In 1909 Jackson presented his tracheotomy technique to the Eastern Section of the American Laryngological, Rhinological and Otological Society. His technique would become the foundation of the tracheostomy, a procedure that would ultimately become widely utilized during the polio epidemic of the early 1900s. In modern surgical practice, Jackson’s open tracheostomy is still used but percutaneous dilatational tracheostomy (PDT) is now also a common method. First described by Ciaglia in 1985, PDT has now become widely accepted due to its relative ease, low cost, and low complication profile.

Initially developed as a technique to primarily relieve upper airway obstruction, in current medical practice, tracheostomy now plays a role primarily in those patients requiring prolonged mechanical ventilation for interstitial inflammatory processes. The indications for tracheostomy are varied; however, the most common indications are adult respiratory distress syndrome and atrophy of the respiratory musculature such as in traumatic brain injury and spinal cord injury. In appropriately selected patients, tracheostomy will improve quality of life and patient comfort. This is in part due to a decreased need for sedation and analgesia and earlier mobility. The clinical benefits of tracheostomy are thought to be realized because of altered airway mechanics including decreased work of breathing and decreased airway resistances.

In their study effect of tracheostomy on work of breathing: Comparison of pre- and post-decannulation, Villalba et al. seek to address the question of work of breathing (WOB) as it is affected by tracheostomy. Although the idea that tracheostomy and endotracheal intubation impacts the WOB is certainly not novel, controversy exists in the literature as to the extent of the effect and how WOB varies by tracheostomy size.

The authors of this article studied WOB in 8 patients during the decannulation process at an LTAC facility and compared WOB in 4 distinct circumstances. Consecutive patients that qualified the decannulation protocol of the LTAC facility were included in the study. WOB measurements were taken using an esophageal balloon and a flow sensor attached to either an oro-nasal mask or the tracheostomy itself. The investigators studied WOB in: (1) Patients breathing through the tracheostomy with an inflated cuff (2) through the upper airway with a deflated and occluded tracheostomy (3) through the upper airway with a cuffless tracheostomy and (4) decannulated with an occlusive dressing over the stoma.

Similarly to Chadda et al., the authors found that bypassing the upper airway with a tracheostomy decreases the work of breathing. The authors concluded that decannulation, restoring a patient’s normal airway anatomy, increases WOB. The role of the anatomical dead space in the upper airway is controversial. The intuitive conclusion is that restoring the upper airway increases anatomic dead space, but this has been challenged by Joseph et al. who concluded that there is no decrease in dead space ventilation following tracheostomy. What is much more likely is that intrinsic “PEEP” generation from upper airway resistance after decannulation is likely the major contributor to this increased WOB.

The recognition of the changes in WOB is important, but understanding its impact on patient outcome is of much greater importance. Thinking purely in terms of WOB, in patients with compromised gas exchange and deconditioned respiratory muscles, early tracheostomy placement be of benefit by decreasing the amount of support needed from the ventilator. The timing of tracheostomy, early versus late, has been one of the most controversial topics when taking care of a patient with acute respiratory failure requiring prolonged intubation. As such, tracheostomy timing has been the focus of several large randomized controlled trials and meta-analyses. An analysis of 109 ICUs found that the median tracheostomy time is 9 days. Three other, large, recent, and well-designed studies have contributed greatly to clinical knowledge regarding tracheostomy timing. Terragni et al. randomized 419 patients to tracheostomy following either 6-8 days (early) or 13-15 days (late) of mechanical ventilation. Early tracheostomy had no effect on the prevalence of pneumonia. Early tracheostomy did however, shorten duration on the ventilator, and decrease ICU length of stay. In 2011 Trouillet et al., in a randomized study, found early tracheostomy
was associated with less sedation, less antipsychotics and increased mobility.\textsuperscript{[7]} Most recently in 2013, The TracMan Randomized Trial in the United Kingdom randomized patients to early tracheostomy (1-4 days) or late tracheostomy (>10 days). The investigators found no difference in mortality or ICU and hospital LOS.\textsuperscript{[17]} Taken together, these trials demonstrate that early tracheostomy may not decrease infectious complications or decrease mortality but may have positive effects on ventilator dependence duration, sedation and ICU LOS. The current work of Villalba et al. further supports this notion under the guise of decreased WOB.

On the back end, at time of decannulation, WOB considerations are equally as important. Restoration of the upper airway resistance, or intrinsic peep, is important to consider. In clinical practice, decannulation often appears to be an afterthought and perhaps should be revisited more aggressively as patients recover from critical illness. Although patients may be comfortable on trach-collar, breathing mechanics are undoubtedly altered as patients take rapid shallow breaths and tidal volumes that are almost half the size of decannulated patients as displayed in Figure 1 of Villalba et al.’s article. The immediate increase in WOB associated with decannulation can then decrease exercise tolerance in rehabilitating patients. Recognizing patients who may potentially be unable to compensate for the extra effort needed to overcome the additional WOB is important.

With this recognized increased WOB secondary to decannulation, another important consideration is the subpopulation of patients who develop subglottic stenosis. Since PDT has gained widespread acceptance, many positive benefits have been found but also a suggested rise in the incidence of subglottic stenosis.\textsuperscript{[14]} A Cochrane Database analysis in 2016 identified 20 randomized-controlled trials from 1990 to 2011 with over 1600 patients. They concluded that there were non-significant but positive benefits of PDT for both mortality and serious adverse events.\textsuperscript{[19]} A second meta-analysis by Delaney et al. found that PDT reduces the rate of wound infection and may reduce bleeding and mortality.\textsuperscript{[5]} Beyond the clinical advantages of PDT, the procedure has been found to be more cost-effective when performed in the ICU and the duration of the procedure shorter.\textsuperscript{[20]} However, the incidence of subglottic stenosis following PDT may be higher than open tracheostomy placement. In a single case series reported by Koitschev et al. in 2006, of 146 patients, the incidence of severe stenosis (>50% of the lumen) was 23.8% for PDT and 7.3% for surgical tracheostomy.\textsuperscript{[21]} Further study is certainly needed to validate or disprove this suggestion but for now, WOB in the face of potential tracheal stenosis, regardless of tracheostomy method used, must be considered.

This current article by Villalba et al., should drive practitioners to specifically consider the increased WOB following decannulation and might even suggest that some sort of prognosticating test or readiness for increased WOB be devised. For the common practitioner, this article highlights perhaps the importance of capping trials prior to decannulation to demonstrate tolerance to the changes in airway anatomy. It would be interesting to repeat this current study and methodology to measure WOB in a subset of patients with identified subglottic stenosis to quantify how much, if any, it may contribute to respiratory mechanics. Although the vast majority of these patients are asymptomatic, even small changes in airway sizes, differences in tracheostomy tubes, and or the presence or absence of a cuff will influence WOB. These findings could additionally prompt clinicians to aggressively downsized patients with tracheostomy tubes in order to gradually increase their WOB in a systematic fashion.

The debate regarding tracheostomy timing will likely continue, but this study highlights the impact of tracheostomy on basic pulmonary mechanics. Early downsizing and decannulation protocols with restoration of normal respiratory anatomy must be considered in light of WOB. This paper underscores the importance of identifying or ruling out significant contributors to upper airway resistance prior to decannulation. Although the role of anatomic dead space and intrinsic PEEP as it relates to WOB is not entirely clear, the work of Vallalba et al. clearly demonstrates how simple changes in airway resistances can dramatically affect WOB. A quantitative bedside test in a patient with a capped tracheostomy may be helpful in prognosticating successful decannulation and should be the focus of future studies.

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REFERENCES

1. Jackson C. Tracheostomy. Laryngoscope 1909;19:285-90.
2. Cheung NH, Napolitano LM. Tracheostomy: Epidemiology, indications, timing, technique, and outcomes. Respir Care 2014;59:895-915.
3. Ciaglia P, Firsching R, Syniec C. Elective percutaneous dilatational tracheostomy: A new simple bedside procedure: preliminary report. Chest 1985;87:715-9.
4. Delaney A, Bapshaw SM, Nalos M. Percutaneous dilatational tracheostomy versus surgical tracheostomy in critically ill patients: A systematic review and meta-analysis. Crit Care 2006;10:R55.
5. Freeman-Sanderson AL, Togher L, Elkins MR, Phipps PR. Quality of life improves with return of voice in tracheostomy patients in intensive care: An observational study. J Crit Care 2016;33:186-91.

6. Nieszkowska A, Combes A, Luyt CE, Kabhi H, Trouillet JL, Gibert C, et al. Impact of tracheotomy on sedative administration, sedation level, and comfort of mechanically ventilated intensive care unit patients. Crit Care Med 2005;33:2527-33.

7. Trouillet JL, Luyt CE, Guiguet M, Ouattara A, Vaissier E, Makri R, et al. Early percutaneous tracheotomy versus prolonged intubation of mechanically ventilated patients after cardiac surgery: A randomized trial. Ann Intern Med 2011;154:373-83.

8. Novaes MA, Knobel E, Bork AM, Pavão OF, Nogueira-Martins LA, Ferraz MB. Stressors in ICU: Perception of the patient, relatives and health care team. Intensive Care Med 1999;25:1421-6.

9. Rumbak MJ, Newton M, Truncale T, Schwartz SW, Adams JW, Hazard PB. A prospective, randomized, study comparing early percutaneous dilational tracheotomy to prolonged translaryngeal intubation (delayed tracheostomy) in critically ill medical patients. Crit Care Med 2004;32:1689-94.

10. Terragni PP, Antonelli M, Fumagalli R, Faggiano C, Berardino M, Pallavicini FB, et al. Early vs. late tracheostomy for prevention of pneumonia in mechanically ventilated adult ICU patients: A randomized controlled trial. JAMA 2016;303:1483-9.

11. Diehl JL, El Atrous S, Touchard D, Lemaire F, Brochard L. Changes in the work of breathing induced by tracheostomy in ventilator-dependent patients. Am J Respir Crit Care Med 1999;159:383-8.

12. Davis K Jr., Campbell RS, Johannigman JA, Valente JF, Branson RD. Changes in respiratory mechanics after tracheostomy. Arch Surg 1999;134:59-62.

13. Mullins JB, Templer JW, Kong J, Davis WE, Hinson J Jr. Airway resistance and work of breathing in tracheostomy tubes. Laryngoscope 1993;103:1367-72.

14. Chadda K, Louis B, Benaisa L, Annane D, Gajdos P, Raphaël JC, et al. Physiological effects of decannulation in tracheostomized patients. Intensive Care Med 2002;28:1761-7.

15. Joseph MJ, Khoury A, Mendoza AE, Adams S, Short KA, Charles AG. Tracheostomy in the critically ill: The myth of dead space. Anaesth Intensive Care 2013;41:216-21.

16. Freeman BD, Morris PE. Tracheostomy practice in adults with acute respiratory failure. Crit Care Med 2012;40:2890-6.

17. Young D, Harrison DA, Cuthbertson BH, Rowan K; TracMan Collaborators. Effect of early vs late tracheostomy placement on survival in patients receiving mechanical ventilation: The TracMan randomized trial. JAMA 2013;309:2121-9.

18. Freeman BD, Isabella K, Lin N, Buchman TG. A meta-analysis of prospective trials comparing percutaneous and surgical tracheostomy in critically ill patients. Chest 2000;118:1412-8.

19. Brass P, Hellmich M, Ladra A, Ladra J, Wrzosek A. Percutaneous techniques versus surgical techniques for tracheostomy. Cochrane Database Syst Rev 2016;7:CD008045.

20. Higgins KM, Punthakee X. Meta-analysis comparison of open versus percutaneous tracheostomy. Laryngoscope 2007;117:447-54.

21. Koitschev A, Simon C, Blumenstock G, Mach H, Graumüller S. Suprastomal tracheal stenosis after dilational and surgical tracheostomy in critically ill patients. Anaesthesia 2006;61:832-7.

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