Mechanical Insufflation-Exsufflation: Room for Improvement

Mechanical insufflation-exsufflation is a technique used to facilitate the clearance of airway secretions in patients with a weak cough. It can be performed in the hospital setting, including patients who are critically ill[1,2] or at home in patients with chronic neuromuscular weakness.[3] With this technique, a specific device first insufflates the respiratory system to a set pressure and then actively withdraws gas to a set negative pressure. Usually the pressure is set at the same level, with the opposite sign for insufflation and exsufflation (+40 cm H_2O/−40 cm H_2O). The goal of treatment is to reach a targeted peak expiratory flow, because the efficacy of cough, and hence airway clearance, has been linked to cough peak flow. A peak flow of >160 L/min has been assumed to be an efficient cough generated by the device.[4]

In patients with respiratory muscle dysfunction, cough strength is part of the whole process of cough efficiency, including the movement of the secretions toward the upper airways for elimination by expectoration or suctioning. It, therefore, could be speculated that the peak expiratory flow mainly serves to make secretions available to be expelled and other factors are involved for clearing secretions from the airway. In this issue of RESPIRATORY CARE, Volpe et al[5] describe a brilliant in vitro study to analyze the movement of mucus over a tube actuated with a mechanical insufflation-exsufflation device set at different combinations of flow and pressure. They found that the peak expiratory flow alone did not contribute to the displacement of mucus toward the outlet of the respiratory system. In fact, they found that the lower the peak insufflation flow or the higher the ratio of peak exsufflation-to-insufflation flow or the greater the ratio of insufflation-to-exsufflation pressure, the greater the displacement of mucus toward the outlet of the respiratory system. In summary, the higher the inspiratory flow relative to the expiratory flow, the higher the risk for accumulated secretions being pushed down the respiratory tract. This finding illustrates a mechanical rule: a cyclic and periodic process (mechanical insufflation-exsufflation) requires asymmetry between its phases (insufflation and exsufflation) to induce a non-zero average displacement. In a pure oscillating process, the displacement induced by the active stroke is erased by the displacement induced by the recovery stroke.

SEE THE ORIGINAL STUDY ON PAGE 1214

There are some practical limitations in the study by Volpe et al.[5] The reproducibility to achieve the low insufflation flow manually has not been evaluated. It could be speculated as being low in the daily practice according to the way that the authors changed the insufflation flow with the model CM-3200 (Philips Respironics, Murrysville, Pennsylvania). Other models of the same brand (CA-3200 or E70) should be assessed. Furthermore, from the mechanical point of view, flow (or flow bias) is not, in theory, the most direct physical parameter nor the only one that allows an explanation for the movement of the mucus induced by a fluid flow. General mechanical laws predict that mucus displacement depends on the shear stress (or force) exerted by the fluid to the mucus and on the rheological properties of the mucus.[6] In a given geometry, the flow is clearly correlated to the shear stress. However, if the geometry changes (eg, adults to children, collapsibility of the airway), then the same flow is associated with a different shear stress. The rheological behavior of the mucus is another key point. A viscoelastic and a shear-thinning behavior, possibly with some thixotropy, are often evoked. In other words, mucus is a very complex material and any slight modification of its physical properties may have a strong impact on the movement of the mucus.

All these points suggest that future guidelines for an efficient setting of mechanical insufflation-exsufflation should integrate "flow bias" that can be easily monitored but will likely have to take into account different categories of airway dimension and pathology. This potential interest of low insufflation flow and pressure during mechanical insufflation-exsufflation, regardless of the impact on mucus displacement, has been suggested in patients with amyotrophic lateral sclerosis in whom the direct la-

The authors have disclosed no conflicts of interest.

Correspondence: Claude Guérin MD PhD, Service de médecine intensive-réanimation, Hôpital de la Croix Rousse, 103 Grande Rue de la Croix Rousse Lyon 69004, France. E-mail: claude.guerin@chu-lyon.fr.

DOI: 10.4187/respcare.06542

ryngeal visualization disclosed that higher insufflation pressure and flow promoted adduction of the vocal folds.[7,8] Evidence-based medicine does not provide sufficient evidence to recommend the systematic use of mechanical insufflation-exsufflation in patients with chronic neuromuscular weakness.[9] Perhaps the negative results of some trials come from suboptimal use of the device. Another potential implication of the present results is the need for monitoring the inspiratory and expiratory flow during the procedure, which is currently lacking.

Beyond the case of mechanical insufflation-exsufflation, the authors presented results that shed light on the setting of inspiratory flow during mechanical ventilation. By observing upper airways with a fiberoptic bronchoscope during noninvasive ventilation in awake or sleeping normal subjects with healthy lungs, Jounieaux et al[10,11] found that higher inspiratory flow was associated with glottis adduction. Inspiratory flow setting has received a growing interest in patients with ARDS as well. Indeed, the new concept of mechanical power has pointed out the role of inspiratory flow as a contributor of ventilator-induced lung injury.[12,13] The stress relaxation that follows tidal volume inflation can be assessed by the difference in airway pressure between the first zero flow and the plateau pressure. The magnitude of this decay correlated with lung edema formation in normal animals with healthy lungs that received invasive mechanical ventilation.[12] Furthermore, the magnitude of this decay is flow dependent.[14] Therefore, it could be that lowering inspiratory flow is lung protective. The present results should encourage further studies in patients during spontaneous breathing or during invasive mechanical ventilation, either at home or in the ICU.

Jean-François Burle

Bernard Vincent

Romain Lachal
Service de médecine intensive-réanimation
Hôpital de la Croix Rousse
Lyon, France

Bruno Louis PhD
Institut Mondor de Recherches Biomédicales
Institut National de la Santé et de la Recherche Médicale
Créteil, France

Claude Guérin MD PhD
Service de médecine intensive-réanimation
Hôpital de la Croix Rousse
Lyon, France
Université de Lyon
Lyon, France
Institut Mondor de Recherches Biomédicales
Institut National de la Santé et de la Recherche Médicale
Créteil, France

REFERENCES

1. Goncalves MR, Honrado T, Winck JC, Paiva JA. Effects of mechanical insufflation-exsufflation in preventing respiratory failure after extubation: a randomized controlled trial. Crit Care 2012;16(2):R48.
2. de Camillis MLF, Savi A, Rosa RG, Figueiredo M, Wickert R, Borges LGA, et al. Effects of mechanical insufflation-exsufflation on airway mucus clearance among mechanically ventilated ICU subjects. Respir Care 2018.
3. Cesareo A, LoMauro A, Santi M, Biffi E, D'Angelo MG, Aliverti A. Acute effects of mechanical insufflation-exsufflation on the breathing pattern in stable subjects with Duchenne muscular dystrophy. Respir Care 2018.
4. Auger C, Hernando V, Galmiche H. Use of mechanical insufflation-exsufflation devices for airway clearance in subjects with neuromuscular disease. Respir Care 2017;62(2):236-245.
5. Volpe MS, Naves JM, Ribeiro GG, Ruas G, Amato MBP. Airway clearance with an optimized mechanical insufflation-exsufflation maneuver. Respir Care 2018.
6. Smith DJ, Gaffney EA, Blake JR. Modelling mucociliary clearance. Respir Physiol Neurobiol 2008;163(1-3):178-188.
7. Andersen T, Sandnes A, Brekka AK, Hilland M, Clemm H, Fondenes O, et al. Laryngeal response patterns influence the efficacy of mechanical assisted cough in amyotrophic lateral sclerosis. Thorax 2017;72(3):221-229.
8. Andersen TM, Sandnes A, Fondenes O, Nilsen RM, Tysnes OB, Heimdal JH, et al. Laryngeal responses to mechanically assisted cough in progressing amyotrophic lateral sclerosis. Respir Care 2018; 63(5):538-549.
9. Morrow B, Zampoli M, van Aswegen H, Argent A. Mechanical insufflation-exsufflation for people with neuromuscular disorders. Cochrane Database Syst Rev 2013;(12):CD010044.
10. Jounieaux V, Aubert G, Dury M, Delguste P, Rodenstein DO. Effects of nasal positive-pressure hyperventilation on the glottis in normal sleeping subjects. J Appl Physiol 1995;79(1):186-193.
11. Jounieaux V, Aubert G, Dury M, Delguste P, Rodenstein DO. Effects of nasal positive-pressure hyperventilation on the glottis in normal awake subjects. J Appl Physiol 1995;79(1):176-185.
12. Cressoni M, Gotti M, Chiurazzi C, Massari D, Algieri I, Amini M, et al. Mechanical power and development of ventilator-induced lung injury. Anesthesiology 2016;124(5):1100-1108.
13. Tonetti T, Vasques F, Rapetti F, Maiolo G, Collino F, Romitti F, et al. Driving pressure and mechanical power: new targets for VILI prevention. Ann Transl Med 2017;5(14):286.
14. Eissa NT, Ranieri VM, Corbeil C, Chassé M, Robatto FM, Braidy J, Milic-Emili J. Analysis of behavior of the respiratory system in ARDS patients: effects of flow, volume, and time. J Appl Physiol 1991;70(6):2719-2729.