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经鼻高流量湿化氧疗与无创正压通气在改善 AECOPD 患者 二氧化碳潴留临床疗效的比较 *

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摘要 目的:经鼻高流量氧疗(HFNC)已广泛应用于缺氧性呼吸衰竭患者的治疗。本研究分析了 HFNC 治疗对慢性阻塞性肺疾病急性加重(AECOPD)合并 II 型呼吸衰竭的治疗效果。**方法:**本研究前瞻性观察分析了 2017 年 1 月至 2019 年 1 月入住我院呼吸科和重症医学科,诊断为 AECOPD 且合并有中度 II 型呼吸衰竭(血气分析 $\text{PaO}_2/\text{FiO}_2 < 200 \text{ mmHg}$, $\text{PaCO}_2 > 45 \text{ mmHg}$, $\text{pH} 7.25 \sim 7.35$)的患者 44 例,随机平均分为两组,参照组 22 例患者采用无创正压通气(NIV)技术治疗,实验组 22 例患者予以 HFNC 治疗。观察两组患者治疗效果(治疗失败改为有创通气、28 天死亡率)、血气分析对比血 pH、 PaCO_2 、 PaO_2 。**结果:**HFNC 组患者(22 例,平均年龄 73 岁,男性占 63.6%)同 NIV 组患者(22 例,平均年龄 77 岁,男性占 54.5%)相比,血 pH、 PaCO_2 、 PaO_2 等血气分析指标两组无显著统计学差异。治疗失败率分别为 22.7% (5/22)和 27.2% (6/22), $P=0.857$ 。28 天死亡率无统计学差异(HFNC 组为 13.6%, NIV 组为 18.2%, $P=0.845$)。**结论:**在 AECOPD 合并 II 型呼吸衰竭的患者中, HFNC 在改善氧合缓解 CO_2 潴留方面具有同 NIV 相似的效应,因其具有更好的舒适性和耐受性,可成为 NIV 的有益补充。

关键词:经鼻高流量吸氧; 无创正压通气; 慢性阻塞性肺疾病急性加重

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High-flow Nasal Cannula Oxygen Therapy Compared with Non-invasive Ventilation For Improving Carbon Dioxide Retention in Patients with AECOPD*

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ABSTRACT Objective: High-flow Nasal Cannula therapy (HFNC) has been widely used in the treatment of hypoxic respiratory failure. The objective of this study is to analyze the therapeutic effect of HFNC on AECOPD (acute exacerbation of chronic obstructive pulmonary disease) complicated with type II respiratory failure. **Methods:** This study prospectively observed and analyzed 44 patients who were admitted to the respiratory department and critical medicine department of our hospital from January 2017 to January 2019, and diagnosed as AECOPD and complicated with moderate type II respiratory failure (blood gas analysis showed that $\text{PaO}_2/\text{FiO}_2 < 200 \text{ mmHg}$, $\text{PaCO}_2 > 45 \text{ mmHg}$, $\text{pH} 7.25 \sim 7.35$). They were randomly divided into two groups. 22 patients in the control group were treated with NIV (non-invasive ventilation), and 22 patients in the experimental group were treated with HFNC. The therapeutic effects of the two groups were observed (the treatment failed and was changed to invasive ventilation, 28-day mortality), blood pH, PaCO_2 and PaO_2 of the two groups were compared. **Results:** There was no significant difference in blood gas analysis indexes such as pH, PaCO_2 and PaO_2 between HFNC group (22 cases, average age 73 years old, male accounted for 63.6%) and NIV group (22 cases, average age 77 years old, male 54.5%). The treatment failure rates were 22.7% (5/22) and 27.2% (6/22) respectively ($P=0.857$). There was no statistical difference in 28-day mortality (13.6% in the HFNC group and 18.2% in the NIV group, $P=0.845$). **Conclusions:** In patients with AECOPD complicated with type II respiratory failure, HFNC has a similar effect as NIV in improving oxygenation and alleviating CO_2 retention. Because of its better comfort and tolerance, it can be a useful supplement to NIV.

Key words: High-flow Nasal Cannula; Non-invasive Ventilation; Acute Exacerbation of Chronic Obstructive Pulmonary Disease

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前言

慢性阻塞性肺疾病(chronic obstructive pulmonary disease, COPD)是呼吸系统常见病和多发病。慢性阻塞性肺疾病急性加重(acute exacerbation of chronic obstructive pulmonary disease, AECOPD)是指各种诱因导致的呼吸道症状急剧恶化,需要额外的治疗^[1]。AECOPD的主要临床表现常为呼吸困难、痰量增加和咳脓性痰三联征,是慢阻肺患者死亡的重要因素^[2]。其引发的急性呼吸衰竭常需要进行呼吸支持治疗。无创正压通气(Non-invasive ventilation, NIV)是AECOPD合并轻-中度呼吸衰竭(pH 7.25-7.35)的首选治疗方式^[3],可以改善症状、提高氧合、缓解二氧化碳潴留,能够有效降低插管率和死亡率^[4,5]。经鼻高流量氧疗(high-flow nasal cannula, HFNC),是近年来逐步在临床上普及的新型氧疗技术。HFNC能够提供精确的吸入氧浓度(21-100%),具备良好的气道湿化效果,同时可提供8-80 L/min的高流速吸入气体^[6]。HFNC通过鼻塞进行氧疗,舒适性和耐受性均显著提升^[7]。HFNC已经应用于单纯低氧性呼吸衰竭的治疗,在以重症肺炎为主的急性I型呼吸衰竭的多中心随机对照研究显示,HFNC能够改善患者90天生存率^[8]。Frizzola^[9]等人的研究显示在动物模型上,随着HFNC气体流速的增加,二氧化碳分压(PaCO₂)逐步降低,从而证明HFNC具有降低PaCO₂的效应。2014年Okuda首次报导对AECOPD患者进行HFNC治疗,并成功改善通气提高意识水平^[10]。Bräunlich等对36名稳定期高碳酸血症患者进行HFNC治疗,发现所有患者的PaCO₂均有显著降低^[11]。对于AECOPD患者,呼吸支持治疗旨在改善患者氧和纠正缺氧同时改善肺通气降低二氧化碳分压,目前HFNC是否能够缓解急性II型呼吸衰竭尚无定论,本研究通过与无创正压通气进行对比来评价HFNC对AECOPD合并II型呼吸衰竭的治疗效果,尤其是其在降低PaCO₂改善二氧化碳潴留方面的具体效应。

1 资料与方法

1.1 临床材料

选择2017年1月至2019年1月就诊于我院呼吸和重症医学科的住院患者,依据慢性阻塞性肺疾病全球倡议(GOLD)标准诊断为AECOPD,且合并有中度II型呼吸衰竭(PaO₂/FiO₂ < 200 mmHg, PaCO₂ > 45 mmHg, pH 7.25~7.35),入组患者44例。排除标准:① 支气管哮喘;② 肺癌;③ 血流动力学不稳定且难以纠正;④ 存在NIV或HFNC禁忌;⑤ 患者不耐受或难以配合。本研究内容经医院伦理委员会批准。

1.2 研究方法

本研究是一项前瞻性观察试验。将入选的44例患者分为HFNC和NIV两组,每组各22例。入院后分别使用HFNC和NIV技术治疗呼吸衰竭。HFNC组使用Fisher&Paykel Optiflow system(Fisher&Paykel Healthcare, Auckland, New Zealand)进行治疗。初始设置FiO₂为50%,流速为30 L/min,温度为37℃;逐步进行滴定至血氧饱和度维持在92%以上以及能够耐受的最大流速(45-60 L/min),治疗过程中注意观察患者闭口呼吸情况及鼻塞佩戴的严密程度。NIV组使用Philips Respironics V60 Ventilator(Respironics California, California, USA)进行治疗,选

用BiPAP S/T模式,初始ipap设置为10 cmH₂O, epap设置为5 cmH₂O,随后逐步调整ipap至最高20 cmH₂O,直至实现目标VT 7-10 mL/kg及血氧饱和度维持在92%以上。并在血pH ≥ 7.35,呼吸频率 < 25次/分,持续24小时以上停止无创呼吸治疗。

1.3 临床观察指标

患者入院时基线血气分析和接受呼吸支持治疗后6小时及24小时的血气分析、呼吸支持时间、并发症、气管插管率、入住ICU时间等。

1.4 统计学分析

采用SPSS进行数据处理和统计学分析,计量资料以($\bar{x} \pm s$)或中位数(四分位数间距)[M(Q,Q)]表示,组间比较行t检验,组内不同时间点比较采用方差分析, $P < 0.05$ 为差异有统计学意义。

2 结果

2.1 患者一般情况

本研究期间的AECOPD患者,经血气分析诊断合并II型呼吸衰竭,排除支气管哮喘、肺癌、血流动力学不稳定且难以纠正、存在NIV或HFNC禁忌、患者不耐受或难以配合等情况,最终共入组44例。其中HFNC组22例, NIV组22例。HFNC组和NIV组患者,平均年龄分别为73岁和77岁,男性分别占63.6%和54.5%,合并高血压分别占43.2%和50%,合并糖尿病分别占27.3%和38.6%,合并心功能衰竭分别占13.6%和25.0%,以肺炎为诱发因素分别占45.5%和40.9%。两组患者在性别、年龄、合并基础疾病、AECOPD的诱因、入院APACHEII评分等指标进行统计,无显著统计学差异,详见表1。并对患者入院时生命体征、相关血气分析实验室检查等基线指标进行对比未见显著统计学差异,详见表2。

2.2 血气分析

两组患者经HFNC或NIV治疗后6小时和24小时后的血气分析对比pH值、PaO₂、PaCO₂,结果均无显著统计学差异,详见图1。

2.3 治疗效果

两组患者均给予抗炎、解痉平喘、化痰、维持内环境稳定、营养支持、基础疾病治疗等药物治疗。观察两组患者治疗失败改为有创通气、呼吸支持时间、28天死亡率等情况,结果均无显著统计学差异,详见表3。

3 讨论

氧疗被认为是AECOPD非药物治疗的基础,对于低氧患者进行控制性氧疗已经达成共识。氧疗虽然可以改善患者氧和状态,但若合并明显的呼吸性酸中毒时,二氧化碳潴留的问题便成为临床治疗中的焦点。无创正压通气是AECOPD的常规治疗手段,是一种通过鼻罩或面罩进行呼吸支持的正压机械通气技术,能够减少气管插管或气管切开等损伤避免呼吸机相关性肺炎。对于具备指征的患者应用NIV治疗可以改善症状、提高氧合、缓解二氧化碳潴留,能够有效降低插管率和死亡率^[4]。NIV的治疗成功率约80%^[12]。重度呼吸衰竭的患者(pH值 < 7.25)往往合并意识水平下降,缺乏气道保护能力,严重的呼吸衰竭往往令患者呼吸微弱难以触发呼吸机通气,而NIV治疗

表 1 两组患者入院时的一般状况
Table 1 General condition of two groups of patients at admission

Index	HFNC(n=22)	NIV(n=22)	P
age	73(68-79)	77(71-80)	0.412
gender male/female	14/8	12/10	0.803
basic diseases			
hypertension	10(43.2)	11(50.0)	0.521
diabetes	6(27.3)	8(38.6)	0.257
cardiac failure	3(13.6)	6(25.0)	0.177
AECOPD inducement			
pneumonia	10	9	0.829
Upper respiratory tract infection	4	6	0.211
cardiac failure	2	3	0.484
unknown	6	4	0.113
APACHE II score at admission	16(11.5-24)	16.5(13-21)	0.540

Abbreviations: HFNC, High flow nasal cannula oxygen therapy; NIV, Non-invasive ventilation.

表 2 患者入院时生命体征及实验室检查状况
Table 2 Vital signs and laboratory examination on admission

Index	HFNC	NIV	P
Mean blood pressure	90.5(79.2-101)	99.5(81.7-113.7)	0.242
PR	106(89.5-117.5)	106.5(91.5-123)	0.277
RR	24(20-28)	26(22-31)	0.235
SpO ₂	88.2±2.7	88.9±3.0	0.66
pH	7.32±0.15	7.31±0.03	0.595
PaO ₂ /FiO ₂	134.6±6.8	133.9±7.8	0.893
PaCO ₂	54.5±8.9	52.6±10.1	0.67
Hb	12.5±2.5	12.9±1.7	0.342
WBC	12.36±0.67	12.43±0.52	0.272

Abbreviations: HFNC, High flow nasal cannula oxygen therapy; NIV, Non-invasive ventilation.

时呼吸机触发比例下降势必会导致通气效率的下降以及腹胀等并发症的出现,因此目前指南不支持对意识障碍患者进行 NIV 治疗^[13]。在临床应用中,呼吸道是否通畅、通气触发、人机同步性以及 NIV 之后的密切观察都是 NIV 能否成功的关键因素^[14-17]。同时患者的耐受性和依从性也是影响 NIV 治疗效果的因素之一^[18]。

HFNC 是一种新的氧疗手段,具有良好的耐受性^[19]。相较于 NIV, HFNC 主要通过鼻塞连接,治疗过程中患者可以咳嗽、进食以及语言表达;具有 PEEP 效应但不够准确且较为有限,同时其基本不需要人机配合,耐受性进一步提高。由此可见 HFNC 的优势在于非人机同步、舒适性及提供恒温恒湿和相对精准的 FiO₂, NIV 则由于能够避免气管插管、改善通气、减少呼吸做功而作为 AECOPD 治疗的首选。目前 HFNC 应用主要集中在轻中度的低氧性呼吸衰竭,对于伴有通气功能受限的 II 型呼吸衰竭的临床疗效尚不确切。

在此研究中,我们统计了患者进行 HFNC 和 NIV 治疗后 6 小时及 24 小时后血气分析的变化情况。HFNC 组血气分析结果显示,在治疗 6 小时和 24 小时后 pH 值逐步提升,同时 PaCO₂ 缓慢降低, PaO₂ 在治疗一段时间后趋于稳定,呼吸性酸中毒得到纠正。同 NIV 组相比血 pH、PaCO₂、PaO₂ 等指标两组无显著统计学差异。AECOPD 合并 II 型呼吸衰竭的病理生理学机制为不断恶化的通气血流比例(V/Q),气道阻力的增加以及气道陷闭和内源性 PEEP 导致的呼气困难。多项研究表明 NIV 能降低 AECOPD 患者的 PaCO₂, 缓解呼吸窘迫^[20-22]。血气分析结果显示 HFNC 在改善氧合缓解 CO₂ 潴留方面具有与 NIV 相似的效应。HFNC 治疗 AECOPD 合并 II 型呼吸衰竭的机制主要考虑为生理死腔冲刷效应^[23], HFNC 提供的流速可调的高流量吸入气,能够对呼气末残留在鼻腔、口腔以及咽部的解剖无效腔进行冲刷,明显减少这些部位潴留的 CO₂, CO₂ 的重复吸入会显著降低^[24]。CO₂ 的清除效率与 HFNC 气体流速及治疗时间

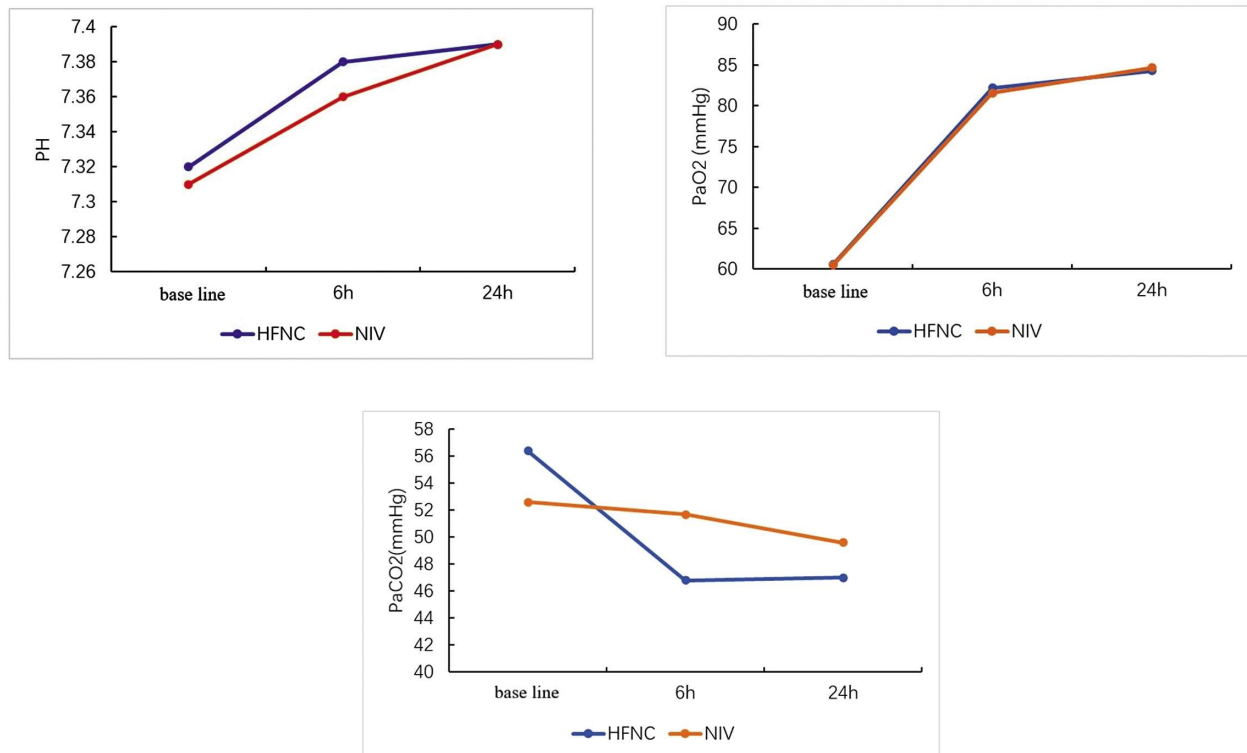


图1 两组患者治疗后血气分析对比

Fig.1 Comparison of blood gas analysis between the two groups after treatment

表3 两组患者临床治疗效果

Table 3 Clinical therapeutic effect of two groups of patients

Index	HFNC(N=22)	NIV(N=22)	P
intubaiton	5	6	0.857
Treatment time	8	7	0.978
28-day mortality	3	4	0.845

Abbreviations: HFNC, High flow nasal cannula oxygen therapy; NIV, Non-invasive ventilation.

相关^[25]。据研究证实 HFNC 能够改善 AECOPD 患者的低氧状态,降低呼吸频率^[26,27]。理论上讲,HFNC 能够对鼻咽部生理死腔产生气体冲刷效应,鼻咽部虽然只占整个呼吸系统生理无效腔约 30 %的体积,但很显然对于以无效腔显著增高为基本病理生理改变的 COPD 患者来说,HFNC 的冲刷效应具有临床治疗意义^[28]。Rosa 等^[29]对机械通气治疗后的危重 AECOPD 患者拔管后序贯 HFNC 和常规面罩氧疗,通过监测两组患者膈肌电位来评估患者呼吸肌做功强度,结果显示 HFNC 组呼吸肌做功显著低于常规氧疗组,并推断 HFNC 有利于 AECOPD 重症患者成功脱机。Fraser 等^[30]使用电阻抗断层成像技术证实相较于鼻导管吸氧,HFNC 能够降低 COPD 患者慢性期长期氧疗的呼吸频率,增加患者潮气量,减少呼吸做功。这些针对不同患者的研究,结果均能为 HFNC 用于 AECOPD 的治疗提供借鉴。

对于 AECOPD 患者,在临床结局上,HFNC 组与 NIV 组在气管插管率、病死率等临床终点指标上相比,无显著统计学差异。目前对于 HFNC 治疗 AECOPD 的研究尚不充分,但因具有更好的舒适性和耐受性,正逐步被大家所接受,由于本研究的样本数量有限,尚不能证明其治疗 AECOPD 合并呼吸衰的显

著优越性,但对于无法实施 NIV 的患者,HFNC 也许可以成为治疗的选择。HFNC 在提供充分湿化精确 FiO₂ 吸入气体;不依赖人机同步;不影响进食与沟通;具有更好的舒适性和耐受性,为临床治疗提供更多选择,可以成为 NIV 的有益补充,也能满足多样的临床治疗需求。

参考文献(References)

- [1] Yves Flattet, Nicolas Garin, Jacques Serratrice, et al. Determining Prognosis in Acute Exacerbation of COPD [J]. *Int J Chron Obstruct Pulmon Dis*, 2017, 12: 467-475
- [2] 慢性阻塞性肺疾病急性加重(AECOPD)诊治专家组,慢性阻塞性肺疾病急性加重(AECOPD)诊治中国专家共识(2017 年更新版) [J]. *国际呼吸杂志*, 2017, 37(14): 1041-1057
- [3] Rochweg B, Brochard L, Elliott MW, et al. Official ERS/ATS clinical practice guidelines: noninvasive ventilation for acute respiratory failure[J]. *Eur Respir J*, 2017, 50(2): 1602426
- [4] Wedzicha JA, Ers Co-Chair, Miravittles M, Hurst JR, et al. Management of COPD exacerbations: a European Respiratory Society/American Thoracic Society guideline [J]. *Eur Respir J*, 2017, 49(3): 1600791

- [5] Kramer N, Meyer TJ, Meharg J, et al. Randomized, prospective trial of noninvasive positive pressure ventilation in acute respiratory failure [J]. *Am J Respir Crit Care Med*, 1995, 151(6): 1799-1806
- [6] Cortegiani A, Accurso G, Mercadante S, et al. High flow nasal therapy in perioperative medicine: from operating room to general ward [J]. *BMC Anesthesiol*, 2018, 18(1): 166
- [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 [J]. *Am J Respir Crit Care Med*, 2014, 190(3): 282-288
- [8] Frat JP, Thille AW, Mercat A, et al. High-Flow oxygen through nasal cannula in acute hypoxemic respiratory failure [J]. *N Engl J Med*, 2015, 372(23): 2185-2196
- [9] Frizzola M, Miller TL, Rodriguez ME, et al. High-flow nasal cannula: impact on oxygenation and ventilation in an acute lung injury model [J]. *Pediatr Pulmonol*, 2011, 46(1): 67-74
- [10] Okuda M, Kashio M, Tanaka N, et al. Nasal high-flow oxygen therapy system for improving sleep-related hypoventilation in chronic obstructive pulmonary disease: a case report [J]. *J Med Case Rep*, 2014, 8: 341
- [11] Bräunlich J, Mauersberger F, Wirtz H. Effectiveness of nasal highflow in hypercapnic COPD patients is flow and leakage dependent [J]. *BMC Pulm Med*, 2018, 18(1): 14
- [12] Sean P Keenan, Tasnim Sinuff, Karen E A Burn, et al. Clinical practice guidelines for the use of noninvasive positive-pressure ventilation and noninvasive continuous positive airway pressure in the acute care setting [J]. *CMAJ*, 2011, 183(3): E195-214
- [13] Michael G Allison, Michael E Winters. Noninvasive Ventilation for the Emergency Physician [J]. *Emerg Med Clin North Am*, 2016, 34(1): 51-62
- [14] Gregoretti C, Pisani L, Cortegiani A, et al. Noninvasive ventilation in critically ill patients [J]. *Crit Care Clin*, 2015, 31(3): 435-457
- [15] Longhini F, Colombo D, Pisani L, et al. Efficacy of ventilator waveform observation for detection of patient-ventilator asynchrony during NIV: a multicentre study [J]. *ERJ Open Res*, 2017, 3(4): 00075-2017
- [16] Nava S, Hill N. Non-invasive ventilation in acute respiratory failure [J]. *Lancet*, 2009, 374(9685): 250-259
- [17] Bruni A, Garofalo E, Pelaia C, et al. Patient-ventilator asynchrony in adult critically ill patients [J]. *Minerva Anesthesiol*, 2019, 85(6): 676-688
- [18] Liu J, Duan J, Bai L, Zhou L. Noninvasive Ventilation Intolerance: Characteristics, Predictors, and Outcomes [J]. *Respir Care*, 2016, 61(3): 277-284
- [19] Longhini F, Pisani L, Lungu R, et al. High-Flow Oxygen Therapy After Noninvasive Ventilation Interruption in Patients Recovering From Hypercapnic Acute Respiratory Failure: A Physiological Crossover Trial [J]. *Crit Care Med*, 2019, 47(6): e506-e511
- [20] Lindenauer PK, Stefan MS, Shieh MS, et al. Outcomes associated with invasive and noninvasive ventilation among patients hospitalized with exacerbations of chronic obstructive pulmonary disease [J]. *JAMA Intern Med*, 2014, 174(12): 1982-1993
- [21] Osadnik CR, Tee VS, Carson-Chahhoud KV, et al. Non-invasive ventilation for the management of acute hypercapnic respiratory failure due to exacerbation of chronic obstructive pulmonary disease [J]. *Cochrane Database Syst Rev*, 2017, 7(7): CD004104
- [22] Stefan MS, Nathanson BH, Higgins TL, et al. Comparative Effectiveness of Noninvasive and Invasive Ventilation in Critically Ill Patients With Acute Exacerbation of Chronic Obstructive Pulmonary Disease [J]. *Crit Care Med*, 2015, 43(7): 1386-1394
- [23] Mundel T, Feng S, Tatkov S, et al. Mechanisms of nasal high flow on ventilation during wakefulness and sleep [J]. *J Appl Physiol* (1985), 2013, 114(8): 1058-1065
- [24] Moller W, Feng S, Domanski U, et al. Nasal high flow reduces dead space [J]. *J Appl Physiol*, 2017, 122(1): 191-197
- [25] Peters SG, Holets SR, Gay PC. High-flow nasal cannula therapy in do-not-intubate patients with hypoxemic respiratory distress [J]. *Respir Care*, 2013, 58(4): 597-600
- [26] Pilcher J, Eastlake L, Richards M, et al. Physiological effects of titrated oxygen via nasal highflow cannulae in COPD exacerbations: a randomized controlled cross-over trial [J]. *Respirology*, 2017, 22(6): 1149-1155
- [27] Chatila W, Nugent T, Vance G, et al. The effects of high-flow vs low-flow oxygen on exercise in advanced obstructive airways disease [J]. *Chest*, 2004, 126(4): 1108-1115
- [28] Pisani L, Vega ML. Use of nasal high flow in stable COPD: rationale and physiology [J]. *COPD*, 2017, 14(3): 346-350
- [29] Rosa Di Mussi, Savino Spadaro, Tania Stripoli, et al. High-flow nasal cannula oxygen therapy decreases postextubation neuroventilatory drive and work of breathing in patients with chronic obstructive pulmonary disease [J]. *Critical Care*, 2018, 22(1): 180
- [30] Fraser JF, Spooner AJ, Dunster KR, et al. Nasal high flow oxygen therapy in patients with COPD reduces respiratory rate and tissue carbon dioxide while increasing tidal and end-expiratory lung volumes: a randomized crossover trial [J]. *Thorax*, 2016, 71(8): 759-761