Commentary

High-flow nasal cannula in postextubation management

Lu Chen[1,2], Hong-Liang Li[2,3], Laurent Brochard[1,2]

[1]Interdepartmental Division of Critical Care Medicine, University of Toronto, Toronto, Canada; [2]Keenan Research Centre and Li Ka Shing Knowledge Institute, Department of Critical Care, St Michael's Hospital, Toronto, Canada; [3]Department of Critical Care Medicine, Peking University Third Hospital, Beijing 100191, China

Correspondence to: Laurent Brochard. 209 Victoria Street, Toronto ON M5B 1T8, Canada. Email: BrochardL@smh.ca.

Submitted Jun 26, 2016. Accepted for publication Jul 02, 2016.
doi: 10.21037/jtd.2016.08.26
View this article at: http://dx.doi.org/10.21037/jtd.2016.08.26

Background

Extubation failure, defined as requiring reintubation within 2–7 days after a planned extubation, is associated with remarkably higher mortality rates compared to successfully extubated patients (1,2). Numbers of studies investigated the rate of extubation failure in various populations of patients in intensive care units (ICU), showing that it varied from 10% to 30% of extubated patients (3). Most patients are reintubated because of respiratory failure but this can be related to excessive secretions, progressive exhaustion, respiratory muscle weakness, aspiration or fluid overload. Several risk factors have been reported to be associated with extubation failure, such as age greater than 65 years, underlying chronic cardiorespiratory disease, acute physiology and chronic health evaluation (APACHE) II score higher than 12 points at time of extubation, airway patency problems, etc. (3,4). Although these factors may allow us to evaluate the potential risk of extubation failure, our understanding on the pathophysiological mechanism is still disappointedly limited. Different strategies for postextubation management, such as applying preventive noninvasive ventilation (NIV) in high-risk patients, have been endeavored to improve extubation outcome. In the last decade, a novel therapy—high-flow nasal cannula (HFNC)—was introduced and has brought wide attention among researchers and clinicians. In this article, we discuss its physiological effects and consequences, and look at recent clinical evidence for implementing this therapy in the post-extubation period.

Physiological effects and consequences

Heated and humidified oxygen with constant concentration

Conventional oxygen administration usually delivers a low-flow rate at 2 to 15 L/min through nasal cannula or masks. Flows exceeding 6 L/min can lead to insufficient humidification provided by nasal mucosa, even when a cold bubble humidifier is used. Inhaling dry and cold oxygen provokes upper airway dryness frequently leading to intolerance (5,6), and potentially impairing mucociliary functions such as secretions clearance and airway defense. Moreover, patients with respiratory failure often generate a peak inspiratory flow varying between 30 and 60 L/min, which means that only a part of the inspired flow can be provided by the low-flow systems whereas the other part has to be entrained from ambient air. Consequently, the actual fraction of inspired oxygen (FiO_2) cannot be guaranteed in low-flow systems, including the Venturi masks. A dedicated high-flow system, HFNC, was therefore developed to deliver oxygen at constant concentration with a high flow rate. It consists of a wide bore nasal cannula, a heated humidifier, and a heated inspiratory circuit, providing heated and humidified oxygen (37 ℃, 44 mg/L) at a predetermined constant concentration (21% to 100%) and using high flow rates (up to 60 L/min). Results of studies supported that it reduces patients' discomfort and upper airway dryness (6-8), whereas a potentially protective effect on mucociliary function requires further investigation.

Positive pharyngeal pressure

HFNC can induce a positive pharyngeal pressure during expiration due to its constant ingoing flow. A carefully designed study by Mündel and colleagues (9) confirmed this effect, and demonstrated that its amplitude depends primarily upon the flow rate provided by HFNC but also upon the expiratory flow exhaled by the patient. It is

therefore not entirely similar from applying a continuous positive airway pressure, which aims to maintain a steady level of positive pressure during the whole cycle of breath. In other words, the target of HFNC is flow instead of pressure; hence for a given rate of flow provided by HFNC, the greater patient's expiratory flow the higher pharyngeal pressure, vice versa. Parke *et al.* (10) reported that HFNC increased the mean pharyngeal pressure by about 1 cmH_2O per 10 L/min, within a range of 30–100 L/min (extra high-flow was offered by using two combined HFNC systems). At the end of expiration, exhaled flow drops close to zero and the actual positive end-expiratory pressure (PEEP) can be low, approximately 0.5–3 cmH_2O as shown in limited data (9,11). Additionally, the increase in mean pharyngeal pressure is attenuated when the mouth is open [mouth closed *vs.* mouth open: 2.7±1.0 *vs.* 1.2±0.8 cmH_2O (11)]. In patients after removal of tracheotomy tubes, Chanques *et al.* (8) measured the tracheal pressure through the residual hole in the trachea, and confirmed that opening mouth can induce a significant decrease in mean tracheal airway pressure, from around 2 to 0.6 cmH_2O.

Despite this uncertainty about how much PEEP can really be offered by HFNC, studies (10,12) have demonstrated that end-expiratory lung impedance was increased with rising flow rate of HFNC, suggesting an increase in end-expiratory lung volume. In addition, by inducing a low external PEEP, HFNC might be able to improve atelectasis, alleviate airway collapse and air trapping, and reduce work of breathing caused by intrinsic PEEP.

Dead-space washout

For a normal adult at rest breathing, approximately one third of tidal volume is rebreathed from the anatomical dead space that is filled with carbon dioxide (CO_2) enriched gas at each end exhalation. This fraction of dead space ventilation can increase to more than a half of tidal volume in patients with rapid shallow breathing (13), leading to a low respiratory efficiency. By providing a high flow of fresh air during expiration, HFNC may be able to washout the CO_2 filled nasopharyngeal cavity more rapidly. Möller *et al.* constructed an anatomically representative upper airway model from a subject's computer tomography scan, to test the effect of HFNC on dead-space clearance in breath-holding condition. After filling the models with gas tracers, they observed a linear positive correlation between tracer-gas clearance in the model and the flow rate of HFNC, approximately 1.8 mL/s increase in clearance for every 1.0 L/min increase in flow. Although circumstances of dynamic breathings are much more complex, this study suggested that HFNC may significantly reduce CO_2 rebreathing. This potential effect perhaps partly explains why respiratory rate is significantly reduced (suggesting lower respiratory drive) with HFNC in a wide range of observations. It is, however, challenging to test this potential effect directly in humans. Of note, similar to water vapor removal in panting dogs (14), the unidirectional breathing with nose in and mouth out has been shown to be the most efficient for CO_2 clearance, minimizing the CO_2 (as water vapor) recycling in the upper airway (13). Further clinical studies taking into account the route of breathing could be interesting to optimize the effects of HFNC.

Clinical trials implementing HFNC in the post-extubation period

The first randomized controlled trial to test the efficacy of HFNC was conducted by Maggiore and his colleagues (7), who compared HFNC with Venturi mask in 105 extubated patients with hypoxemia. They found that HFNC improved oxygenation for the same set FiO_2 and reduced discomfort both related to the interface and to airway dryness. The improvement in oxygenation, however, is difficult to interpret since HFNC can deliver a precise preset FiO_2 whereas Venturi mask cannot. Interestingly, significantly less reintubations and need for NIV (within 48 hours) was also observed in the HFNC group. A larger multicenter trial in a similar group of patients is currently ongoing by the same group (ClinicalTrials.gov Identifier: NCT02107183).

Recently, Hernández and his colleagues performed a large, multicenter randomized controlled trial (NCT01191489) to determine whether HFNC would reduce reintubation rate. The investigators enrolled a total of 1,130 patients but allocated the patients into two studies (4,15) according to their risk for reintubation. Patients at low risk for reintubation were randomly receiving HFNC or conventional oxygen therapy (nasal cannula or non-rebreathing facemask) whereas patients at high risk were randomly receiving HFNC or NIV. The study comparing HFNC with conventional oxygen therapy in low-risk patients has been published in full (4).

In this study, 527 patients who passed a spontaneous breathing trial and in the absence of selected risk factors for reintubation—as partly aforementioned—were enrolled. Patients who were hypercapnic during the spontaneous breathing trial were also excluded because clinicians

preferred to use preventive NIV in this case. In the HFNC group, HFNC was administered for the first 24 hours of postextubation, and afterwards conventional oxygen therapy was allowed. In both groups, FiO_2 was adjusted to maintain peripheral oxygen saturation greater than 92%. Eventually, reintubation rate within 72 hours, as the primary outcome, was significantly lower in the HFNC group than that in the conventional group (4.9% *vs.* 12.2%, respectively). Probably attributed to limiting HFNC to 24 hours after extubation, preventive HFNC did not delay reintubation compared with conventional group (i.e., similar time to reintubation). This is important for safety concern, since delayed reintubation could worsen outcome (16).

This study represents clinical evidence for implementing preventive HFNC during the first post-extubation day even among patients at low risk for reintubation. As mentioned, this entire project was divided into two studies according to risk factors for reintubation, to compare the effects of HFNC with other therapies (low-flow or NIV). This is justified by evidence showing the benefit of NIV in high-risk patients. Comparing HFNV with NIV in this population therefore sounds reasonable. Yet, selecting patients relied on these outcome-associated risk factors is arguable since the risk factors may not be modified by the interventions. For example, none of these therapies can modify the general characteristics such as age and APACHE II score. Consequently, risks indicated by these factors may not be directly alleviated by applying the three interventions. Some researchers and clinicians may favor to select patients based on the type of respiratory failure (e.g., hypoxemic, hypercapnic, or cardiogenic pulmonary edema/fluid overload). However, whether etiology of respiratory failure at intubation has a strong link with extubation outcome remains unclear. The ongoing randomized controlled trial (NCT02107183) performed by Maggiore and his colleagues choose to select patients who presented hypoxemia within 30 minutes after extubation while breathing through a venturi mask, to test the effectiveness of HFNC Versus Venturi. Further physiological studies are needed to better understand the mechanisms of extubation failure and effects of HFNC. Meanwhile, we look forward to seeing the detailed results of comparing HFNC with NIV in patients at high risk for reintubation (15), as well as other clinical trials on this topic.

Acknowledgements

None.

Footnote

Provenance: This is an invited Commentary commissioned by the Section Editor Zhongheng Zhang (Department of Critical Care Medicine, Jinhua Municipal Central Hospital, Jinhua Hospital of Zhejiang University, Jinhua, China).
Conflicts of Interest: L Brochard's laboratory has received equipment and a research grant for studies on high-flow therapy (Fisher Paykel). His laboratory has also received equipment or grants from Medtronic Covidien, Philips, General Electric, Air Liquide and Maquet.

Comment on: Hernández G, Vaquero C, González P, *et al.* Effect of Postextubation High-Flow Nasal Cannula vs Conventional Oxygen Therapy on Reintubation in Low-Risk Patients: A Randomized Clinical Trial. JAMA 2016;315:1354-61.

References

1. Thille AW, Harrois A, Schortgen F, et al. Outcomes of extubation failure in medical intensive care unit patients. Crit Care Med 2011;39:2612-8.
2. Epstein SK, Ciubotaru RL, Wong JB. Effect of failed extubation on the outcome of mechanical ventilation. Chest 1997;112:186-92.
3. Thille AW, Richard JC, Brochard L. The decision to extubate in the intensive care unit. Am J Respir Crit Care Med 2013;187:1294-302.
4. Hernández G, Vaquero C, González P, et al. Effect of Postextubation High-Flow Nasal Cannula vs Conventional Oxygen Therapy on Reintubation in Low-Risk Patients: A Randomized Clinical Trial. JAMA 2016;315:1354-61.
5. Chanques G, Constantin JM, Sauter M, et al. Discomfort associated with underhumidified high-flow oxygen therapy in critically ill patients. Intensive Care Med 2009;35:996-1003.
6. Cuquemelle E, Pham T, Papon JF, et al. Heated and humidified high-flow oxygen therapy reduces discomfort during hypoxemic respiratory failure. Respir Care 2012;57:1571-7.
7. Maggiore SM, Idone FA, Vaschetto R, et al. Nasal high-flow versus Venturi mask oxygen therapy after extubation. Effects on oxygenation, comfort, and clinical outcome. Am J Respir Crit Care Med 2014;190:282-8.
8. Chanques G, Riboulet F, Molinari N, et al. Comparison of three high flow oxygen therapy delivery devices: a clinical physiological cross-over study. Minerva Anestesiol

2013;79:1344-55.
9. Mündel T, Feng S, Tatkov S, et al. Mechanisms of nasal high flow on ventilation during wakefulness and sleep. J Appl Physiol (1985) 2013;114:1058-65.
10. Parke RL, Bloch A, McGuinness SP. Effect of Very-High-Flow Nasal Therapy on Airway Pressure and End-Expiratory Lung Impedance in Healthy Volunteers. Respir Care 2015;60:1397-403.
11. Parke R, McGuinness S, Eccleston M. Nasal high-flow therapy delivers low level positive airway pressure. Br J Anaesth 2009;103:886-90.
12. Corley A, Caruana LR, Barnett AG, et al. Oxygen delivery through high-flow nasal cannulae increase end-expiratory lung volume and reduce respiratory rate in post-cardiac surgical patients. Br J Anaesth 2011;107:998-1004.
13. Jiang Y, Liang Y, Kacmarek RM. The principle of upper airway unidirectional flow facilitates breathing in humans. J Appl Physiol (1985) 2008;105:854-8.
14. Schmidt-Nielsen K, Bretz WL, Taylor CR. Panting in dogs: unidirectional air flow over evaporative surfaces. Science 1970;169:1102-4.
15. Hernandez G, Vaquero C, Gonzalez P, et al. High flow conditioned oxygen therapy for prevention of reintubation in critically ill patients at high risk for extubation failure: a multicenter randomised controlled trial. Intensive Care Med Exp 2015;3:A823.
16. Kang BJ, Koh Y, Lim CM, et al. Failure of high-flow nasal cannula therapy may delay intubation and increase mortality. Intensive Care Med 2015;41:623-32.

Cite this article as: Chen L, Li HL, Brochard L. High-flow nasal cannula in postextubation management. J Thorac Dis 2016;8(9):E1013-E1016. doi: 10.21037/jtd.2016.08.26

