# Less Complication When Calculating Duration? Evaluating the Accuracy of the LTV-1000 Cylinder Duration Calculator Feature

Transporting critically ill patients has become a common occurrence in the work life of most respiratory therapists. Roentgenograms, the mainstay of diagnostic tools, have been joined by other diagnostic tests and interventions that seemed exotic a couple of decades ago. As with any form of technology, the extraordinary becomes the routine, the routine becomes the expected, and the expected becomes the standard. The new standards for diagnosis and treatment seem to translate to more patient transporting, including those requiring mechanical ventilatory support. Fortunately, mechanical ventilation has not been left behind in the technical evolution. The new generation of transport ventilators are no longer mechanized manual resuscitators; they are now capable of providing ventilatory support with features equal to many "bedside" critical care ventilators.

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Arguably, the key component for safe patient transport is preparation. A savvy therapist preparing to transport a ventilator patient knows never to depart on a transport without ensuring an adequate oxygen supply. Thoughts such as "Is one cylinder enough? Will I run out of gas if there is a delay? Maybe I'll take an extra cylinder just in case" are part of the mental dialogue. It is best to plan for the worst-case scenario, and determining how many cylinders are needed is critical to the planning process. That being said, wouldn't it be nice to push a button and let the ventilator do some of the work of planning for you? In this issue of RESPIRATORY CARE, Blakeman et al[1] report results from a bench study evaluating a new feature of the Pulmonetic Systems LTV-1000 ventilator series that calculates cylinder duration.

Cylinder duration is a function of initial gas volume and rate of gas consumption. The LTV-1000 feature performs a calculation based on input by the practitioner (cylinder size and pressure) and the ventilator settings (primarily fraction of inspired oxygen [$F_{IO_2}$] and minute ventilation [$\dot{V}_E$]) at the time of the calculation. Blakeman and colleagues compared the actual cylinder duration to the expected duration obtained by calculations performed manually and those via the feature of the ventilator. The results showed that the ventilator-calculated values closely correlated with the manual calculations. However, both values underestimated the actual cylinder duration by approximately 12%. Blakeman and colleagues tested several combinations of settings, including high versus low positive end-expiratory pressure, and pressure-control ventilation versus volume-control ventilation, and showed no effect on cylinder duration. They also confirmed that the ventilator's calculator uses actual, not set $\dot{V}_E$ when determining duration. Blakeman et al also noted that when a patient's respiratory rate increases after the initial calculation is made, the new recalculated value is indeed shorter in duration.

How might practitioners incorporate this information into practice when preparing for transport? Can one assume, based on the Blakeman et al findings, that there will always be "room to breathe" when it comes to the duration of an E cylinder? Would the decision not to include a reserve E cylinder on a transport be based on the information from the LTV-1000's automatic calculation? The answer is probably no. What the study suggests is that the ventilator calculation could be considered just as reliable as a manual calculation. For those leery of either the ventilator or their own calculations, the correlation shown by Blakeman et al could support using either method as a double check, or mini quality-assurance test of the practitioner's assessment of cylinder duration.

The study does well to point out several potential limitations of the calculator function. The authors emphasize that if $\dot{V}_E$ was not stable then the ventilator's calculation was no longer reliable. In addition, if either $F_{IO_2}$ or $\dot{V}_E$ changes after the calculation, gas consumption will change and so will the actual cylinder duration. This finding is consistent with the cautionary reminder provided in the LTV-1000's operator manual,[2] where the manufacturer notes that "variations in the patient's $\dot{V}_E$, inspiratory-expiratory ratio, and/or ventilator setting changes or equipment status (ie, circuit leaks) affect the consumption rate of oxygen." The manual also includes a warning that the information obtained from the feature is to be used for reference purposes only and recommends that a back-up cylinder be available at all times. Therefore, this is not a defect in the performance of the feature but an anticipated outcome of changing $\dot{V}_E$ or $F_{IO_2}$ after the initial calculation, and in the scheme of things, a manual calculation will be affected in a similar manner because both are static measurements. This is important, especially if the patient is not completely sedated and $\dot{V}_E$ increases as a result of the transport or $F_{IO_2}$ is increased because of patient decompensation. The authors do suggest that the calculation could be repeated during transport to reevaluate gas supply.

Another factor that may lead to variation between calculated and actual cylinder duration is accurate determination of the volume of gas in the cylinder, particularly in determining the true cylinder fill volume and cylinder pressure. As noted earlier, the calculation is based on user input of maximum fill volume of a given cylinder and the cylinder pressure at the time of the calculation. Cylinders are labeled to indicate the amount of gas in the cylinder, yet they can be overfilled by as much as 10%. As pointed out in the study, there was always more gas in the cylinder than anticipated, but how much more was not known until the cylinder expended all of its contents during testing. Potential cylinder overfill could have accounted for a significant amount of the underestimation of duration. This issue can be further complicated when entering cylinder pressure. Unfortunately, determining cylinder pressure becomes less precise when rounding off pressure increments to the closest 100 psi, or, worse yet, the gauge indicates degrees of fullness with no numeric information.

In review of the LTV-1000's operator manual we read that the ventilator will default to a preset value of 622 L, although the user can enter the appropriate value. Blakeman et al state that their findings varied by 26% from the finding of a previous report.[3] That study[3] used a cylinder volume factor of 660 L, which was smaller than the value of 697 L used by Blakeman. This may have played a role in the difference in the findings between the 2 studies, although it shouldn't have accounted for more than a 5–6% difference. More importantly, it does suggest that there appears not to be a standard value for an E cylinder and that defaulting to the lower 622 L seems like a prudent value. In the end, is an overly full cylinder a problem? Not necessarily, as long as the practitioner doesn't rely on there being an extra 10% in the cylinder.

In contemplating the findings of the Blakeman et al study one might pose the question, why is this gas duration function incorporated in the first place? Arguably, the feature is intended to increase patient safety during transport. The feature in itself may not dictate the exact needs of the transport, but can provide opportunities to the practitioner to create transport scenarios and gather information prior to initiation. Using the calculation feature and a test lung, the practitioner can review trends or anticipate increases in minute ventilation or $F_{IO_2}$ and gather information in a controlled fashion prior to connecting the ventilator to a patient. Although this type of preparation may not be needed for every transport, it may prove to be an extremely valuable piece of information for patients who are unstable or have high ventilatory requirements.

Although previous studies of patient transport have reported that unwanted or unexpected events can occur,[4,5] few report empty cylinders as the cause for the patient deterioration. Is the reason for perceived lack of reporting mishaps due to low cylinder pressure in the literature because it is just second nature for the conscientious clinician to inherently monitor cylinder pressure, or is it because no one wants to admit that they have "run out of gas"? With the growing emphasis on developing, assessing, and promoting "cultures of safety,"[6] tools should be used to enhance, not replace, the clinician's need to employ their skills of observation and monitoring while transporting patients. Promoting a culture of safety involves adopting a glossary of patient safety terms that will facilitate reporting and process-improvement initiatives.[7] In a culture of safe practices built on skilled and knowledge-based behavior, events such as running out of compressed gas on a patient transport could be classified as a "lapse." A lapse can be defined as a skill-based failure of knowing what to do, failing to do it, omitting a step, or losing one's place in a process—all failures of omission. Caregivers should strive to develop processes to neutralize such lapses in an attempt to minimize unwanted events or mishaps, as these events are arguably preventable.

Lack of preparation and communication among members of the transport team has been shown to be a preventable cause of unsuccessful transports.[5] A focus in the safety culture is to increase the level of communication between members of the patient's health-care team.[8] Knowing how long the cylinder should last is optimal, but is not that helpful if the length of the trip is not understood. Communicating within the transport team and personnel at the destination regarding what is involved in the move and what resources are available at the destination provide details vital to the successful plan. While a dedicated team may be assembled or preferred, it does not need to be mandated in order to successfully transport the mechanically ventilated patient. Safe and successful transport teams include skilled clinicians who move in a coordinated fashion throughout the course of the transport. It also dictates that staff responsible for the ventilator should be aware of the machine's operation and communicate any potential challenges in its use to other members of the transport team.

As clinicians, we know that we should monitor the patient, not the equipment, yet the technology and equipment can alert us before the patient shows signs of distress. Monitoring guidelines are provided from a variety of professional organizations.[9,10] Guidelines often refer to the physiologic and patient variables to monitor and essential equipment to use, such as electrocardiograph, yet few guidelines specifically refer to monitoring the oxygen supply.[11]

It seems reasonable to include this in future versions of patient transport guidelines. It might also be suggested that personnel maintaining ventilatory equipment adopt standard operating procedures that detail standards and acceptable variability for the equipment that they service, in an effort to lessen the impact of variation in the clinical setting.

It seems like it was only a few years ago that we relied on hand-held calculators and small alarms atop giant bellows to monitor patients. The Blakeman et al study sheds light on a useful and reliable new tool provided through an application of the LTV-1000. A prudent practitioner can use this option when evaluating the needs of the patient prior to transport, in order to understand what provisions are needed. Readers of the study should consider a few things when contemplating the use of this feature. Patients should be evaluated on the transport ventilator prior to the actual transport, to ensure that it will adequately support the patient, and to give the practitioner an opportunity to calculate the compressed gas needs. The information gathered from the pre-transport evaluation should be compared to the documented $\dot{V}_E$ to understand if the evaluation is a snapshot in time, or consistent with the needs of the patient. The nature and duration of the transport should be considered for its potential effect on the patient's breathing pattern and for unexpected delays that could lengthen the transport process; they can thus be anticipated and planned for in advance. We welcome new advances in technology and all that they offer, with the caveat that they are no replacement for the training and experience of a skilled practitioner.

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**REFERENCES**

1. Blakeman TC, Rodriquez D, Branson RD. Accuracy of the oxygen cylinder duration calculator of the LTV-1000 portable ventilator. Respir Care 2009;54(9):1183-1186.
2. Innovations for life: LTV series ventilator operator's manual. Minneapolis: Pulmonetic Systems.
3. Chipman DW, Caramez MP, Miyoshi E, Kratohvil JP, Kacmarek RM. Performance comparison of 15 transport ventilators. Respir Care 2007;52(6):740-751.
4. Doring BL, Kerr ME, Lovasik DA, Thayer T. Factors that contribute to complications during intrahospital transport of the critically ill. J Neurosci Nurs 1999;31(2):80-86.
5. Papson JPN, Russell KL, Taylor DM. Unexpected events during the intrahospital transport of critically ill patients. Acad Emerg Med 2007;14(6):574-577.
6. Nieva VF, Sorra J. Safety culture assessment: a tool for improving patient safety in healthcare organizations. Qual Saf Health Care 2003; 12(ii):17-23.
7. Battles JB, Lilford R. Organizing patient safety research to identify risks and hazards. Qual Saf Health Care 2003;12(ii):2-7.
8. Kirk S, Parker D, Claridge T, Esmail A, Marshall M. Patient safety culture in primary care: developing a theoretical framework for practical use. Qual Saf Health Care 2007;16(4):313-320.
9. Warren J, Fromm RE Jr, Orr RA, Rotello LC, Horst HM; American College of Critical Care Medicine. Guidelines for the inter-and intrahospital transport of critically ill patients. Crit Care Med 2004; 32(1):256-262.
10. American Association for Respiratory Care. Clinical practice guideline. In-hospital transport of the mechanically ventilated patient–2002 revision & update. Respir Care 2002;47(6):721-723.
11. Dunn M, Gwinnutt C, Gray AJ. Critical care in the emergency department: patient transfer. Emerg Med 2007;24(1):40-44.