UDC 615.816.2
DOI 10.31379/2411.2616.15.1.1

PROS AND CONS OF A HIGH-FLOW NASAL OXYGEN THERAPY IN PATIENTS WITH RESPIRATORY FAILURE

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ПЕРЕВАГИ ТА НЕДОЛІКИ ВИСОКОПОТОКОВОЇ НАЗАЛЬНОЇ ОКСИГЕНОТЕРАПІЇ У ПАЦІЄНТІВ З ДИХАЛЬНОЮ НЕДОСТАТНІСТЮ

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Мета: оцінити клінічну ефективність высокопотокової назальної оксигенотерапії (ВПНО) у пацієнтів з дихальною недостатністю.

Методи: Проспективне двоетапне пошукове рандомізоване дослідження 100 пацієнтів з дихальною недостатністю I-II ступеня тяжкості при позагоспітальній правобічній нижньодольовій пневмонії (ПП) і задній медіастинальній гастроезофагопластиці торакоабдомінальним доступом з внутрішньоплевральним анастомозом (ГЕП). На першому етапі порівнювалось використання ВПНО через носові канюлі та неінвазивна масочна вентиляція легенів (НІМВЛ) через носову маску у пацієнтів із ПП. На другому етапі - у пацієнтів з ГЕП - застосування ВПНО і стандартної респіраторної терапії (РТ). Вивчалися зміни індексу оксигенації (PaO2/FiO2); артеріальної сатурації (Sa02), динаміка рентгенологічної та КТ картини органів грудної клітини; оцінювались тривалість сеансу вентиляції; ступінь його переносимості пацієнтом (шкала від 1 до 10); частота необхідності переведення на ШВЛ, тривалість лікування пацієнта в реанімації.

Результати: при позалікарняній пневмонії літні пацієнти комфортніше переносили ВПНО (8±1 бала vs. 4±2 при НІМВЛ) при значимо більшій тривалості сеансу (до 20 год vs.3) при співставних показниках індексу оксигенації і насичення артеріальної крові. Тривалість реанімаційного періоду та необхідність в переведенні на примусові режими вентиляції можна співставні. На другому етапі у пацієнтів після ГЕП при співставних параметрах оксигенації при ВПНО відзначені менша потреба в переведенні на примусову вентиляцію (15% vs.

22,5%), число переходу в ателектаз (50% проти 62,5%) та, відповідно, скорочена тривалість реанімаційного періоду (12±4 vs. 18±3).

Висновки: Використання ВПНО у пацієнтів з дихальною недостатністю показує свою клінічну ефективність, краще переносимо, але не виключає застосування інших методів респіраторної терапії.

Ключові слова: дихальна недостатність; респіраторна терапія, високопоточна оксигенотерапія, неінвазивна вентиляція легенів, інтенсивна терапія.

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PROS AND CONS OF A HIGH-FLOW NASAL OXYGEN THERAPY IN PATIENTS WITH RESPIRATORY FAILURE

Yu.V. Korolyova, A.V. Geyze, G.Z. Edzhibiya, G.P. Plotnikov

Objectives: to evaluate clinical efficiency of high-flow nasal oxygen therapy (HFNOT) in patients with respiratory failure.

Methods: Prospective two-stage randomized clinical trial including 100 patients with I-II grade respiratory failure and community-acquired right-sided lower lobe pneumonia and posterior mediastinal gastro-esophogoplasty (GEP) with thoracoabdominal access and intrapleural anastomosis. At first stage HFNOT and non-invasive mask ventilation (NIMV) were compared for patients with community-acquired pneumonia. At second stage the use of HFNOT and standard respiratory therapy (RT) were evaluated for patients with (GEP). Following characteristics were analyzed: oxygenation index (PaO_2/FiO_2); arterial saturation (SaO_2), chest X-ray and CT-scan; ventilation time; ventilation tolerability (scale from 1 to 10); conversion to mechanical ventilation frequency; ICU-stay.

Results: Patients with community-acquired pneumonia better tolerated HFNOT (8±1 pts vs. 4±2 pts NIMV) with significantly longer ventilation time (up to 20 hrs. vs 3) and with comparable oxygenation index and arterial saturation. ICU-stay and conversion to mechanical ventilation were also comparable. At second stage patients after GEP had comparable oxygenation parameters, but they had lesser conversion to mechanical ventilation rate (15% vs. 22,5%), atelectasis rate (50 vs против 62,5%) and consequently shorter ICU-stay (12±4 vs. 18±3).

Conclusion: HFNOT use in patients with respiratory failure shows clinical efficacy, is more tolerable by patients, but does not exclude other respiratory therapy methods.

Key words: respiratory failure; respiratory therapy; high-flow oxygen therapy; non-invasive lung ventilation; intensive care.

Introduction. Acute respiratory failure is one of the most common causes of admission to ICU, and oxygen therapy remains first-line treatment for these patients. In recent years nasal oxygen insufflation was described as a useful alternative to traditional oxygen therapy in patients with respiratory failure, with all its pros and cons. [1] Respiratory failure symptom control and oxygenation improvement are ensured by maintaining adequate oxygenation and alveolar ventilation, by insufflation of humidified oxygen with high-volume flow (up to 60 l/min) and by reducing lung dead space with a positive end-expiratory pressure flow. [2] Increasing lung resistance by the end of the exhale (35-60 l/min flow leads to mean pressure 2-3 cm H2O with mouth opened and 5– 7 cm H2O with mouth shut) correlates with lung capacities because of better al-

veoli recruitment. [3,4] Oxygen flow going through the nasopharynx washes away CO2, that prevents reverse ventilation and as a consequence physical activity tolerance and oxygenation improves and dyspnea reduction. [5,6]. The use of conditioned gas (i.e. at ideal temperature and humidity) leads to better tolerance and comfort for patients with respiratory failure, which leads to lower respiratory rate and better oxygenation. Active humidification improves function of mucous membrane, relieves secretion and decrease atelectasis forming and improving ventilation/perfusion and oxygenation rate. [7,8]. In comparison with NIMV and standard oxygenation, HFNOT reduces conversion to mechanical ventilation rate due to hypoxemic acute respiratory failure and also reduces frequency of repeated intubation. At the same time using HFNOT prevents from forming too much positive end expiratory pressure that prevents alveoli atelectasis. That is why the main goal of this study is to evaluate clinical benefits and limitations of HFNOT in treatment of patients with respiratory failure in postoperative period.

Methods. Prospective two-stage randomized clinical trial, approved by the local ethical committee, with patients' informed consent. At first stage HFNOT effectiveness for patients with community-acquired right-sided lower love pneumonia and respiratory failure was evaluated. Two groups: 1st (n=10) – with HFNOT (AIRVO-2 device, Fisher and Paykel, New Zealand) through nasal cannula, 2nd (n=10) – non-invasive mask ventilation (NIMV) (VENTimotion, Weinmann, Germany) through face mask; randomization using envelopes. Both groups were comparable in all baseline characteristics, for all of them p >0,05 (table 1). All patients received standard antibacterial treatment (azithromycin 500 mg/day + ceftriaxone 4g/day, until sputum culture data was received) + respiratory treatment. Inclusion criteria: patients with community-acquired right-sided lower lobe pneumonia, respiratory failure grade I-II, (respiratory failure classification Davidson C., Treacher D. Respiratory CriticalCare. London, 2002.) age 70-89.

Exclusion criteria: patients with community-acquired bilateral pneumonia, respiratory failure grade III, age <70 or >89, absence of informed consent.

Parameters of respiratory treatment were adjusted individually using oxygenation index (PaO_2/FiO_2), arterial saturation (SaO_2). The change in these parameters, ventilation duration and patient's tolerability (scale from 1 to 10) and ICU stay were evaluated.

Table 1. Baseline characteristics

	HFNOT, n=10	**NIMV (n=10)**
Age, years, M±σ (min, max)	76±9 (75;81)	74±6 (70;85)
Sex, m/f, n(%)	7/3 (70/30)	6/4 (60/40)
BMI, M±σ (min, max)	22±3(18,25)	21±5 (16,25)
Respiratory failure, n(%):		
I	2 (20)	3 (30)
II	8 (80)	7 (70)
Respiratory rate/min,M±σ (min, max)	19±7 (18;25)	18±5 (17;24)
PaO_2/FiO_2, M±σ (min, max)	260±27 (230;290)	250±35 (230;270)
SO_2, %, M±σ (min, max)	90±5(85;95)	89±4(85;93)

Note: For all characteristics p>0,05. HFNOT- high-flow nasal oxygen therapy. BMI – body mass index. NIMV- non-invasive mask ventilation. PaO_2/FiO_2 – oxygenation index. SaO_2 – capillary blood saturation.

Respiratory complications in patients, who underwent esophagus surgery (esophagus extirpation with simultaneous reconstruction with gastric tube, Lewis type) after tracheoplasty are the most common cause of death in ICU. Since NIMV is contraindicated [10,11] for these patients, at second stage there were evaluated respiratory therapy options for patients with malignant tumors of mid- and lower thoracic esophagus.

Inclusion criteria: patients with subtotal esophagus resection (esophagectomy) and posterior mediastinal gastroesophagoplasty with thoracoabdominal access and intrapleural anastomosis, with no surgical complications, male, age 25-80, extubated, hemodynamically stable.

Exclusion criteria: female, age>80, unstable hemodynamics in postoperative period, patients on prolonged mechanical ventilation; absence of informed consent. Standard basic intense and antibacterial treatment (Ciprofloxacin 40 mg/day, metronidazole 1500 mg/day until sputum culture data received). Two groups: 1st (retrospective, n=40) with standard respiratory therapy – high-volume spirometry and nasal oxygen therapy. 2nd group (prospective, n=60) – with HFNOT (AIRVO-2 device, Fisher and Paykel, *New Zealand).* Both groups were comparable in all baseline characteristics (p>0,05) (table 2).

Parameters of respiratory treatment were adjusted individually until target oxygenation index and arterial saturation were reached. The change in these parameters, ventilation duration and patient's tolerability (scale from 1 to 10) and ICU stay were evaluated.

For data collection Microsoft Access program was used. Statistical analysis was performed using «STATISTICA 6.0» (StatSoft, USA) (№AXXR003E608729FAN10 от 31.03.2010, StatSoft Inc., USA) and Microsoft EXEL.

All results presented as mean value ± standard deviation (σ). To evaluate the diversity significance between all parameters Student's T-test for normal distribution and χ^2–parameter for discrete values were used. P-level <0,05 was considered as significant.

Results. Among-group analysis at 1st stage has shown certain advantages for HFNOT during respiratory therapy in senior patients (table 3)

Patients had no discomfort during long therapy, while NIMV was repeatedly interrupted because of the nasal mask pressure, sense of overfilled with air stomach and etc. Persistence of HFNOT allowed to slowly reduce O_2 flow, that was needed for adequate

Table 2. Baseline characteristics

	RT, n=40	**HFNOT, n=60**
Age, years, M±σ (min, max)	68±12 (58;78)	69±14 (56;80)
BMI, M±σ (min, max)	20±8 (16;24)	21±9 (18;24)
Respiratory failure, n(%): I	6 (15)	10 (16,7)
II	34 (85)	50 (83,3)
Respiratory rate/min, M±σ (min, max)	22±7 (20;29)	21±6 (18;28)
PaO2/FiO2, M±σ (min, max)	280±60 (220;312)	295±75 (215;305)
SO2, %, M±σ (min, max)	90±9 (87;93)	91±14 (88;96)

Note: For all characteristics p>0,05. RT – standard respiratory therapy. HFNOT – high-flow nasal oxygen therapy. BMI – body mass index. NIMV – non-invasive mask ventilation. PaO_2/FiO_2 – oxygenation index. SO_2 – capillary blood saturation.

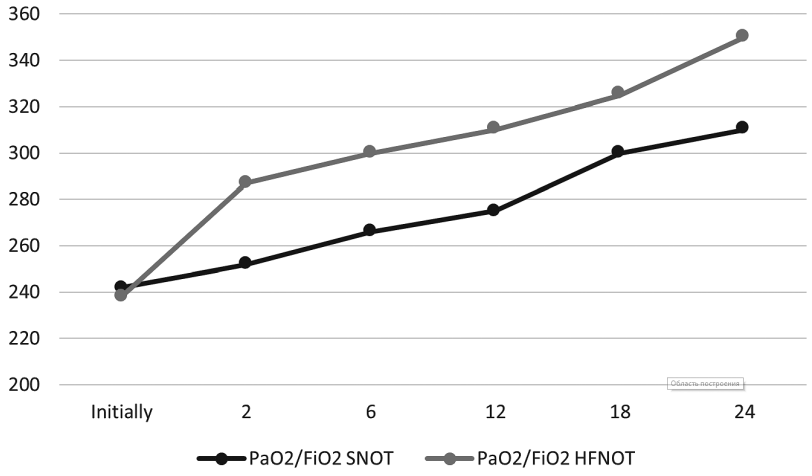
Table 3. Ventilation parameters change and treatment duration at 1st stage

	HFNOT, n=10	NIMV (n=10)	p
Tolerability, score	8,3 [6,5; 9,3]	4,3 [4,1;6,3]	0,039
RT duration, hrs	18,5 [12; 20,5]	3,3 [2,5; 6,9]	<0,01
SO_2, %	96 [91; 98]	94,5 [90,5; 97]	0,09
PaO_2/FiO_2	312 [298; 326]	324 [302; 330]	0,11
Conversion to mechanical ventilation, n (%)	2 (20)	3 (30)	-
ICU-stay, hrs	264 [216; 360]	336 [240; 384]	0,055

Note. P – at among-group analysis of mean values. RT – standard respiratory therapy. HFNOT – high-flow nasal oxygen therapy. NIMV- non-invasive mask ventilation. PaO_2/FiO_2 – oxygenation index. ICU – intensive care unit.

oxygenation index and saturation, whilst in NIMV group oxygen fraction remained high all the time. Also, two conversions to mechanical ventilation in HFNOT group were associated with inflammatory process progression and deterioration of overall condition (sepsis and polyorganic insufficiency syndrome development), and in NIMV group it was associated with spontaneous pneumothorax and its following drainage, which was the cause of a longer ICU-stay. HFNOT was considered effective in patients with respiratory failure, that is why this technique was used in postoperative period on patients after esophagectomy and posterior mediastinal gastroesophagoplasty via thoracoabdominal access and intrapleural anastomosis.

In this group of patients high flow with manageable fraction of O_2 allows to reach target oxygenation index levels at comparable saturation (94±3%; min 91; max 97) at standard oxygenation and 96±4% (min 92; max 100) at high-flow oxygenation (pic. 1).



Picture 1. Changes in saturation and oxygenation index in 1 day in patients after posterior mediastinal gastroesophagoplasty and intrapleural anastomosis using standard nasal oxygenation therapy and high-flow nasal oxygen therapy.

Note. X-axis – hours of monitoring, Y-axis – oxygenation index (PaO_2/FiO_2). SNOT – standard nasal oxygen therapy –HFNOT – high-flow nasal oxygen therapy.

Table 4. Clinical data and treatment duration on 2nd stage

	SNOT, n=40	HFNOT (n=60)	p
Atelectasis, n (%)	28 (70)	30 (50)	<0,01*
Conversion to MV, n (%)	13 (32,5)	9 (15)	<0,01*
ICU-stay, M±σ (min, max)	16±12 (4;28)	8,5±5,5(3;14)	0,039**

Note. p* – comparing relative values; p** – comparing mean values. SNOT – standard nasal oxygen therapy. HFNOT – high-volume nasal oxygen therapy. MV – mechanical ventilation. ICU – intensive care unit.

At the same time humidified and warm air mixture with constant end expiratory pressure prevents atelectasis by alveoli recruitment, that reduce infiltrative lung changes and thus lower conversion to mechanical ventilation rate as well as ICU-stay (table.4)

The most frequent cause of conversion to MV in both groups was progression of respiratory failure because of septical polyorganic insufficiency syndrome due to gastroesophageal anastomosis dehiscence (10-45,45%), as well as hospital-acquired pneumonia (8-36,4%); occasionally – total pneumo- and hydrothorax (4-18,2%).

Discussion. HFNOT can be used as an alternative to NIMV or to provide adequate oxygenation during cessation from NIMV. Choosing one of these methods depends on different factors, such as necessity of ventilation, positive end expiratory pressure (PEEP), patient's preference and NIMV mask tolerability. For example, HFNOT hardly provides necessary PEEP for certain patients (acute respiratory distress syndrome) and can't be used for those who need NIMV for ventilation (i.e. hypercapnic hypoxemic respiratory failure due to hypoventilation). [12,13]. Advantages of this method is good tolerability, constant humidification and warming of oxygen mix, absence of face sore and macerations from face mask, prevention of atelectasis development. However, if atelectasis have already occurred, it is more preferable to use NIMV, as you can manage different modes, pressure flows depending on atelectasis level [14, 15]. At the same time, we have faced mismatch between favourable oxygenation index and x-ray image, same mismatch is described by other researchers in different studies [16]. Probably, it can complicate acute respiratory distress syndrome (ARDS) diagnosis via oxygenation index. Some authors consider oxygenation improvement in ARDS patients on HFNOT could lead to misdiagnosis. This theoretical disadvantage can be improved by potential benefits, such as lower lung damage on mechanical ventilation, interruption of hypoxemic respiratory failure progression to ARDS [16, 19]. That is why we are measuring oxygenation index on proper breathing with 21% oxygen-air mix and routine examination (CT-scan, chest X-ray) to detect any signs of infiltrative changes in lungs.

Contraindications for HFNOT include anomalies, traumas or surgery on face, nose or airways that exclude nasal catheter use, central apnea, and upper airway obstruction [22, 23]. Some authors don't use HFNOT after upper airway surgery to avoid theoretical risk of venous thromboembolism (VTE) at high pressure [19]. We prefer set initial flow speed from 20 to 35 l/min (potential range is 5 to 60 l/min) and FiO2 40% (range from 30 to 70 %), further changes could be done depending on clinical response. HFNOT can be used for a long period of time (hours, days) and patients can be switched to standard nasal catheters with low flow as soon as flow speed reaches ≤20 l/min and FiO2 ≤35 %.

Such subsequence, as we assume, allows avoiding excess pressure and as a consequence, during our study no VTE occurred.

HFNOT complications include abdominal distension, aspiration and, rarely, barotrauma (pneumothorax). However, barotrauma incidence is way lower then while using NIMV or mechanical ventilation via endotracheal tube [19,20].

Conclusion. The use of high-flow nasal oxygen therapy is reasonable as a part of complex respiratory therapy in patients with mild or moderate respiratory failure. Advantages of HFNOT compared to standard oxygen delivery systems are higher comfort, increased humidification of tracheobronchial secretions for better sputum expectoration, decreasing dead space to enhance ventilation effectiveness. However, there are no absolute indications to HFNOT and most of the proven benefits are subjective and physiological. Patients with severe hypoxemic respiratory failure, as we assume, HFNOT will be an alternative to other methods with high flow and non-invasive ventilation. Choosing between these methods should be personalized and should depend on patient's condition, preference, severity of hypoxemia, requirement of ventilation and positive end expiratory pressure.

Study limitations. Single-center, on a small patient selection, with retrospective analysis.

Disclosures. Authors of this study have nothing to disclose.

ЛІТЕРАТУРА

1. Masclans, J.R., Roca, O. High-flow oxygen therapy in acute respiratory failure. / J.R. Masclans, O. Roca // Clin Pulm Med. – 2012. – Vol. 19. – P. 127-130.
2. Research in high flow therapy: mechanisms of action. / K. Dysart [et al.] // Respir Med. – 2009. – Vol. 103. – P. 1400- 1405. http://dx.doi.org/10.1016/j.rmed.2009.04.007 | Medline
3. Oxygen delivery through high-flow nasal cannulae increase end-expiratory lung volume and reduce respiratory rate in post-cardiac surgical patients. / A. Corley [et al.] // Br J Anaesth. – 2011. – Vol. 107. – P. 998-1004. http://dx.doi.org/10.1093/bja/aer265 | Medline
4. Impact of high-flow nasal cannula oxygen therapy on intensive care unit patients with acute respiratory failure: a prospective observational study. / B. Sztrymf [et al.] // J Crit Care. – 2012. – Vol. 27. – P. 324. http://dx.doi.org/10.1016/j.jcrc.2011.07.075 | Medline
5. Dewan, N.A., Bell, C.W. Effect of low flow and high flow oxygen delivery on exercise tolerance and sensation of dyspnea. A study comparing the transtracheal catheter and nasal prongs. / N.A. Dewan, C.W. Bell // Chest. – 1994. – Vol. 105. – P. 1061-1065.
6. The effects of high-flow vs low-flow oxygen on exercise in advanced obstructive airways disease. / W. Chatila [et al.] // Chest. – 2004. – Vol. 126. – P. 1108-1115. http://dx.doi.org/10.1378/chest.126.4.1108 | Medline
7. Ricard, J.D., Boyer, A. Humidification during oxygen therapy and non-invasive ventilation: do we need some and how much? / J.D. Ricard, A. Boyer // Intensive Care Med. – 2009. – Vol. 35. – P. 963-965. http://dx.doi.org/10.1007/s00134-009-1457-9 | Medline
8. Beneficial effects of humidified high flow nasal oxygen in critical care patients: a prospective pilot study. / B. Sztrymf [et al.] // Intensive Care Med. – 2011. – Vol. 37. – P. 1780-1786. http://dx.doi.org/10.1007/s00134-011-2354-6 | Medline
9. Parke, R., McGuinness, S., Eccleston, M. Nasal high-flow therapy delivers low level positive airway pressure. / R. Parke, S. McGuinness, M. Eccleston // Br J Anaesth. – 2009. – Vol. 103. – P. 886-890. http://dx.doi.org/10.1093/bja/aep280 | Medline
10. A multiple-center survey on the use in clinical practice of noninvasive ventilation as a first-line intervention for acute respiratory distress syndrome. / M. Antonelli [et al.] // Crit Care Med. – 2007. – Vol. 35. – P.18-25.

11. Esophageal perforation associated with noninvasive ventilation: a case report. / A. Van de Louw [et al.] // Chest. – 2002. – Vol. 122. – P. 1857-8.
12. Dysart, K. et al. Research in high flow therapy: mechanisms of action. / K. Dysart [et al.] // Respir Med. – 2009. – Vol. 103. – P. 1400.
13. Parke, R., McGunness, S., Eccleston, M. Nasal high-flow therapy delivers low level positive airway pressure. / R. Parke, S. McGunness, M. Eccleston // Br J Anaesth. – 2009. – Vol. 103. – P. 886–90.
14. High-flow oxygen therapy in acute respiratory failure. / O. Roca [et al.] // Respir Care. – 2010. – Vol. 55. – P. 408.
15. High-flow nasal oxygen vs high-flow face mask: a randomized crossover trial in extubated patients. / R. Tiruvoipati [et al.] // J Crit Care. – 2010. – Vol. 25. – P. 463.
16. Chertoff, J. High-Flow Oxygen, Positive End-Expiratory Pressure, and the Berlin Definition of Acute Respiratory Distress Syndrome: Are They Mutually Exclusive? / J. Chertoff // Am J Respir Crit Care Med. – 2017. – Vol. 196. – P. 396.
17. Applications of nasal high-flow oxygen therapy in critically ill adult patients. / J. Porhomayon [et al.] // Lung. – 2016. – Vol. 194(5). – P. 705-14.
18. Failure of high-flow nasal cannula therapy may delay intubation and increase mortality. / B.J. Kang [et al.] // Intensive Care Med. – 2015. – Vol. 41. – P. 623–632.
19. Brochard, L., Slutsky, A., Pesenti, A. Mechanical Ventilation to Minimize Progression of Lung Injury in Acute Respiratory Failure. / L. Brochard, A. Slutsky, A. Pesenti // Am J Respir Crit Care Med. – 2017. – Vol. 195. – P. 438.
20. Hegde, S., Prodhan, P. Serious air leak syndrome complicating highflow nasal cannula therapy: a report of 3 cases. / S. Hegde, P. Prodhan // Pediatrics. – 2013. – Vol. 131(3). – P. 939–944.

REFERENCES

1. Masclans, J.R., Roca, O. High-flow oxygen therapy in acute respiratory failure. Clin Pulm Med, 2012, vol. 19, pp. 127-130.
2. Dysart, K. et al. Research in high flow therapy: mechanisms of action. Respir Med, 2009, vol. 103, pp. 1400- 1405. http://dx.doi.org/10.1016/j.rmed.2009.04.007 | Medline
3. Corley, A. 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, vol. 107, pp. 998-1004. http://dx.doi.org/10.1093/bja/aer265 | Medline
4. Sztrymf, B. et al. Impact of high-flow nasal cannula oxygen therapy on intensive care unit patients with acute respiratory failure: a prospective observational study. J Crit Care, 2012, vol. 27, pp. 324. http://dx.doi.org/10.1016/j.jcrc.2011.07.075 | Medline
5. Dewan, N.A., Bell, C.W. Effect of low flow and high flow oxygen delivery on exercise tolerance and sensation of dyspnea. A study comparing the transtracheal catheter and nasal prongs. Chest, 1994, vol. 105, pp. 1061-1065.
6. Chatila, W. et al. The effects of high-flow vs low-flow oxygen on exercise in advanced obstructive airways disease. Chest, 2004, vol. 126, pp. 1108-1115. http://dx.doi.org/10.1378/chest.126.4.1108 | Medline
7. Ricard, J.D., Boyer, A. Humidification during oxygen therapy and non-invasive ventilation: do we need some and how much? Intensive Care Med, 2009, vol. 35, pp. 963-965. http://dx.doi.org/10.1007/s00134-009-1457-9 | Medline
8. Sztrymf, B. et al. Beneficial effects of humidified high flow nasal oxygen in critical care patients: a prospective pilot study. Intensive Care Med, 2011, vol. 37, pp. 1780-1786. http://dx.doi.org/10.1007/s00134-011-2354-6 | Medline
9. Parke, R., McGuinness, S., Eccleston, M. Nasal high-flow therapy delivers low level positive airway pressure. Br J Anaesth, 2009, vol. 103, pp. 886-890. http://dx.doi.org/10.1093/bja/aep280 | Medline

10. Antonelli, M. et al. A multiple-center survey on the use in clinical practice of noninvasive ventilation as a first-line intervention for acute respiratory distress syndrome. Crit Care Med, 2007, vol. 35, pp.18-25.
11. Van de Louw, A., et al. Esophageal perforation associated with noninvasive ventilation: a case report. Chest, 2002, vol. 122, pp. 1857-8.
12. Dysart, K. et al. Research in high flow therapy: mechanisms of action. Respir Med, 2009, vol. 103, pp. 1400.
13. Parke, R., McGunness, S., Eccleston, M. Nasal high-flow therapy delivers low level positive airway pressure. Br J Anaesth, 2009, vol. 103, pp. 886–90.
14. Roca, O. et al. High-flow oxygen therapy in acute respiratory failure. Respir Care, 2010, vol. 55, pp. 408.
15. Tiruvoipati, R. et al. High-flow nasal oxygen vs high-flow face mask: a randomized crossover trial in extubated patients. J Crit Care, 2010, vol. 25, p. 463.
16. Chertoff, J. High-Flow Oxygen, Positive End-Expiratory Pressure, and the Berlin Definition of Acute Respiratory Distress Syndrome: Are They Mutually Exclusive? Am J Respir Crit Care Med, 2017, vol. 196, p. 396.
17. Porhomayon, J. et al. Applications of nasal high-flow oxygen therapy in critically ill adult patients. Lung, 2016, vol. 194(5), pp. 705-14.
18. Kang, B.J. et al. Failure of high-flow nasal cannula therapy may delay intubation and increase mortality. Intensive Care Med, 2015, vol. 41, pp. 623–632.
19. Brochard, L., Slutsky, A., Pesenti, A. Mechanical Ventilation to Minimize Progression of Lung Injury in Acute Respiratory Failure. Am J Respir Crit Care Med, 2017, vol. 195, p. 438.
20. Hegde, S., Prodhan, P. Serious air leak syndrome complicating highflow nasal cannula therapy: a report of 3 cases. Pediatrics, 2013, vol. 131(3), pp. 939–944.

Submitted 16.12.2019
Reviewer MD, prof. A. Zlotnik, date of review 20.12.2019