To Change Is to Improve

Around the world there has been a steady increase in the number of children discharged on home mechanical ventilation.[1-4] As expected, a concomitant increase in health care costs has also been observed.[5] Increased survival among infants with bronchopulmonary dysplasia (BPD) and increased interventions among infants with congenital abnormalities may be the reason why most of the increase has been seen in children < 4 y of age.[4,5] Children receiving mechanical ventilation at home and their families have unique needs while preparing for discharge from hospital to home. Standardizing the discharge process has been shown to reduce the hospital length of stay (LOS), but studies have not reported data on one of the first steps of the discharge process: transition to a portable home ventilator.[6]

In this month's issue of RESPIRATORY CARE, Willis et al[7] describe the results of a quality improvement initiative designed to standardize the transition of infants from an ICU ventilator to a portable ventilator for home use. This well-conducted retrospective analysis reports the 8-y experience of transitioning children to portable ventilators in an intermediate care unit. Only children < 3 y old were included, which led to overrepresentation of BPD and congenital airway/pulmonary indications for long-term mechanical ventilation. Fifty-five children were included in the analysis, 44% of whom had a diagnosis of BPD. Thirty-one of the children (56%) transitioned were from the neonatal ICU, and 19 (35%) were from the pediatric ICU. Pressure controlled synchronized intermittent mandatory ventilation using the Maquet Servo-i was the primary mode of ventilation, and the Vyaire LTV 1200 was the most commonly used portable ventilator. During the latter 4 y of the study period, a standardized protocol for transition was used. The protocol included comprehensive transition readiness criteria, detailed guidelines for the transition process, documentation, and monitoring requirements as well as criteria for discontinuation of the portable ventilator trial. The protocol also included documentation of the cause of failure of the portable ventilator trial. Primary outcome was the number of failed attempts to transition to a portable ventilator, with a successful attempt defined as demonstrating clinical stability (ie, no signs and symptoms of increased effort of breathing, patient-ventilator asynchrony, or escalation of care) for at least 14 d after transition to the portable ventilator. The baseline demographic variables between the before- and after-protocol groups were not significantly different. After excluding attempts that were associated with acute illness or elective procedures, there were 88 transition attempts in 27 subjects prior to the protocol versus 45 attempts in 28 subjects after the protocol was implemented. The mean ± SD number of failed attempts was reduced by more than half post-protocol (1.6 ± 1.1 pre-protocol versus 0.6 ± 1.1 post-protocol; $P = .005$). For subjects in the neonatal ICU, an even bigger reduction in failed attempts was noticed (3 ± 3.1 pre-protocol versus 0.8 ± 1.3 post-protocol; $P = .02$). Statistically nonsignificant reductions in failed attempts were observed in subjects situated in ICUs other than the neonatal ICU, but this is likely due to the small sample and varying diagnoses in children from other ICUs. The mean length of time from a failed initial attempt to a successful attempt and the total LOS were also significantly reduced post-protocol. While many variables affect LOS, including portable ventilator training and social determinants, at least some credit must go to the institution of a transition protocol.

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The transition process to a portable ventilator is complex and involves multiple providers along with the family. The process involves the selection of the right patient to be transitioned at the right time, using size-appropriate equipment and ventilator settings that best approximate the ICU ventilator. It follows that failure to transition is related to patient factors and equipment factors. Although the sample size for subpopulation analysis was small, the study by Willis et al[7] indicates that infants with BPD have a higher propensity to fail the initial transition and that the use of a systematic approach to transition is likely to have the most benefit in this patient group. Infants with BPD, compared to children with other diagnoses requiring home mechanical ventilation, are likely to have worse lung disease and to require higher settings, are likely to

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have other factors contributing to respiratory failure (eg, control of breathing issues, pulmonary hypertension, or shunts), and are likely to be smaller. Due to their smaller size, infants with BPD require smaller tidal volumes, and errors of tidal volume measurements and leaks around the tracheostomy are likely to have greater impact in this subgroup of patients. Infants with BPD requiring long-term mechanical ventilation also often have varying degrees of tracheomalacia, air trapping, and intrinsic PEEP. These factors combined with the generally higher resting breathing frequencies result in ineffective triggering and ventilator-patient asynchrony. Further, most portable ventilators are approved for use with children weighing $>$ 5 kg. Many infants requiring home ventilation weigh less than this, and a recent study of 2 portable ventilators (LTV 1200 and Trilogy 202) reported significant variability in the percent of triggered breaths, which varied from 45% to 100%.[8] Portable ventilators have different triggering algorithms, triggering mechanisms (eg, close to airway or in the ventilator), types of circuits, leak-compensation algorithms, and available modes of ventilation. In trying to match the ICU ventilator settings and patient-ventilator interactions on the ICU ventilator, a good understanding of the ventilator being used and the patient's condition is essential. With so many variables in play, standardizing the process of transition to portable ventilator seems like the most logical thing to do. In their study, Willis et al[7] standardized not only the process but also the equipment and the mode of ventilation before and after the transition. The benefits of this approach seem obvious and are demonstrated by the resulting reduction in failure to transition and LOS. There are potential drawbacks to be considered, too. One size does not fit all; there will be some patients who may be better served with a different ventilator or a different mode of ventilation. The type of equipment used may also depend on insurance, local health care systems, and providers' familiarity with the equipment. Willis et al[7] are to be commended for reporting the impact of their quality improvement project, but more studies in different health care systems using different portable ventilators need to be done to understand how replicable these findings are. Further research should also explore using larger sample sizes and the impact of the primary diagnosis on the transition process.

Our own experience in the neonatal ICU has paralleled that of Willis and co-workers.[7] However, this has not been the case in our pediatric ICU. Differences may lie in the more accepted use of cuffed endotracheal tubes in such patients particularly if the main reasons for prolonged ventilation are chronic lung or obstructed airways diseases.[9] Here, the initial tracheostomy is cuffed and the transition to a home ventilator is predominantly made with the cuff inflated to reduce leaks around the tube and anxiety-provoking alarms. Once the patient is stable, the tracheotomy tube is switched to an uncuffed tube. It is also possible that another factor is the presence in our pediatric ICU of a full-time intensivist who plays the important role of the physician in the transition rather than a necessarily part-time pulmonologist.

Willis et al[7] also reported the consequences of not having a standardized process (ie, the impact of increased failure of transitions to portable ventilator). These include increased time to successful transition and increased overall LOS. There are likely to be physiologic derangements associated with failed transition, such as increased effort of breathing, increased sedation requirement, unnecessary investigations (eg, workups for infections), parental distress, and possibly parental loss of trust in the treatment team. It is therefore essential that any quality improvement program include the measurement of these patient-centered outcomes while including the family as an integral part of the process.

The Institute of Medicine report titled *To Err Is Human* was a call to improve the quality of care and to reduce errors by creating safety systems in health care organizations.[10] Transitioning a ventilator-dependent child from an ICU ventilator to portable home ventilator is a relatively high-risk procedure and can expose the child to adverse events, especially when the transition is unsuccessful. Creating a standardized process for such transitions is therefore doing the right thing and doing it the right way.[11]

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REFERENCES

1. Gowans M, Keenan HT, Bratton SL. The population prevalence of children receiving invasive home ventilation in Utah. Pediatric Pulmonol 2007;42(3):231-236.
2. Graham RJ, Fleegler EW, Robinson WM. Chronic ventilator need in the community: a 2005 pediatric census of Massachusetts. Pediatrics 2007;119(6):e1280-e1287.
3. Park M, Jang H, Sol IS, Kim SY, Kim YS, Kim YH, et al. Pediatric home mechanical Ventilation in Korea: the present situation and future strategy. J Korean Med Sci 2019;34(42):e268.
4. Paulides FM, Plötz FB, Verweij-van den Oudenrijn LP, van Gestel JP, Kampelmacher MJ. Thirty years of home mechanical ventilation in children: escalating need for pediatric intensive care beds. Intensive Care Med 2012;38(5):847-852.
5. Benneyworth BD, Gebremariam A, Clark SJ, Shanley TP, Davis MM. Inpatient health care utilization for children dependent on long-term mechanical ventilation. Pediatrics 2011;127(6):e1533-e1541.

6. Baker CD, Martin S, Thrasher J, Moore HM, Baker J, Abman SH, et al. A standardized discharge process decreases length of stay for ventilator-dependent children. Pediatrics 2016;137(4):e20150637.
7. Willis LD, Lowe G, Pearce P, Spray BJ, Willis R, Scott A, et al. Transition from an ICU ventilator to a portable home ventilator in children. Respir Care 2020;65(12):1791-1799.
8. DiBlasi RM, Crotwell DN, Poli J, Hotz J, Cogen JD, Carter E. A pilot study to assess short-term physiologic outcomes of transitioning infants with severe bronchopulmonary dysplasia from ICU to two subacute ventilators. Can J Respir Ther 2018;54(1):6-11.
9. Newth CJ, Rachman B, Patel N, Hammer J. The use of cuffed versus uncuffed endotracheal tubes in pediatric intensive care. J Pediatr 2004;144(3):333-337.
10. Institute of Medicine Committee on Quality of Health Care in America. To err is human: building a safer health system. Kohn LT, Corrigan JM, Donaldson MS, editors. Washington, DC: National Academies Press; 2000.
11. U.S. Department of Health and Human Services, Agency for Healthcare Research and Quality. Your guide to choosing quality healthcare: a quick look at quality. Available at: https://archive.ahrq.gov/consumer/qnt/qntqlook.htm. *Accessed October 8, 2020.*