Commentary

Helium oxygen mixtures in the intensive care unit

Jean-Claude Chevrolet

University Hospital, Geneva, Switzerland

Correspondence: Jean-Claude Chevrolet, chevrole@cmu.unige.ch

Published online: 13 July 2001
Critical Care 2001, **5**:179–181

Abstract

Heliox, a mixture of helium and oxygen, has a density that is less than that of air. Breathing heliox leads to a reduction in resistance to flow within the airways, and consequently to a decrease in the work of breathing (WOB), particularly in disorders that are characterized by increased airways resistance. Beneficial effects have been observed in patients with asthma, chronic obstructive pulmonary disease (COPD), bronchiolitis, bronchopulmonary dysplasia and upper airways obstruction. Until we have conclusive data that attest to the efficacy of heliox in such conditions, it use will remain controversial. Meanwhile, it appears wise not to incorporate heliox therapy into routine practice because of technical complications and high costs.

Keywords helium, heliox, mechanical ventilation, work of breathing

Human airways are complex tubes, and airflow in a tube may occur in a laminar, a transitional or a turbulent manner [1]. Reynolds number can approximately predict the nature of flow [2]. Flow characteristics are determined by complex interplays between many different factors, including the branching patterns of trachea and bronchi, the diameter of the conduits, the angles of branching, and the degree of roughness of the walls. The flow characteristics in the airways may also vary depending on the inspiratory and expiratory flow rates [2,3].

During quiet breathing in normal humans, a transition from turbulent to laminar flow occurs through the trachea to around the second generation of bronchi. In patients with airways obstruction, however, turbulent flow occurs very frequently, even in low breathing rates and quiet breathing patterns [4]. This leads to increased work of breathing (WOB).

Breathing helium decreases work of breathing

In turbulent flows, the pressure necessary to generate a given flow rate is dependent on the density of the inspired gases [4,5]. Helium has a density that is significantly lower than that of air [4]. Therefore, a mixture of helium and oxygen, termed heliox, has a lower density than does a mixture of nitrogen and oxygen (air, or airox) [6,7]. Breathing heliox leads to a reduction in resistance to flow within the airways, and consequently to a decrease in the WOB, particularly in disorders that are characterized by increased airways resistance [8]. These beneficial effects have been observed in a few patients with asthma, chronic obstructive pulmonary disease (COPD), bronchiolitis, bronchopulmonary dysplasia and upper airways obstruction [9]. Heliox has not only been used in patients breathing spontaneously, but also in the settings of both invasive mechanical ventilation (ie with tracheal intubation) [10] and noninvasive mechanical ventilation (NIV) [11,12]. Nevertheless, the usefulness of heliox in the intensive care unit remains debatable.

The controversy regarding the use of heliox

Upper airways obstruction

In upper airways obstruction, heliox appears to be a reasonable option in severe respiratory distress that results from upper airways obstruction [13]. The gas mixture may allow the intensivist to 'buy time' while awaiting treatment that is aimed at alleviating the obstruction. Of course, helium *per se* has no curative action [9,14], and

COPD = chronic obstructive pulmonary disease; NIV = noninvasive mechanical ventilation; WOB = work of breathing.

in a randomized protocol in children with moderate upper airways obstruction [15] there was no difference between heliox and racemic epinephrine (adrenaline) in alleviating symptoms.

Acute asthma crisis

There is controversy regarding the use of heliox in acute asthma crisis. In a meta-analysis of four randomized controlled trials performed in children and adults presenting at the emergency room with moderate to severe asthma [16], there was no evidence favouring the use of heliox. However, there are several studies (randomized protocols) that reported findings in favour of heliox in acute severe asthma [17–19], showing a more rapid decrease in pulsus paradoxus and in airflow obstruction with helium than with air oxygen mixtures in nonintubated patients. As in upper airways obstruction, there is no curative effect of heliox in asthma crisis, and in no circumstances should heliox replace aggressive bronchodilator and corticosteroid therapy [9].

Our present policy is that, in acute severe asthma in spontaneously breathing patients, heliox can be given after failure of the initial bronchodilator therapy. In so doing we aim to avoid intubation, which (as reported by many authors [20,21]) is a dangerous procedure, particularly in asthmatic persons. Heliox has also been used in intubated asthma patients, and an improvement in blood gases with a reduction in inflation pressure was observed [22]. From a practical standpoint, we usually restrict the use of heliox to patients who are difficult to ventilate, with high inflation pressures and haemodynamic instability.

Chronic obstructive pulmonary disease

Heliox has been used in both nonintubated and intubated COPD patients. NIV has become the standard initial treatment in the majority of such patients [23]. COPD patients in acute decompensation are at risk for respiratory failure precipitated by an increase in their WOB, leading to inspiratory muscle fatigue. NIV decreases the WOB in these patients [24]. Therefore, it was hypothesized that the WOB associated with NIV could be further reduced by combining that form of ventilation with heliox. Two studies have been reported [11,12] that support this hypothesis. However, the proof that NIV with heliox is superior to NIV with an air–oxygen mixture in avoiding intubation in COPD patients is nevertheless lacking. We are aware of two ongoing multicentre trials in Europe that are attempting to resolve this issue. Until the results of those studies are known, it seems wise to refrain from introducing heliox into routine practice because of the costs of the gas.

Heliox has also been used in COPD patients once intubated and mechanically ventilated, in order to reduce intrinsic positive end-expiratory pressure and hyperinflation, and to lessen the impact of high alveolar pressure on haemodynamic and respiratory mechanics [25]. By reducing the respiratory resistance, heliox could enhance expiratory flow rate, and it could help to reduce intrinsic positive end-expiratory pressure. This was recently demonstrated in intubated and acutely decompensated COPD patients [10]. Thus, heliox may be administered to mechanically ventilated COPD patients with high levels of dynamic hyperinflation and severe consequences on haemodynamics and high respiratory pressures. Use of heliox while weaning the patient from the respirator remains to be investigated.

Other uses

Other more anecdotal uses of heliox have been reported, including use in children with acute bronchiolitis [26] or bronchopulmonary dysplasia [27], during bronchoscopy [28], and even as a treatment for pneumothorax [29] and hyperammonaemia [30].

Technical and cost issues may discourage widespread use … for now

Several words should be added regarding the technical and the financial issues associated with the use of helium. In spontaneously breathing patients, heliox (generally pressurized as 78 : 22 helium:oxygen) should be administered with a nonrebreather face mask, and if necessary oxygen can be added through a nasal canula. The use of heliox with a ventilator raises various technical and safety issues (fractional inspiration of oxygen measurements, volume measurements, valve functioning, etc) that need to be resolved before we can begin to use this mixture of gas in ventilated patients [31,32].

Finally, even if helium is the second most abundant element in the universe, the extraction and processing costs on Earth are high. In Switzerland, a 60-l tank of 78 : 22 heliox pressurized at 200 Bars (10,000 l at atmospheric pressure) costs US$275. However, these high costs should be balanced against the benefits, such as improving patient outcome and reducing the duration of intensive care unit stay. Such issues should be addressed in further studies into heliox therapy.

Competing interests

None declared.

References

1. O'Grady K, Doyle DJ, Irish J, Gullane P: **Biophysics of airflow within the airway: a review.** *J Otolaryngol* 1997, **26**:123–128.
2. Pedley T, Schroter R, Sudlow M: **Gas flow and mixing in the airways.** In: *Bioengeenering Aspects of the Lungs*. Edited by West J. New York, Basel: Marcel Dekker; 1977:163–265.
3. Olson D, Dart G, Filley G: **Pressure drop and fluid flow regime of air inspired into the human lung.** *J Appl Physiol* 1970, **28**: 482–494.
4. Otis A, Bembower W: **Effect of gas density on resistance to respiratory gas flow in man.** *J Appl Physiol* 1949, **2**:300–306.
5. Wood LD, Engel LA, Griffin P, Despas P, Macklem PT: **Effect of gas physical properties and flow on lower pulmonary resistance.** *J Appl Physiol* 1976, **41**:234–244.

6. Dubois A: **Resistance to breathing.** In: *Handbook of Physiology*. Edited by Macklem PT, Mead J. Bethesda: American Society of Physiology; 1986:451–461.
7. Radford E. **The physic of gases.** In: *Handbook of Physiology*. Edited by Macklem PT, Mead J. Bethesda: American Physiological Society; 1964:125–151.
8. Barnett TB: **Effects of helium and oxygen mixtures on pulmonary mechanics during airway constriction.** *J Appl Physiol* 1967, **22**:707–713.
9. Jolliet P, Tassaux D, Chevrolet J: **Beneficial effects of helium-oxygen mixtures in acute respiratory failure.** In: *Yearbook of Intensive Care and Emergency Medicine*. Edited by Vincent J. Berlin: Springer Verlag; 1999:244–251.
10. Tassaux D, Jolliet P, Roeseler J, Chevrolet JC: **Effects of helium-oxygen on intrinsic positive end-expiratory pressure in intubated and mechanically ventilated patients with severe chronic obstructive pulmonary disease.** *Crit Care Med* 2000, **28**:2721–2728.
11. Jolliet P, Tassaux D, Thouret JM, Chevrolet JC: **Beneficial effects of helium:oxygen versus air:oxygen noninvasive pressure support in patients with decompensated chronic obstructive pulmonary disease.** *Crit Care Med* 1999, **27**:2422–2429.
12. Jaber S, Fodil R, Carlucci A, Boussarsar M, Pigeot J, Lemaire F, Harf A, Lofaso F, Isabey D, Brochard L: **Noninvasive ventilation with helium-oxygen in acute exacerbations of chronic obstructive pulmonary disease.** *Am J Respir Crit Care Med* 2000, **161**:1191–1200.
13. Manthous CA, Morgan S, Pohlman A, Hall JB: **Heliox in the treatment of airflow obstruction.** *Respir Care* 1997, **42**:1034–1042.
14. Boorstein JM, Boorstein SM, Humphries GN, Johnston CC: **Using helium-oxygen mixtures in the emergency management of acute upper airway obstruction.** *Ann Emerg Med* 1989, **18**: 688–690.
15. Weber JE, Chudnofsky CR, Younger JG, Larkin GL, Boczar M, Wilkerson MD, Zuriekat GY, Nolan B, Eicke DM: **A randomized comparison of helium-oxygen mixture (heliox) and racemic epinephrine for the treatment of moderate to severe croup.** *Pediatrics* 2001, **107**:E96.
16. Rodrigo G, Rodrigo C, Pollack C, Travers A: **Helium-oxygen mixture for nonintubated acute asthma patients (Cochrane Review).** Cochrane Database Syst Rev 2001; 1.
17. Kudukis TM, Manthous CA, Schmidt GA, Hall JB, Wylam ME: **Inhaled helium-oxygen revisited: effect of inhaled helium-oxygen during the treatment of status asthmaticus in children.** *J Pediatr* 1997, **130**:217–224.
18. Manthous CA, Hall JB, Caputo MA, Walter J, Klocksieben JM, Schmidt GA, Wood LD: **Heliox improves pulsus paradoxus and peak expiratory flow in nonintubated patients with severe asthma.** *Am J Respir Crit Care Med* 1995, **151**:310–314.
19. Kass JE, Terregino CA: **The effect of heliox in acute severe asthma: a randomized controlled trial.** *Chest* 1999, **116**: 296–300.
20. Darioli R, Perret C: **Mechanical controlled hypoventilation in status asthmaticus.** *Am Rev Respir Dis* 1984, **129**:385–387.
21. Mansel JK, Stogner SW, Petrini MF, Norman JR: **Mechanical ventilation in patients with acute severe asthma.** *Am J Med* 1990, **89**:42–48.
22. Kass JE, Castriotta RJ: **Heliox therapy in acute severe asthma.** *Chest* 1995, **107**:757–760.
23. Brochard L, Mancebo J, Wysocki M, Lofaso F, Conti G, Rauss A: **Non-invasive ventilation for acute exacerbations of chronic obstructive pulmonary disease.** *N Engl J Med* 1995, **333**:17–22.
24. Brochard L, Isabey D, Piquet A, Mancebo J, Messaadi A: **Reversal of acute exacerbations of chronic obstructive lung disease by inspiratory assistance with a face mask.** *N Engl J Med* 1990, **323**:1523–1530.
25. Rossi A, Polese G, Brandi G, Conti G: **Intrinsic positive end-expiratory pressure (PEEPi).** *Intensive Care Med* 1995, **21**:522–536.
26. Hollman G, Shen G, Zeng L, Yngsdal-Krenz R, Perloff W, Zimmerman J, Strayss R: **Helium-oxygen improves clinical asthma scores in children with acute bronchiolitis.** *Crit Care Med* 1998, **26**:1731–1736.
27. Wolfson MR, Bhutani VK, Shaffer TH, Bowen FW Jr: **Mechanics and energetics of breathing helium in infants with bronchopulmonary dysplasia.** *J Pediatr* 1984, **104**:752–757.
28. Pingleton SK, Bone RC, Ruth WC: **Helium-oxygen mixtures during bronchoscopy.** *Crit Care Med* 1980, **8**:50–53.
29. Barr J, Lushkov G, Starinsky R, Klin B, Berkovitch M, Eshel G: **Heliox therapy for pneumothorax: new indication for an old remedy.** *Ann Emerg Med* 1997, **30**:159–162.
30. Barr J, Eshel G, Chen-Levy Z, Lahat E: **Heliox use in the treatment of acute hyperammonemia.** *J Child Neurol* 2001, **16**: 456–458.
31. Tassaux D, Jolliet P, Thouret JM, Roeseler J, Dorne R, Chevrolet JC: **Calibration of seven ICU ventilators for mechanical ventilation with helium-oxygen mixtures.** *Am J Respir Crit Care Med* 1999, **160**:22–32.
32. Chatmongkolchart S, Kacmarek RM, Hess DR: **Heliox delivery with noninvasive positive pressure ventilation: a laboratory study.** *Respir Care* 2001, **46**:248–254.