Resisting Resistance Is Not Futile

Rob Graham, R.R.T./N.R.C.P.

I dedicate this column to the late Dr. Andrew (Andy) Shennan, the founder of the perinatal program at Women's College Hospital (now at Sunnybrook Health Sciences Centre). To my teacher, my mentor and the man I owe my career as it is to, thank you. You have earned your place where there are no hospitals and no NICUs, where all the babies do is laugh and giggle and sleep.

"Resistance (R) and Compliance (C) determine a system's time constant (τ); as they increase, τ increases, and as they decrease τ decreases."

Resistance (R) and Compliance (C) determine a system's time constant (τ); as they increase, τ increases, and as they decrease τ decreases. In mechanical ventilation, τ determines the point at which the volume entering the lung can no longer be delivered entirely, and the point at which volume delivered to the lung can no longer completely escape.

Each component of the system has a τ associated with it. We cannot measure differences in C between alveoli nor differences in R between airways, but we know that R increases exponentially as airway diameter decreases. The best we can do is estimate an average for the system and watch for signs of gas trapping, such as hyperinflation and inadvertent PEEP. One must exercise caution when assessing hyperinflation because it may be from too much mean airway pressure (MAP) or gas trapping resulting from an insufficient MAP. It is not an exact science, and warnings come after the fact.

While relatively low C, the endotracheal tube (ETT) has a fixed and calculable R for any given pressure and flow. It is a source of increased R simply because the ETT inner diameter is smaller than that of the airway in which it sits, and it effectively increases anatomical dead space due to its length. When considering R, we rightly focus on airway diameter, but R also increases linearly as ETT length increases and flow rate increases.

As our patient population becomes ever smaller, the risk of gas trapping increases, exacerbated by smaller ETTs. R associated with a 2.0 mm ETT is roughly triple that of a 2.5. Once stocked for rare emergencies, these small tubes are now routinely used in some units. The R of the 5 Fr catheters required to suction a 2.0 mm ETT is so high that the physical passage of the catheter is likely more effective at clearing the tube than removing secretions, especially if secretions are viscous.

Secretions in the ETT itself or the conducting airways also increase R and may result in localised gas trapping due to a ball valve effect. At the bedside, a caregiver may report suctioning scant secretions yet observe a marked improvement in ventilation after doing so; it takes very few secretions in a tiny airway to interfere with ventilation. The lack of observable secretions in the catheter may lead to less suctioning, which may not be helpful. Additionally, the high R of the catheter increases the time required to get secretions up at a given pressure, and a quick pass down the ETT and out may not be effective.

"The lack of observable secretions in the catheter may lead to less suctioning, which may not be helpful. Additionally, the high R of the catheter increases the time required to get secretions up at a given pressure, and a quick pass down the ETT and out may not be effective."

We cannot change the laws of physics, but in clinical practice, we can take steps to reduce R. Making an ETT as short as possible is one, and although this does not have a significant effect on R, it also decreases dead space, thus increasing ventilatory efficiency. Proper ETT sizing is also essential, and the most appropriate size should be chosen whenever possible.

Beyond the above mitigations, the tools available to clinicians are limited by available ETTs. Here not all are created equal. For instance, at least one ETT is available with a smaller outer diameter for a given size than others on the market: the Intube® from Intersurgical® (1). Decreasing the outer diameter may allow a larger inner diameter ETT to be placed and reduce the need for a 2.0 ETT. It does, however, not address the tube's inner diameter.

Quite some time ago, I listened to a talk at what was formerly known as the "Snowbird" conference. The presentation was about

a different kind of ETT with thin walls reinforced with a steel coil. The design was such that a 2.5 mm ETT had the same inner diameter as a standard 3.0 mm. The presenter was puzzled about the lack of demand given the product's superiority, despite its higher cost. It was the Kolobow tube. A study comparing a 2.5 Kolobow ETT to a conventional 2.5 one found the Kolobow ETT had 59% less R, and that work of breathing was reduced by 45% (2). These findings are remarkable and predictable, given the physics behind the resistance. Another study showed improved ventilatory efficiency. (The tube used in the latter study was not identified as a Kolobow tube but did fit the description) (3).

"A study comparing a 2.5 Kolobow ETT to a conventional 2.5 one found the Kolobow ETT had 59% less R, and that work of breathing was reduced by 45% (2). These findings are remarkable and predictable, given the physics behind the resistance. "

At the time of this presentation, a 23-week post-menstrual age (PMA) infant was rarely offered resuscitation (indeed, resuscitation was actively discouraged), nor were those weighing less than 500 grams. (I recall tiny babies being weighed before any active resuscitation commenced). Fast forward to the present times, and this is no longer the case. Ventilating the "nano-premie" may require inserting a 2.0 mm ETT with all its inherent problems. Were a 2.0 mm ETT available with a 2.5 mm ETT's inner diameter, ventilation and suctioning would be vastly easier.

Dr. Kolobow died in 2018 and was instrumental in developing many medical devices, including ECMO (4) and a unique ETT that did not require suctioning (5). It would be a real shame if the Kolobow ETT is lost with him.

"Other than the ETT, the choice of ventilation mode impacts the effects of R, namely high-frequency jet ventilation (HFJV). The physics behind the jet's delivery of fresh gas flow, along with an inspiratory to an expiratory ratio of up to 1:12, reduces (but does not eliminate) the likelihood of R-induced gas trapping."

A good motto is "All tiny babies are either gas trapping or are about to." Other than the ETT, the choice of ventilation mode impacts the effects of R, namely high-frequency jet ventilation (HFJV). The physics behind the jet's delivery of fresh gas flow, along with an inspiratory to an expiratory ratio of up to 1:12, reduces (but does not eliminate) the likelihood of R-induced gas trapping. Comparing ventilator set PEEP with that measured by the jet helps the clinician identify when gas trapping is occurring; jet measured PEEP approaching ventilator set PEEP indicates gas trapping or imminent gas trapping. I believe HFJV is the mode of choice for ventilating the smallest babies.

"Using a 2.5 mm ETT as a bridge between the LifePort® and the smaller ETT is easy to do and is also more secure. I would be happy to send a short video clip demonstration to anyone unsure of how this is done."

Just as there once was no 3.0 LifePort®adapter for the Bunnell LifePulse® jet ventilator, currently, there is no 2.0 adapter available. Clinicians shoehorned a 3.5 LifePort® adapter into a 3.0 ETT before the 3.0 adaptor was available. Using a 2.5 LifePort® in a 2.0 ETT is a more significant challenge as it is more difficult to dilate the tube sufficiently to accommodate the larger size. In my limited experience doing so, I have found it is easily inadvertently disconnected. Using a 2.5 mm ETT as a bridge between the LifePort® and the smaller ETT is easy to do and is also more secure. I would be happy to send a short video clip demonstration to anyone unsure of how this is done.

Where HFJV is not available, avoiding higher frequencies when using high-frequency oscillatory ventilation (HFOV) and ensuring optimal inflation with appropriate MAP gives more time for gas to exit the lung while maintaining airway patency reduces R. What the best choice of mode to ventilate tiny babies remains a topic of controversy and debate. Nevertheless, in this author's opinion, conventional ventilation makes it unsuitable for tiny babies. To paraphrase, "It's the resistance, stupid!"

"Where HFJV is not available, avoiding higher frequencies when using high-frequency oscillatory ventilation (HFOV) and ensuring optimal inflation with appropriate MAP gives more time for gas to exit the lung while maintaining airway patency reduces R. What the best choice of mode to ventilate tiny babies remains a topic of controversy and debate."

This is not a product endorsement or recommendation.

References:

1. https://pubmed.ncbi.nlm.nih.gov/9034264/
2. https://pubmed.ncbi.nlm.nih.gov/9118667/
3. https://en.wikipedia.org/wiki/Theodor_Kolobow
4. ttps://link.springer.com/article/10.1007/s00134-006-0268-5

Disclosures: The author receives compensation from Bunnell Inc for teaching and training users of the LifePulse HFJV in Canada. He is not involved in sales or marketing of the device nor does he receive more than per diem compensation. Also, while the author practices within Sunnybrook H.S.C. This paper should not be construed as Sunnybrook policy per se. This article contains elements considered "off label" as well as maneuvers, which may sometimes be very effective but come with inherent risks. As with any therapy, the risk-benefit ratio must be carefully considered before they are initiated.

NT

Corresponding Author

Rob Graham, R.R.T./N.R.C.P.
Advanced Practice Neonatal RRT
Sunnybrook Health Science Centre
43 Wellesley St. East
Toronto, ON
Canada M4Y 1H1
Email: rcgnrcp57@yahoo.ca
Telephone: 416-967-8500