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纤维支气管镜肺泡灌洗术联合振动排痰法在重症肺炎机械通气患儿的临床应用

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[摘要] 目的: 研究纤维支气管镜(以下简称纤支镜)肺泡灌洗术(bronchoalveolar lavage, BAL)联合振动排痰法救治重症肺炎机械通气患儿的临床效果。方法: 选取2018年2月至2020年1月在德阳市人民医院儿童重症医学科(pediatric intensive care unit, PICU)接受救治的120例重症肺炎机械通气患儿, 采用简单随机分组法将患儿分为BAL组和联合组, 每组均60例。所有患儿均接受抗感染、化痰、止咳等对症治疗, BAL组给予BAL治疗, 灌洗期间密切生命体征监测; 联合组给予BAL联合高频振动排痰治疗, 高频振动排痰在BAL治疗前20 min进行。观察两组患儿BAL治疗前后呼吸功能和炎症因子等指标变化, 比较两组患儿排痰量、机械通气时间、PICU住院时间、28 d病死率和评估临床疗效。结果: 两组治疗2 h后氧合指数(oxygenation index, PaO_2/FiO_2)、动态顺应性(dynamic compliance, $Cydn$)均较治疗前明显升高, 动脉二氧化碳分压(partial pressure of carbon dioxide, $PaCO_2$)显著下降($P<0.05$), 联合组治疗2 h后上述指标均较BAL组明显改善($P<0.05$); 两组治疗5 d后血清降钙素原(procalcitonin, PCT)、C-反应蛋白(C-reactive protein, CRP)、白细胞计数(white blood cell, WBC)均较治疗前明显下降($P<0.05$), 联合组治疗5 d后血清PCT、CRP显著低于BAL组($P<0.05$); 联合组BAL排痰量多于BAL组, 机械通气时间、PICU住院时间短于BAL组, 差异均有统计学意义($P<0.05$), 组间28 d病死率比较无明显差异($P>0.05$)。联合组治疗总有效率96.67%, 明显高于BAL组的85.00%($P<0.05$)。结论: BAL联合振动排痰法可帮助重症肺炎机械通气患儿充分排痰和改善呼吸功能, 减轻炎症反应, 缩短机械通气时间和PICU住院时间, 增益临床疗效。

[关键词] 重症肺炎; 机械通气; 患儿; 纤维支气管镜肺泡灌洗术; 振动排痰法; 气道管理; 呼吸功能; 近期预后

Clinical application of bronchoalveolar lavage combined with vibration expectoration in children with severe pneumonia undergoing mechanical ventilation

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Abstract **Objective:** To study the clinical effect of bronchoalveolar lavage (BAL) combined with vibration expectoration in

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the treatment of children with severe pneumonia undergoing mechanical ventilation. **Methods:** From February 2018 to January 2020, 120 children with severe pneumonia receiving mechanical ventilation in the pediatric intensive care unit (PICU) of Deyang People's Hospital were selected. The children were randomly divided into a BAL group and a combined group, with 60 cases in each group. All the children received symptomatic treatment such as anti-infection, expectoration, and cough relieving. The children in the BAL group were given BAL treatment, and vital signs were closely monitored during lavage; the children in the combined group were given bronchoalveolar lavage combined with high-frequency vibration expectoration treatment, which was performed 20 minutes before BAL treatment. The changes of respiratory function and inflammatory factors before and after BAL treatment were observed. The sputum output, mechanical ventilation time, PICU hospital stay, 28-day mortality, and clinical efficacy were compared between the 2 groups. **Results:** After 2 hours of treatment for both groups, oxygenation index ($\text{PaO}_2/\text{FiO}_2$) and dynamic compliance (C_{dyn}) were significantly increased, partial pressure of carbon dioxide (PaCO_2) was significantly decreased ($P<0.05$); the above indexes in the combined group were significantly improved than those in the BAL group ($P<0.05$). After 5 days of treatment, serum procalcitonin (PCT), C-reactive protein (CRP), and white blood cell (WBC) in the 2 groups were significantly lower than those before the treatment ($P<0.05$); the levels of serum PCT and CRP in the combined group were significantly lower than those in the BAL group ($P<0.05$). The sputum excretion volume of BAL in the combined group was more than that in the BAL group and the mechanical ventilation time and PICU hospitalization time were shorter than those in the BAL group ($P<0.05$). However, there was no significant difference in 28-day mortality between the 2 groups ($P>0.05$). After the treatment, the total effective rate of the combined group was 96.67%, which was significantly higher than that of the BAL group (85.00%, $P<0.05$). **Conclusion:** BAL combined with vibration expectoration can help children with severe pneumonia fully expectorate, improve respiratory function, reduce inflammatory reaction, shorten mechanical ventilation time and PICU hospitalization time, and increase clinical efficacy.

Keywords severe pneumonia; mechanical ventilation; children; bronchoalveolar lavage; vibration expectoration; airway management; respiratory function; short-term prognosis

重症肺炎是儿童重症医学科(pediatric intensive care unit, PICU)的常见病型, 主要由细菌、病毒、真菌等引起, 多见于致病性较强的细菌、耐药菌或多种细菌混合感染, 因病情凶险, 常规全身使用抗生素无法使病灶达到理想的药物浓度, 难以有效控制疾病, 病情易进展, 致死率较高, 居儿童病因性死亡的第1位^[1]。重症肺炎患者存在肺通气换气功能障碍, 机体存在持续低氧血症和二氧化碳潴留, 呼吸困难, 常需要接受机械通气辅助治疗。但机械通气改善患者通气的同时, 也存在诸多不足, 比如镇静剂或肌肉松弛剂的使用, 抑制咳嗽反射, 同时机械通气患者呼吸道失去对空气加温加湿作用, 气道干燥使得纤毛运动减弱等, 造成气道内大量炎性黏稠分泌物在深部支气管潴留, 堵塞呼吸道, 影响肺通气和换气功能, 因此充分

排痰对保障机械通气治疗效果和改善预后尤为重要。纤维支气管镜(以下简称纤支镜)肺泡灌洗术(bronchoalveolar lavage, BAL)最早用于治疗尘肺病, 近些年逐渐用于重症肺炎的临床诊疗, 用于PICU也具有较好安全性, 有助于清除气管分泌物和改善肺通气-换气功能, 促进病情转归。但临床发现, 仍有10%~20%患者BAL治疗效果欠佳, 原因可能与重症肺炎机械通气患者痰液黏稠度较高、痰液分泌量较多和易形成痰栓等有关^[2-3]。因此借助物理排痰手段联合BAL治疗成为临床研究的热点, 但目前关于二者联合治疗重症肺炎机械通气患儿的报道偏少, 其安全性和有无明确临床优势尚缺乏足够循证依据。本研究对120例重症肺炎机械通气患儿进行随机对照研究, 探讨BAL联合振动排痰法对患儿气道管理和近期预后的临床价值。

1 对象与方法

1.1 对象

选取2018年2月至2020年1月德阳市人民医院PICU救治的120例重症肺炎机械通气患儿为研究对象。入选标准：1)结合症状体征、实验室检查和胸部X线片等检查，均符合重症肺炎的诊断标准^[4]；2)呼吸困难，接受气管插管机械通气辅助治疗，且通气治疗时间 ≥ 48 h；3)年龄5个月至14岁，家属对本研究知情同意。排除标准：1)经实验室和体格检查，存在BAL或振动排痰禁忌；2)免疫功能缺陷或近期使用免疫抑制剂者；3)合并先天性心脏病、肝肾功能不全、脑炎或哮喘等基础疾病。剔除标准：中途转院或主动放弃研究者。采用简单随机分组法分成BAL组($n=60$)和联合组($n=60$)，两组患儿性别、年龄、体重、病程和小儿危重病例评分等基线资料比较无显著差异($P>0.05$ ，表1)。本研究经德阳市人民医院伦理委员会通过(批号201801-011)。

1.2 方法

所有患儿均由同组PICU医师给予抗感染、止咳、化痰、平喘、退热、体位引流和气道加温加湿等对症治疗，由同组PICU护理团队实施病情监护、人工叩背等护理。

1.2.1 BAL组

BAL治疗前均完善相关检查，排除BAL禁忌。BAL术前常规禁食禁饮4~6 h，建立静脉通路，连接心电监护仪，密切监测心率(heart rate, HR)、呼吸频率(respiratory rate, RR)、平均动脉压(mean arterial pressure, MAP)等体征指标，血氧饱和度(pulse oxygen saturation, SpO_2) $<90\%$ 患儿提高吸

入氧浓度，维持 $SpO_2 \geq 90\%$ 。机械通气患儿均使用咪达唑仑镇静、舒芬太尼镇痛，对 >3 岁且镇静镇痛效果欠佳者予静脉推注丙泊酚，纤支镜外涂奥布卡因凝胶，待达到理想镇静效果后实施BAL治疗。仪器采用日本Olympus CV290电子支气管镜，根据患儿年龄和体重等具体情况，将合适大小型号(外径2.8 mm或3.6 mm)的纤支镜通过Y型管经气管导管缓慢插入气道，借助胸部X线片观察分泌物和痰栓部位，给予1 mL/(kg·次)的37℃生理盐水依次对各个肺叶、肺段和亚段支气管等病变部位进行灌洗吸痰，每个部位灌洗2~3次，对气管黏膜局部炎症明显或肺不张的部位可反复灌洗3~5次，根据患儿耐受性和病变部位分泌物程度决定每次灌洗时间，留取灌洗液标本，放入一次性硅化收集容器中，用于灌洗液细菌培养和药敏试验。待患儿病变肺段支气管开口处灌洗液澄清，退出纤支镜。灌洗期间全程呼吸机给氧，密切监测患儿生命体征，若患儿体征变化波动较大如心动过缓/过速、 SpO_2 明显下降等情况时，应立即停止BAL操作，待患儿体征稳定后继续BAL治疗。BAL结束后禁食禁饮3 h，继续密切监测患儿体征。

1.2.2 联合组

给予BAL联合振荡排痰方案治疗，其中BAL仪器和操作方法均同BAL组，振荡排痰法：BAL治疗前20 min选用国产PTJ-5000多频振动排痰机进行振动排痰治疗，安抚患儿，调整呼吸，尽可能稳定和安抚患儿情绪，指导患儿取健侧卧位，选择合适大小的叩击治疗头和15~30 Hz自动模式频率叩击患儿背部，由外向内和自下而上振动排痰，叩击时保持叩击柄箭头标识与气管平行，振动排痰约10 min/次，3次/d，每次叩击结束后患儿休息3~5 min后，再行BAL治疗。

表1 两组基线资料比较($n=60$, $\bar{x} \pm s$)

Table 1 Comparison of baseline data between two groups ($n=60$, $\bar{x} \pm s$)

组别	男性/[例(%)]	年龄/岁	体重/kg	病程/d	小儿危重病例评分
BAL组	38 (63.33)	5.28 \pm 0.39	19.83 \pm 2.72	4.37 \pm 0.72	70.54 \pm 8.03
联合组	35 (58.33)	5.30 \pm 0.42	19.79 \pm 2.80	4.40 \pm 0.68	69.94 \pm 7.87
χ^2/t	0.315	0.270	0.079	0.235	0.413
P	0.575	0.787	0.937	0.815	0.680

1.3 研究指标

1) 比较两组患儿BAL治疗前和治疗2 h后氧合指数(oxygenation index, $\text{PaO}_2/\text{FiO}_2$)、动脉二氧化碳分压(partial pressure of carbon dioxide, PaCO_2)和动态顺应性(dynamic compliance, Cydn)水平; 2) 比较两组患儿BAL治疗前和治疗5 d后降钙素原(procalcitonin, PCT)、C-反应蛋白(C-reactive protein, CRP)和白细胞计数(white blood cell, WBC)等常规检测指标水平; 3) 比较两组患儿首次BAL治疗的排痰量、机械通气时间、PICU住院时间和28 d病死率, 其中排痰量 \approx 肺泡灌洗液回收量-灌洗液; 4) 两组治疗7 d后评估临床疗效, 疗效标准^[2,5]: ①治愈, 患儿咳嗽、发热、肺部湿啰音等症状体征消失, 实验室指标恢复正常, 胸部X线或CT检查提示病灶消失和肺复张; ②显效, 患儿症状体征基本消失, 实验室指标接近正常范围, 胸部X线或CT检查显示肺叶大部分复张, 病灶缩小 $>85\%$; ③有效: 患儿症状体征和实验室指标有一定改善, 但未达到正常水平, 胸部X线或CT肺叶小部分复张, 病灶缩小 $65\% \sim 85\%$; ④无效: 患儿治疗后症状体征、实验室指标和影像学检查未达到上述改善标准。总有效=治愈+显效+有效。

1.4 统计学处理

选用SPSS 20.0分析相关数据, 两组患儿性别构成、28 d病死率等为计数资料, 用例(%)表示, 组间行 χ^2 检验; 患儿年龄、病程、体重、体征监测指标和常规生化检测指标、BAL排痰量、机械通气时间和PICU住院时间等为计量指标, 经检验后均满足方差齐性和正态分布, 用均数 \pm 标准差($\bar{x} \pm s$)表示, 组间比较行LSD-*t*检验, 组内比较行重复测量方差分析, $P < 0.05$ 为差异有统计学意义。

2 结果

2.1 两组患儿治疗前后 $\text{PaO}_2/\text{FiO}_2$ 、 PaCO_2 、Cydn 比较

本研究无中途转院和退出病例, 入组患儿均成功完成BAL或BAL联合振动排痰治疗, 联合组患儿振动排痰前后生命体征稳定。两组BAL治疗中均无大咯血或呼吸心跳骤停等严重并发症发生, 仅有少量一过性并发症发生, 其中BAL组出现一过性 SpO_2 下降4例, 窦性心动过缓和剧烈咳嗽各3例, 联合组出现一过性 SpO_2 下降和剧烈咳嗽各3例, 窦性心动过缓2例, 组间不良反应率比较无明显差异($P > 0.05$), 经退出纤支镜、调整吸氧浓度等处理后好转。本研究显示两组治疗2 h后 $\text{PaO}_2/\text{FiO}_2$ 、Cydn均较治疗前明显升高, PaCO_2 显著下降($P < 0.05$), 与BAL组治疗后比较, 联合组 $\text{PaO}_2/\text{FiO}_2$ 、 PaCO_2 、Cydn均显著改善($P < 0.05$, 表2)。

2.2 两组患儿治疗前后 PCT、CRP、WBC 比较

两组患儿治疗5 d后血清PCT、CRP和WBC均较治疗前明显下降($P < 0.05$), 联合组治疗5 d上述炎症指标水平低于BAL组, 其中血清PCT、CRP水平显著较低($P < 0.05$, 表3)。

2.3 两组患儿 BAL 排痰量和近期预后比较

联合组患儿BAL排痰量明显多于BAL组($P < 0.05$), 机械通气时间、PICU住院时间明显少于BAL组($P < 0.05$), 组间28 d病死率比较差异无统计学意义($P > 0.05$, 表4)。

2.4 两组患儿治疗 14 d 临床疗效比较

联合组患儿治疗14 d总有效率明显高于BAL组($P < 0.05$, 表5)。

表2 两组治疗前和治疗2 h后 $\text{PaO}_2/\text{FiO}_2$ 、 PaCO_2 、Cydn比较($n=60$, $\bar{x} \pm s$)

Table 2 Comparison of $\text{PaO}_2/\text{FiO}_2$, PaCO_2 and Cydn between the two groups before and after 2 hours of treatment ($n=60$, $\bar{x} \pm s$)

组别	$\text{PaO}_2/\text{FiO}_2/\text{mmHg}$		$\text{PaCO}_2/\text{mmHg}$		Cydn/($\text{mL} \cdot \text{cmH}_2\text{O}^{-1}$)	
	治疗前	治疗2 h	治疗前	治疗2 h	治疗前	治疗2 h
BAL组	265.73 \pm 18.90	340.20 \pm 21.92*	52.07 \pm 6.84	43.80 \pm 6.28*	19.85 \pm 1.83	28.94 \pm 3.12*
联合组	267.05 \pm 19.32	361.28 \pm 22.08*	51.92 \pm 7.03	36.71 \pm 5.57*	20.03 \pm 1.85	34.03 \pm 3.26*
<i>t</i>	0.378	5.248	0.118	6.542	0.536	8.737
<i>P</i>	0.706	<0.001	0.906	<0.001	0.593	<0.001

*与治疗前比较, 均 $P < 0.05$

*Compared with before treatment, all $P < 0.05$

表3 两组治疗前和治疗5 d后PCT、CRP、WBC比较($n=60$, $\bar{x} \pm s$)Table 3 Comparison of PCT, CRP and WBC between the two groups before and after 5 days of treatment ($n=60$, $\bar{x} \pm s$)

组别	PCT/($\mu\text{g}\cdot\text{L}^{-1}$)		CRP/($\text{mg}\cdot\text{L}^{-1}$)		WBC/($\times 10^9\cdot\text{L}^{-1}$)	
	治疗前	治疗5 d	治疗前	治疗5 d	治疗前	治疗5 d
BAL组	5.41 \pm 1.36	2.19 \pm 0.49*	29.76 \pm 6.28	15.84 \pm 4.20*	14.82 \pm 4.36	10.18 \pm 2.84*
联合组	5.26 \pm 1.25	1.42 \pm 0.35*	28.93 \pm 7.01	9.37 \pm 3.02*	14.39 \pm 4.27	9.23 \pm 2.50*
<i>t</i>	0.629	9.905	0.683	9.688	0.546	1.945
<i>P</i>	0.531	<0.001	0.496	<0.001	0.586	0.054

*与治疗前比较, 均 $P<0.05$ *Compared with before treatment, all $P<0.05$ 表4 两组患儿BAL排痰量和近期预后指标比较($n=60$, $\bar{x} \pm s$)Table 4 Comparison of BAL sputum output and short-term prognosis between the two groups ($n=60$, $\bar{x} \pm s$)

组别	BAL排痰量/mL	机械通气时间/d	PICU住院时间/d	28 d病死率/[例(%)]
BAL组	29.37 \pm 5.38	6.78 \pm 1.02	9.42 \pm 1.20	3 (5.00)
联合组	35.39 \pm 7.04	6.35 \pm 0.93	8.78 \pm 1.08	2 (3.33)
χ^2/t	5.263	2.413	3.071	0.000
<i>P</i>	<0.001	0.017	0.003	1.000

表5 两组患儿治疗14 d临床疗效比较($n=60$)Table 5 Comparison of clinical efficacy of 14 days treatment between the two groups ($n=60$)

组别	治愈/[例(%)]	显效/[例(%)]	有效/[例(%)]	无效/[例(%)]	总有效/[例(%)]
BAL组	4 (6.67)	20 (33.33)	27 (45.00)	9 (15.00)	51 (85.00)
联合组	6 (10.00)	27 (45.00)	25 (41.67)	2 (3.33)	58 (96.67)
χ^2					4.904
<i>P</i>					0.027

3 讨论

小儿重症肺炎的发病率较高, 原因与小儿体质娇嫩, 呼吸系统和免疫系统发育不充分有关, 与成人相比, 小儿抵抗力较差, 更易受病原菌感染, 且患儿感染肺炎后, 由病原体及其代谢产物、炎症递质共同参与的全身炎症反应综合征, 能迅速加剧病情进展, 机体应激反应更加严重, 加上小儿气管直径小, 自主排痰能力较差, 分泌物不易被排出, 造成患儿呼吸道分泌物引流不畅和气道不同程度堵塞, 易出现气道梗阻, 进一步损害肺功能, 较易导致重症肺炎^[6-7]。基于重症肺炎机械通气患儿的病情和呼吸解剖学特点, 患儿大量黏稠分泌物在深部

支气管集聚, 机械通气效果往往欠佳, 也是导致患儿预后不良甚至死亡的重要因素^[8-9]。因此有效清除气管分泌物是提高重症肺炎患儿机械通气效果和改善预后的重要环节。

BAL是通过纤支镜对支气管以下肺段或亚肺段用无菌生理盐水进行灌洗、回收和检测分析的诊疗技术, 纤支镜质地柔软, 形状可弯曲, 可经鼻腔或口腔进入气管和支气管部位, 在直视条件下进行灌洗, 清除气管淤积分泌物, 避免呼吸道堵塞和保持气道通畅, 同时生理盐水能稀释炎性物质, 避免细菌滋养和促进病灶愈合, 减轻炎症反应, 同时根据回收液的细菌培养结果, 还能指导临床抗菌药物的合理使用^[10]。过去观点认

为重症肺炎患者病情危重,一定程度限制了BAL在重症肺炎救治中的应用,但随着BAL技术不断完善和适应证更加明确,BAL应用于PICU也是安全可行的^[11]。本研究显示BAL组患儿治疗2 h后PaO₂/FiO₂、Cyd_n较治疗前明显升高,PaCO₂和血清PCT、CRP、WBC显著下降,患儿顺利排痰(29.37±5.38) mL,虽然BAL治疗时出现脉搏氧饱和度下降、窦性心律过缓等少量一过性并发症,但经简单对症处理后好转或自行消失,未出现明显异常反应,也说明BAL对重症肺炎机械通气患儿的显著灌洗效果,能帮助患儿排痰和改善呼吸功能,且安全性较好。但本研究观察发现,BAL组有部分患儿灌洗效果欠佳,排痰量偏少,BAL治疗后PaO₂/FiO₂、PaCO₂、Cyd_n和炎症因子PCT、CRP、WBC改善幅度明显较差,机械通气时间和PICU住院时间也明显长于其他患儿,原因多与BAL无法清除痰滞在患儿肺内细小气道的痰栓和其他分泌物有关^[12-13]。

振动排痰法为ICU气道管理提供了新途径,对辅助BAL治疗重症肺炎机械通气患儿有良好价值,其作用途径是借助利用物理定向叩击原理的机械振动仪,叩击患儿肺部对应的背部区域,叩击力度适中,与人工叩背等传统物理排痰手段相比,振动排痰具有穿透性强、背部受力均匀和叩击力度平稳性好等优点,不仅排痰效果更为显著,而且均匀且力度适中的叩击能促进患儿局部血液循环,诱导肌肉放松,舒适性佳,患儿的配合性较好。有报道^[14-15]指出:振动排痰叩击时能在患者体表施加2个不同方向的作用力,其中垂直体表的作用力通过叩击、震颤,使支气管黏膜表的黏液发生松动,与体表保持平行方向的作用力能促进黏液从支气管排出。本研究在BAL治疗前20 min实施振动排痰,能松弛并移动痰滞在肺内细小气道的黏痰和痰栓,有效弥补了BAL的不足,为BAL灌洗和充分吸出提供保障。本研究显示:与BAL组比较,联合组治疗2 h后PaO₂/FiO₂、PaCO₂、Cyd_n均显著改善,治疗5 d血清PCT、CRP水平也明显降低,说明BAL联合振动排痰法对改善患儿呼吸功能和减轻炎症反应效果显著。有报道^[16]利用高频胸壁振荡排痰法(high-frequency chest wall oscillation system expectoration, HFCWO)治疗重度慢性阻塞性肺部疾病急性加重期(acute exacerbation of chronic obstructive pulmonary diseases, AECOPD)患者,取得良好的肺康复效果。还有报道^[17-18]发现:与单纯BAL比较,BAL联合振动排痰能明显改善重症肺炎机械通气患者的血气分析指标和炎症

反应,增益临床疗效,与本研究有共通之处,同时本研究还进一步观察发现:联合组BAL排痰量明显多于BAL组,机械通气时间和PICU住院时间也明显缩短。表明BAL联合振动排痰能在促进重症肺炎机械通气患儿病情康复进程、节约医疗负担方面作用显著^[19]。

综上所述,采用BAL联合振动排痰法进行重症肺炎机械通气患儿的气道管理,能提高BAL灌洗排痰效果,有助于快速稳定病情和改善近期预后,减少住院时间和节约住院费用,具有较好医学价值和经济价值,而且振动排痰操作简单、安全性和舒适性较好,便于推广应用。

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