

Weaning of mechanical ventilation is the process during which the work of breathing is progressively transferred from the ventilator back to the patient.[1] Failure to wean a patient off of a mechanical ventilator has been shown to prolong the length of time on a mechanical ventilator, prolong intensive care unit *(ICU)* length of stay *(LOS)*, and increase the incidence of Ventilator Associated Events *(VAEs)*.[2-7] The financial impact associated with prolonged mechanical ventilation is also quite substantial. Khan et al 2008 estimated the cost to be $625 per additional day in the ICU.[8] In addition, Zimlichman et al 2013 estimated the cost per VAE to be $41,000.[9]

In order to increase weaning success, societies such as the American Thoracic Society *(ATS®)* and the American College of Chest Physicians *(CHEST®)*, recommend specific weaning protocols which have been demonstrated in randomized controlled trials to reduce the length of time on a mechanical ventilator.[4,10] These recommendations include the daily use of spontaneous breathing trials *(SBT)*, continuous attempts to minimize sedation, and ventilator weaning protocols to decrease mechanical support. Adhering to these protocols have been shown to yield worthwhile results with average decreases in length of mechanical ventilation by 1 - 4.5 days and ICU length of stay by 1 - 3.7 days as well as a reduction in VAEs from 9.7% to 5.2%.[3-7] For an average sized hospital with 1,000 ICU patients per year, the estimated cost savings for reducing ICU LOS and VAEs ranges from $625,000 - $2,312,500 and $1,845,000 respectively. Therefore the total estimated cost savings is $2,470,000 - $4,157,500.

Introduction *(continued)*

However, clinician compliance with weaning protocols are not always so straightforward, and outside of these formally controlled trials, real-world evidence doesn't support these great results.[11-13] Factors that have been shown to cause difficulties adhering to protocols are coordinating cross-collaboration between clinical groups *(nurses, RTs, physicians, etc.)* and the absence of accountability resulting in variable practice within the institution. One potential solution is to integrate computerized technology, such as the Respiratory Knowledge Portal *(RKP) (Vyaire Medical, Mettawa, IL)*, into the weaning process in order to make weaning protocols visible across departments and allow managers to hold their staff accountable. It accomplishes this by inputting the institution's best practice weaning protocol into its system, which clinicians from all departments can log into. RKP then outputs near-time information related to the patient's ability to wean, adherence to weaning protocols, and gaps in practice. The objectives of this study were to compare the differences in intensive care unit *(ICU)* length of stay *(LOS)*, time spent on mechanical ventilation, compliance to SBT, and economic savings between non-protocolized weaning, protocolized weaning without computerized technology, and protocolized weaning with computerized technology *(ie: RKP)* at Medical City of Dallas Hospital.

Methods

This was a non-interventional, unblended pre-, post-design quality improvement project that was completed at Medical City Dallas between January 1, 2015 and December 31, 2016 to evaluate the Respiratory Knowledge Portal *(RKP)*. All mechanically ventilated patients in the MICU, SICU, and NVICU between January 1, 2015 and December 31, 2016 were included in the study. The project included three time periods *(Table 1)*: During the first three-month period *("Pre (No Protocol)")* standard of care was followed and no weaning protocol was implemented. For the next 9 months *("Pre (Protocol)")*, MC Dallas' best practice weaning protocol was initiated, but clinicians were blinded to RKP. For the final 12 months *("Post")*, clinicians used RKP to direct care and assist in following the implemented weaning protocol.

Kruskal–Wallis one-way ANOVAs were performed to compare the median ICU length of the stay *(LOS)*, ventilation durations, and compliance to SBT. Chi-square tests were performed to compare proportions between the three groups. Incidence of Ventilator Associated Events *(VAEs)* and Infection-related Ventilator-Associated Complications *(IVACs)* during the entire Pre period *(i.e., January 1 – December 31, 2015)* and Post period were compared using Chi-square tests. Estimated cost savings were determined based on the reduction in ICU LOS and VAE incidence. Specifically, we estimated a $625 reduction in variable costs per ICU day[8] and a $41,000 reduction per VAE avoided.[9] Annual saving were calculated based on an estimated 730 mechanically ventilated ICU patients per year.

Data are presented as median [25th, 75th percentile] unless otherwise indicated.

Overview of quality improvement project study periods

Period name	RKP blinded/unblinded	Weaning protocol?	Start date	End date	Number of patients
Pre *(No protocol)*	Blinded	No	January 1, 2015	March 31, 2015	51
Pre *(Protocol)*	Blinded	Yes	April 1, 2015	December 31, 2015	190
Post	Unblinded	Yes	January 1, 2016	December 31, 2016	328

Table 1

Results

A total of 615 patients were intubated during the study period. Forty patients had incomplete data and were excluded from the study. Therefore, 575 patients were included in the analysis. 51, 190, and 328 patients were intubated during the Pre *(No Protocol)*, Pre *(Protocol)*, and Post study periods, respectively. Each period had a similar proportion of males *(29 (57%), 110 (58%), and 181 (55%), respectively, p = 0.83, chi-square Test)*.

ICU length of stay (LOS) decreased to 11.2 days after RKP was unblinded in the Post period compared to 14.7 and 14.2 days in the Pre *(No Protocol)* and Pre *(Protocol)* periods, respectively (p = 0.035, Kruskal–Wallis one-way ANOVA, Figure 1). Furthermore, total duration spent on mechanical ventilation decreased from 4.1 and 2.7 days during the Pre *(No Protocol)* and Pre (Protocol) periods, down to 1.7 days in the Post Period *(p = 0.0059, Kruskal–Wallis one-way ANOVA, Figure 2)*. Reintubation rates were similar across the three study periods *(5.9%, 8.4%, and 6.7%, respectively, p = 0.71, chi-square test)*.

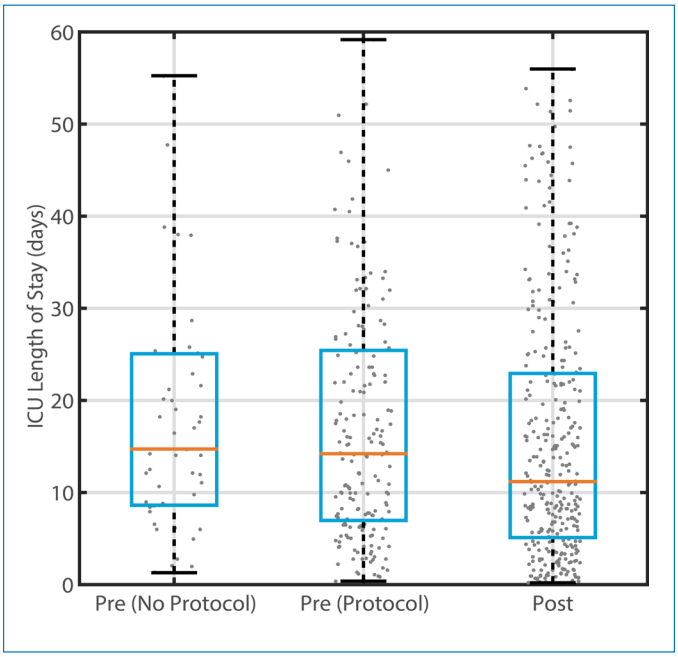

Figure 1. Comparison of ICU length of stay *(LOS)* for patients intubated during the Pre *(No Protocol)*, Pre *(Protocol)* and Post study periods. Gray markers represent individual patients. Median *(red horizontal lines)* ICU LOS were 14.7, 14.2, and 11.2 days during the three study periods, respectively, *(p = 0.035, Kruskal–Wallis one-way ANOVA)*. The 25th and 75th percentiles are depicted in blue.

To further investigate why patients in the Post period spent less time on the ventilator, we examined the spontaneous breathing trials in more detail. A larger proportion of patients had a successful first SBT in the Post period *(26.5%)* relative to the Pre *(No Protocol) (13.7%)* and Pre *(Protocol) (23.2%)* periods *(Figure 3)*. Further, the portion of SBT within the protocol period increased from 23.5% in the Pre (Protocol) period to 40.0% in the Post period.

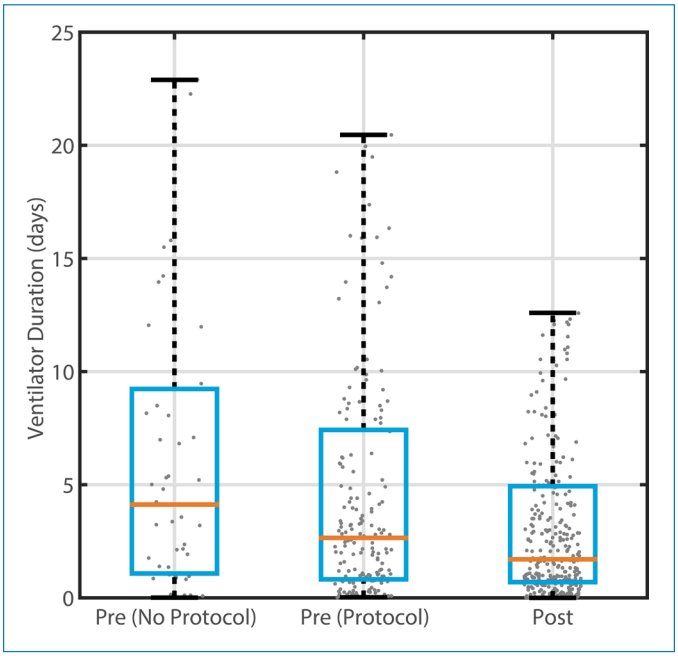

Figure 2. Comparison of duration of mechanical ventilation for patients intubated during the Pre *(No Protocol)*, Pre *(Protocol)* and Post study periods. Gray markers represent individual patients. Median *(red horizontal lines)* ventilator durations were 4.1, 2.7, and 1.7 days during the three study periods, respectively, *(p = 0.0059, Kruskal–Wallis one-way ANOVA)*. The 25th and 75th percentiles are depicted in blue.

The initial ventilator settings immediately after a patient was intubated were compared. The initial FiO_2 delivered to the patient immediately following intubation was higher during the Post period *(50.0 [41.5,63.4]%)* compared to the Pre *(No Protocol) (45.9 [40.0,60.3]%)* and Pre *(Protocol) (46.6 [40.2,53.0]%)* periods *(p = 0.0056)*. The initial PEEP settings were similar across the three study periods *(average: 5.4, 5.1, and 5.2 cmH_2O, respectively, p = 0.35)*. Further, the initial MV delivered to patients following intubation was

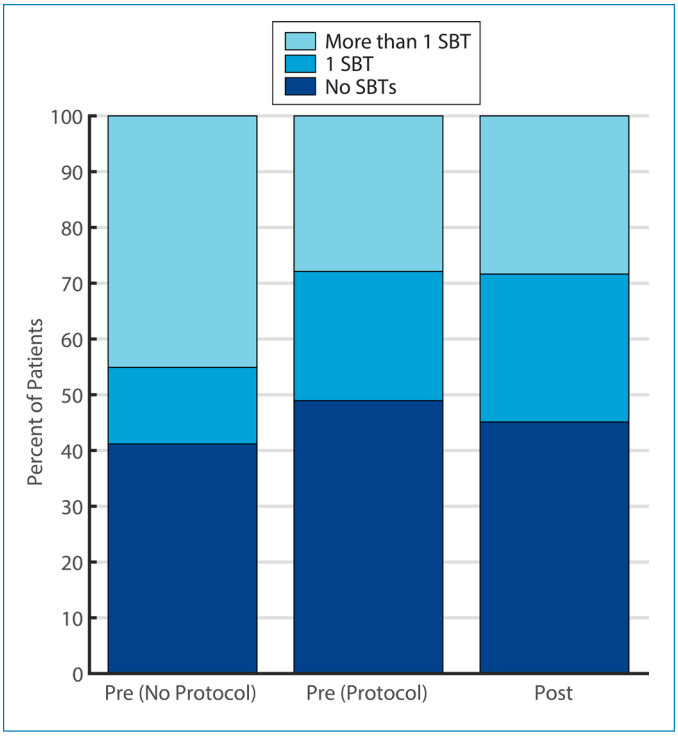

Figure 3. Portion of patients within each of the three study periods who had no spontaneous breathing trials *(SBT)*, exactly one SBT and more than one SBT. The percentage of patients whose first SBT was successful were 13.7%, 23.2%, and 26.5% for the three periods, respectively.

similar for the three study periods *(average: 9.0, 8.7, and 9.0 L/min, respectively, p = 0.20)*.

VAEs decreased from 40 *(i.e., 1 VAE per 6.0 patients)* during the Pre periods *(Protocol and No Protocol combined)* to 29 *(i.e., 1 VAE per 11.3 patients)* during the Post period *(p = 0.005)*. Further, IVACs decreased from 18 *(i.e., 1 IVAC per 13.4 patients)* during the Per periods to only 6 *(i.e., 1 IVAC per 54.7 patients)* during the Post period *(p = 0.0009)*.

From an economic standpoint, a decrease in ICU LOS of 3.5 days from the Pre *(No Protocol)* period to the Post period translates to an estimated savings of $2,190 per patient and an annual savings of $1,600,000. The reduction of VAEs from 40 to 29 results in an estimated savings of $451,000. Therefore, implementation of RKP would reduce annual hospital costs by an estimated $2,051,000.

Discussion

In this retrospective comparative study there were three major findings. First, the institution of a weaning protocol significantly reduced the total duration spent on mechanical ventilation *(4.1 days Pre (No Protocol) group vs 2.7 days Pre (Protocol) group)*, the ICU length of stay *(LOS) (14.7 days Pre (No Protocol) group vs 14.2 days Pre (Protocol) group)*, and the incidence of VAE and IVACs from 40 to 29 per year and 18 to 6 per year respectively. Second, compliance to the weaning protocol in a real world setting is challenging. This was demonstrated when only 23.5% of the Pre *(Protocol)* group complied to performing a SBT within the protocol period compared to 40.0% in the Post group. Third, the implementation of the Respiratory Knowledge Portal *(RKP)* improved protocol adherence *(40.0% Post group vs 23.5% Pre (Protocol) group)* and further reduced the total duration spent on mechanical ventilation *(1.7 days Post group vs 2.7 days Pre (Protocol) group)* and the ICU length of stay *(LOS) (11.2 days Post group vs 14.2 days Pre (Protocol) group)*. The implementation of RKP also resulted in significant cost savings. The 3.5 days reduction in ICU LOS translates to $2,190 per patient or $1,600,000 annually and the reduction in VAE results in $451,000 of savings. Therefore, the total annual cost savings is estimated to be $2,051,000.

"...an implementation of RKP would reduce annual hospital costs by an estimated $2,051,000."

Conclusion

The implementation of a computerized technology improved weaning compliance which substantially increased value for an average size hospital by reducing the incidence of VAE as well as the time on a mechanical ventilator and ICU LOS.

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