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CA-125对ICU机械通气患者拔管后发生呼吸衰竭诊断的预测价值

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摘　要

目的：评估CA-125对ICU机械通气患者在拔管后发生呼吸衰竭的诊断和预测价值。方法：纳入2024年8月至2025年7月在济宁市第一人民医院ICU住院的机械通气患者164例。根据撤机结果将患者分为撤机成功组(n = 134)和撤机失败组(n = 30)，比较两组的临床资料。采用多因素Logistic回归分析探讨成人ICU机械通气患者在撤机后出现呼吸衰竭的影响因素。采用ROC曲线评估CA-125及其正常值范围对成人ICU机械通气患者撤机后出现呼吸衰竭的预测价值。此外，以CA-125为分界指标，将患者分为CA-125 < 42.25组(n = 113)和CA-125 ≥ 42.25组(n = 51)，比较不同CA-125水平患者的机械通气时间和住院时间。结果：撤机成功组入ICU时的APACHEII评分、SOFA评分、CA-125水平及RSBI均低于撤机失败组(P < 0.05)。多因素Logistic回归分析结果显示，通过SBT试验后进行拔管时的CA-125水平是成人ICU机械通气患者撤机后出现呼吸衰竭的独立影响因素(P < 0.05)。ROC曲线分析结果显示，通过SBT试验后进行拔管时CA-125预测成人ICU机械通气患者撤机后出现呼吸衰竭的AUC为0.752 [95% CI (0.628, 0.862)]，对应Youden指数最大的截断值为42.25 UI/ml，灵敏度为0.767，特异度为0.784。将CA-125固定为35.00 UI/ml时，其预测成人ICU机械通气患者撤机后出现呼吸衰竭的AUC为0.743 [95% CI (0.658, 0.823)]，灵敏度为0.800，特异度为0.687。按CA-125分层比较，CA-125 < 42.25组的机械通气时间和住院时间均长于CA-125 ≥ 42.25组，差异具有统计学意义(P < 0.05)。结论：CA-125对成人ICU机械通气患者撤机后出现呼吸衰竭有一定预测效能。

关键词

机械通气，CA-125，重症监护病房，呼吸衰竭，成年人，预测

Predictive Value of CA-125 for the Diagnosis of Post-Extubation Respiratory Failure in Mechanically Ventilated ICU Patients

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Abstract

Objective: To evaluate the diagnostic and predictive value of CA-125 for post-extubation respiratory failure in mechanically ventilated ICU patients. Methods: We enrolled 164 mechanically ventilated patients admitted to the ICU of Jining First People's Hospital from August 2024 to July 2025. Based on weaning outcomes, patients were classified into a weaning-success group (n = 134) and a weaning-failure group (n = 30), and clinical characteristics were compared between groups. Multivariable logistic regression was used to examine factors associated with post-weaning respiratory failure in adult ICU patients receiving mechanical ventilation. Receiver operating characteristic (ROC) curves were applied to assess the predictive value of CA-125 and its normal reference range for post-weaning respiratory failure in this population. In addition, using CA-125 as the stratification threshold, patients were divided into a CA-125 < 42.25 group (n = 113) and a CA-125 ≥ 42.25 group (n = 51), and mechanical ventilation duration and hospital length of stay were compared between the two groups. Results: At ICU admission, the weaning-success group had lower APACHE II scores, SOFA scores, CA-125 levels, and RSBI values than the weaning-failure group (P < 0.05). In multivariable logistic regression, the CA-125 level at the time of extubation following a successful spontaneous breathing trial (SBT) was an independent factor associated with post-weaning respiratory failure in mechanically ventilated adult ICU patients (P < 0.05). Receiver operating characteristic (ROC) analysis showed that CA-125 measured at extubation after SBT predicted post-extubation respiratory failure with an AUC of 0.752 (95% CI, 0.628~0.862); the cutoff corresponding to the maximal Youden index was 42.25 U/mL, with a sensitivity of 0.767 and a specificity of 0.784. Using a fixed CA-125 threshold of 35.00 U/mL yielded an AUC of 0.743 (95% CI, 0.658~0.823), with a sensitivity of 0.800 and a specificity of 0.687. When stratified by CA-125, patients with CA-125 < 42.25 had longer durations of mechanical ventilation and hospital stay than those with CA-125 ≥ 42.25 (P < 0.05). Conclusion: CA-125 demonstrates predictive utility for identifying post-extubation respiratory failure among mechanically ventilated adult ICU patients.

Keywords

Mechanical Ventilation, CA-125, Intensive Care Unit, Respiratory Failure, Adults, Prediction

1. 引言

机械通气是重症监护病房呼吸衰竭患者最常用的生命支持方式[1]。随着病情逐渐稳定、自主呼吸功能逐渐恢复，临床应开始进行呼吸机撤机。但研究表明，约 20%~30%患者因呼吸肌功能尚未完全恢复而出现撤机困难或延迟[2]。延长机械通气时间可能导致呼吸机相关性肺炎、膈肌功能障碍等并发症的发生，

并对肺功能预后产生不良影响[3] [4]。因此，正确判断撤机时机对提高撤机成活率具有重要的临床意义。目前，临床上用于评估撤机时机的指标有膈肌超声、呼吸浅快指数(RSBI)等[5] [6]，而在实践中，仅有单项指标应用往往难以完全反映患者整体的呼吸储备功能，产生的预测效能有限。

CA-125 (或称为 MUC16)是由浆膜和上皮细胞分泌的一种高分子糖蛋白，最初用于卵巢肿瘤的监测[7]。现已有很多研究表明 CA-125 水平还受炎症反应、体液潴留、静脉或淋巴回流受阻、心肺充血等诸多因素的影响[8] [9]。CA-125 在胸腔积液、心力衰竭、肺水肿等情况下增高，提示体内可能存在体液分布异常和浆膜活化。患者机械通气后在撤机和拔管期间，心肺负担、呼吸肌肉耐力和容量状况等会在短时间内发生迅速变化，常见的拔管失败机制有心源性肺水肿、呼吸肌疲劳、气道水肿和分泌物潴留等[10] [11]。上述机制均可引起浆膜细胞活化，再加上对体液的外渗，使得 CA-125 升高。因此，推测 CA-125 可能因反映炎症和容量负荷而成为拔管后呼吸衰竭的潜在生物学信号[12]。本文的主要目的，以研究 CA-125 对成人 ICU 机械通气患者拔管后出现呼吸衰竭的预测价值，为提高机械通气患者拔管成功，使有关并发症发生率和医疗费用降低，提供参考。

2. 资料与方法

2.1. 研究对象

选取 2024 年 8 月至 2025 年 7 月期间在济宁市第一人民医院 ICU 住院，因各种原因接受机械通气的患者共 164 例。纳入标准：(1) 年龄 ≥ 18 岁；(2) 机械通气时间 ≥ 48 h；(3) 自主呼吸试验(spontaneous breathing trial, SBT)评估成功并进入首次撤机流程的患者。排除标准：(1) 合并恶性肿瘤者；(2) 临床资料不完整者；(3) 已行气管切开者；(4) 合并妊娠者；(5) 因颈椎损伤或口咽部畸形无法经口气管插管者；(6) 合并自身免疫性疾病或神经肌肉疾病者。根据撤机结果将患者分为撤机成功组(n = 134)和撤机失败组(n = 30)。撤机失败定义为撤机后 48 h 内出现呼吸衰竭表现。呼吸衰竭的判定标准为：至少符合以下两项中的任意两项：1) 出现呼吸性酸中毒；2) 血氧饱和度 < 90%且吸入氧浓度(FiO_2) ≥ 50%；3) 连续 2 小时呼吸频率 > 25 次/min 或出现临床可见的呼吸肌疲劳。本研究经济宁市第一人民医院医学伦理委员会审核通过，所有患者均签署知情同意书。

2.2. 观察指标

(1) 比较撤机成功组与撤机失败组的临床资料，包括：性别、年龄、通过 SBT 试验后进行拔管时急性生理与慢性健康状况评分系统 II (acute physiology and chronic health evaluation II, APACHE II)评分、体质指数、营养评分、原发疾病、氧合指数、呼吸指数、浅快呼吸指数(RSBI)、SaO_2、PaO_2、$PaCO_2$、机械通气时间、左室射血分数、拔管前 24 h 出入量、ICU 住院时间、住院生存时间。其中实验室检查指标均为在通过 SBT 试验后、实施拔管时获得。(2) 根据 CA-125 水平将患者分为 CA-125 < 42.25 组(n = 113)和 CA-125 ≥ 42.25 组(n = 51)，比较两组的机械通气时间及住院时间。

2.3. 统计学方法

采用 SPSS 27.0 软件进行统计分析。符合正态分布的连续变量以均值 ± 标准差表示，非正态分布的连续变量以中位数及四分位间距表示，分类变量以百分比表示。组间连续变量比较采用 t 检验或 U 检验；分类变量比较采用 χ^2 检验或 Fisher 确切概率法。绘制散点图并采用 Spearman 相关分析评估 CA-125 与拔管后出现呼吸衰竭相关指标之间的相关性。利用受试者工作特征(ROC)曲线下面积(AUC)评估 CA-125 对拔管后出现呼吸衰竭的判别能力。采用 Logistic 回归模型分析相关危险因素。以 P < 0.05 为差异具有统计学意义。

3. 结果

3.1. 撤机成功组与撤机失败组的临床资料比较结果

两组在性别、年龄、体质指数、营养评分、呼吸指数、动脉血氧分压、左室射血分数及拔管前 24 h 出入量方面差异均无统计学意义($P > 0.05$)。撤机成功组在通过 SBT 试验后进行拔管时的 APACHEII 评分、SOFA 评分、RSBI、心衰及慢性肺疾病作为主要病因的比例、CA-125 水平及 BNP 水平均低于撤机失败组，GCS 评分高于撤机失败组，差异均具有统计学意义($P < 0.05$)，见表 1。

Table 1. Comparison of baseline characteristics between the successful and failed weaning groups
表 1. 撤机成功组与撤机失败组患者一般资料比较

	撤机成功组(n = 134)	撤机失败组(n = 30)	P
年龄(岁)	66.00 [58.50~74.00]	74.00 [67.00~83.50]	0.0533
性别[n (%)]			0.122
男性	42 (62.7%)	12 (80.0%)	
女性	25 (37.3%)	3 (20.0%)	
BMI (kg/m^2)	23.53 [21.91~24.91]	23.39 [20.15~25.22]	0.6184
营养评分(median IQR)	3.00 [3.00~4.00]	3.00 [2.50~4.00]	0.6513
病因			
心衰[n (%)]	9 (25.0%)	2 (4.3%)	0.017
慢性肺疾病[n (%)]	14 (38.9%)	8 (17.4%)	0.029
实验室指标			
BNP (pg/ml)	102.0 [72.5~196.0]	281.0 [203.5~542.5]	<0.001
血气分析指标			
SaO_2 (%)	98.00 [97.00~99.00]	98.00 [97.50~99.00]	0.5235
PaO_2 (mmHg)	102.00 [80.50~120.00]	96.00 [83.58~139.50]	0.6921
呼吸指数	1.00 [0.45~1.55]	1.50 [0.80~2.40]	0.1654
左室射血分数(%)	0.55 [0.53~0.57]	0.49 [0.46~0.53]	0.0004
GCS 评分	12.00 [10.00~13.00]	5.00 [4.00~8.00]	0.001
机械通气时间(median IQR)	3.20 [2.60~7.00]	10.00 [8.50~17.75]	0.0003
24 小时无插管期间液体平衡量[ml, (median IQR)]	−40.00 [−492.00~426.00]	−100.00 [−480.00~370.00]	0.8714
住院时间(median IQR)	15.0 (13.0~44.5)	28.0 (10.0~22.0)	0.0004
死亡率[n (%)]	10 (14.92%)	9 (60%)	<0.001
APACHEII (median IQR)	19.00 (15.00~23.75)	24.00 (20.25~26.00)	0.003
SOFA (median IQR)	4.00 (3.00~4.75)	6.00 (6.00~7.00)	<0.001
RSBI (median IQR)	42.14 (29.55~72.09)	108.05 (99.88~111.92)	<0.001
CA-125 [ml, (median IQR)]	23.35 (13.80~40.05)	50.39 (42.54~66.56)	<0.001

3.2. 成人ICU机械通气患者撤机后出现呼吸衰竭的多因素Logistic回归分析结果

以通过SBT试验后进行拔管时的APACHEII评分、CA-125、RSBI及SOFA的实测值作为自变量，以撤机结果作为因变量(赋值：撤机成功 = 0，撤机失败 = 1)进行多因素Logistic回归分析。结果显示，CA-125、RSBI及SOFA均为成人ICU机械通气患者撤机后出现呼吸衰竭的独立影响因素($P < 0.05$)，见表2。

Table 2. Univariate and multivariate logistic regression analyses of factors associated with post-extubation respiratory failure in mechanically ventilated patients

表2. 机械通气患者撤机后出现呼吸衰竭的单因素与多因素logistic分析

变量	单变量分析		多变量分析	
	OR (95% CI)	P值	OR (95% CI)	P值
年龄	1.038 (0.989~1.091)	0.133		
PaO_2/FiO_2	0.933 (0.901~0.965)	<0.001		
D-二聚体	1.218 (1.085~1.367)	<0.001		
$PaCO_2$	1.091 (1.017~1.171)	0.015		
CA-125	1.036 (1.016~1.056)	<0.001	1.082 (1.014~1.154)	0.001
APACHEII	1.079 (1.035~1.200)	0.0281	1.076 (0.895~1.295)	0.435
SOFA	3.104 (1.748~5.515)	<0.001	5.120 (1.449~18.083)	0.001
RSBI	1.070 (1.034~1.108)	<0.001	1.152 (1.016~1.306)	0.027

3.3. 通过SBT试验后进行拔管时CA-125对成人ICU机械通气患者撤机后出现呼吸衰竭的预测价值

ROC曲线分析结果显示，该时点CA-125预测撤机后发生呼吸衰竭的AUC为0.752 [95% CI (0.628, 0.862)]。Youden指数最大时对应的截断值为42.25 U/ml，灵敏度为0.767，特异度为0.784。将CA-125固定为35.00 U/ml时，其预测撤机后发生呼吸衰竭的AUC为0.743 [95% CI (0.658, 0.823)]，灵敏度为0.800，特异度为0.687，见图1。

3.4. CA-125 < 42.25组与CA-125 ≥ 42.25组的治疗时间比较

CA-125 < 42.25组的机械通气时间和住院时间均长于CA-125 ≥ 42.25组，差异具有统计学意义($P < 0.05$)，见表3。

4. 讨论

自主呼吸试验是临床常用的标准化撤机评估流程，但单独依赖该试验判断撤机结局的效能仍有限。研究显示，约30%的机械通气患者在首次自主呼吸试验中失败；即使在30 min自主呼吸试验中通过，仍有约11.6%的患者在试验延长至120 min时出现失败[13] [14]。CA-125是一项常规血液指标，易于获得，可实时收集并进行动态监测。除用于机械通气撤机失败的评估外，CA-125还被用于卵巢上皮性肿瘤的辅助诊断、疗效监测和复发评估；在附件肿块良恶性风险分层(如RMI/ROMA模型)、子宫内膜异位症及盆腔炎性疾病的病情评估与随访、恶性/良性胸腹水及腹膜病变活动度的判断中亦具有应用价值[15] [16]。此外，CA-125还被用于充血性心力衰竭患者的体液潴留及预后评估，以及胃肠道、胰腺、肺等多种实体肿瘤的疾病负荷与疗效反映[17] [18]。本文结果显示缓和组在通过SBT试验后进行拔管时的APACHEII

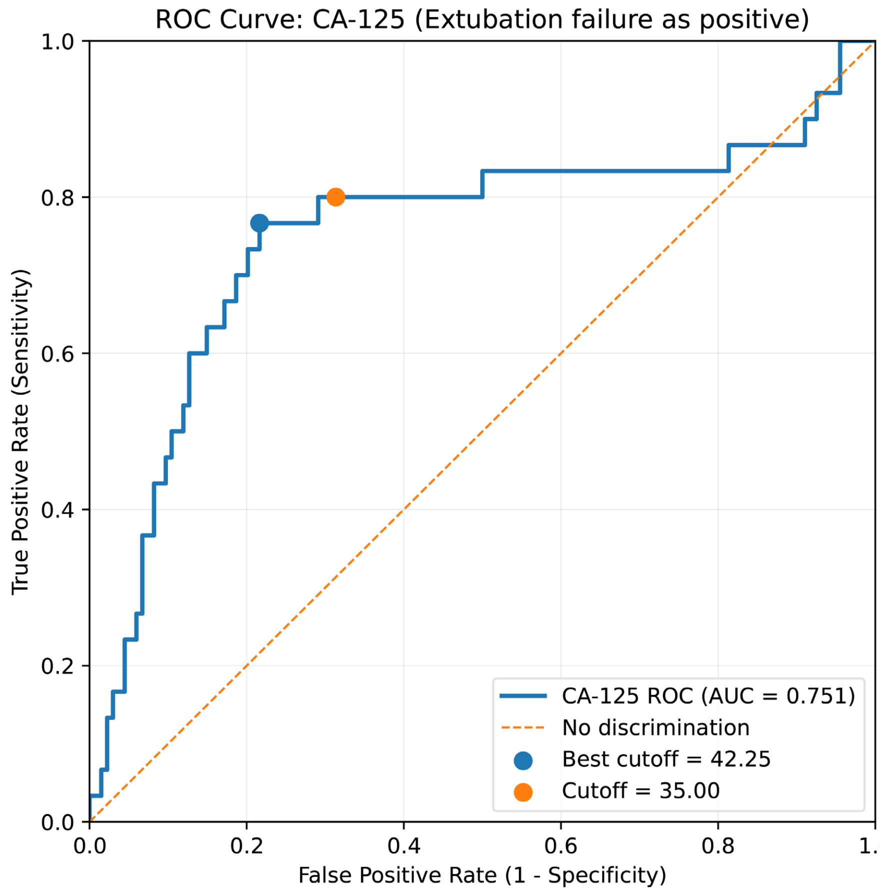

Figure 1. Receiver operating characteristic (ROC) curve of serum CA-125 for predicting post-extubation respiratory failure in mechanically ventilated patients
图 1. CA-125 预测机械通气拔管后出现是否呼吸衰竭的 ROC 曲线

Table 3. Comparison of treatment duration between patients with CA-125 < 42.25 U/mL and those with CA-125 ≥ 42.25 U/mL
表 3. CA-125 < 42.25 组与 CA-125 ≥ 42.25 组的治疗时间比较

组别	例数	机械通气时间($\bar{x} \pm s$, d)	住院时间($\bar{x} \pm s$, d)
CA-125 < 42.25 组	113	5.33 ± 4.57	13.31 ± 10.68
CA-125 ≥ 42.25 组	51	12.95 ± 8.98	29.99 ± 30.24
t (χ^2)值		5.729	3.832
P 值		P < 0.0001	P = 0.0003

评分、SOFA 评分、RSBI 及 CA-125 水平均低于失败组。多因素 Logistic 回归分析结果提示拔管时的 APACHEII 评分及 IPI 为成人 ICU 机械通气患者撤机后出现呼吸衰竭的独立影响因素，该结果与既往相关研究一致。拔管后患者转入自主呼吸阶段，若潜在的心肺充血及胸膜－心包等浆膜炎症未完全纠正，肺顺应性下降与肺泡通气障碍更易在“负压负荷”下被放大。此时血清 CA-125 (MUC16)作为由胸膜、腹膜、心包间皮细胞及气道上皮表达的膜型黏蛋白，其水平可上调，并可同时反映浆膜刺激(如胸腔积液)、全身炎症状态、静脉回流增加导致的体液潴留以及心源性充血负担，而这些因素正是拔管后呼吸衰竭(尤其是撤机相关心源性肺水肿)的重要病理生理基础。因此，CA-125 升高往往提示“充血－积液－炎症”三因素并存的高危生理状态：一方面，CA-125 水平与心力衰竭、静脉淤血负担及不良预后密切相关，提示

患者在撤机时更易发生左右心功能失衡及肺间质水肿[19]；另一方面，CA-125 亦与胸腔积液负荷、慢性阻塞性肺疾病急性加重及气道－浆膜炎症相关，提示肺顺应性进一步降低、呼吸肌做功需求上升，从而增加拔管失败和再插管风险[20]。由此可见，CA-125 可作为同时反映循环充血状态与浆膜/气道炎症反应的外周易测指标，其用于预测拔管后呼吸衰竭的发生具有明确的生物学合理性与潜在的预测意义。

CA-125 (MUC16)可反映“充血－浆膜炎症－胸腔积液”的综合负担。在心力衰竭人群中，CA-125 水平和静脉淤血程度及不良转归间有稳定关系；在肺部疾病中，CA-125 亦与胸腔积液体量和 AECOPD 等事件相关[21] [22]。这些病理生理过程与撤机后心源性肺水肿和肺间质含液增多密切相关，构成拔管后呼吸衰竭的重要基础。但是目前的证据尚不能用单一 CA-125 便可同时获得较高的敏感性与特异性，因此，临床应用中更为适当的做法是将 CA-125 与呼吸力学指标，气体交换指标，超声心动图结果及心力衰竭相关生物标志物(如 NT-proBNP)等多维信息联合评估，该联合用于拔管前的风险分层及围撤机管理的决策支持[23] [24]，因此，多项指标可联合用于撤机风险评估。本研究的 ROC 曲线结果表明，CA-125 在预测成人 ICU 机械通气患者拔管后出现呼吸衰竭方面具有一定的潜能，尤其是与拔管时 SOFA 评分联合应用时，AUC 明显有所提高。此外，非但仅凭多因素 Logistic 回归分析结果，亦不能定量对机械通气患者撤机后出现呼吸衰竭的发生风险及 CA-125 预测撤机失败的最佳阈值予以明确。本研究的 ROC 分析结果显示，CA-125 预测成人 ICU 机械通气患者撤机后出现呼吸衰竭的最佳截断值为 42.25 U/ml，和常规 CA-125 所认为的阈值 35U/ml 有相近结果。Lombuli 等的研究再次提示 CA-125 水平升高与呼吸衰竭发生率较高有相关性，该相关性在是否合并心力衰竭或不同 LUS 评分情况下均保持一致。尽管在识别存在 PERF 风险的患者中单次测量 CA-125 的准确性仅为中等程度，但是也提示将 CA-125 纳入常规充血评估中具有潜在应用价值[25]。最后本研究的结果表明 CA-125 < 42.25 U/ml 分组的机械通气时间及 ICU 住院时间均较 CA-125 ≥ 42.25 U/ml 分组者长，提示 CA-125 不仅可能用于判断撤机失败风险，且又可能与患者的临床结局相关。

5. 结论

综上所述，CA-125 对成人 ICU 机械通气患者撤机后出现呼吸衰竭具有一定的预测价值。本研究亦存在局限性，包括样本量较小及单中心研究设计等，仍需在更大样本量的多中心研究中进一步验证上述结果。

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