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突发公共卫生事件对mPIRO量表预测儿童社区获得性肺炎预后性能的影响

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摘　要

目的：探索新型冠状病毒肺炎这一突发公共卫生事件对改良PIRO（mPIRO)量表预测社区获得性肺炎(Community-Acquired Pneumonia, CAP)患儿预后性能的影响。方法：回顾性地收集了2016年至2021年入住重庆医科大学附属儿童医院诊断为CAP患儿资料，并分为两部分，2016年至2019年为疫情前，2020年至2021年为疫情后，研究关注的不良预后为CAP患儿住院期间死亡、转入ICU或使用有创呼吸机治疗。分别计算疫情前后mPIRO量表预测CAP患儿不良预后的特异度、敏感度及受试者工作特征曲线下面积(AUC)，作为量表区分性能评价标准；并疫情前后比较mPIRO量表反应的病情变化与CAP患儿实际变化情况。从以上两方面来分析突发公共卫生事件对mPIRO量表预测性能的影响。结果：疫情前后mPIRO量表预测CAP患儿不良预后的性能始终优良。具体来说，预测死亡时的AUC分别为0.87 vs. 0.84，特异度分别为73.1% vs. 74.9%，敏感度分别为86.3% vs. 78.6%；预测转入ICU的AUC分别为0.87 vs. 0.84，特异度分别为73.1% vs. 76.4%，敏感度分别为85.0% vs. 85.0%；预测使用有创呼吸机风险的AUC分别为0.88 vs. 0.88，特异度分别为75.25% vs. 76.4%，敏感度分别为85.92% vs. 85.16%。并且mPIRO量表反应的病情严重变化与实际不良预后变化是一致的。结论：mPIRO量表预测性能不被公共卫生突发事件影响，在后疫情时代，mPIRO量表仍然可作为一种可靠的决策辅助工具，指导儿科医师对有高不良预后风险的患儿采取更积极治疗措施。

关键词

儿童，社区获得性肺炎，预后，改良PIRO量表

The Impact of Public Health Emergencies on the Prognostic Performance of the mPIRO Scale in Predicting Community-Acquired Pneumonia in Children

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Abstract

Objective: This study aims to investigate the influence of COVID-19, a public health emergency, on the prognostic performance of the Modified PIRO (mPIRO) scale in children with Community Acquired Pneumonia (CAP). Methods: We retrospectively collected data on children diagnosed with CAP admitted to the Children's Hospital of Chongqing Medical University between 2016 and 2021. The data were divided into two groups: pre-epidemic (2016~2019) and post-epidemic (2020~2021). Poor prognosis was defined as in-hospital mortality, admitted to the ICU, and/or use of invasive mechanical ventilation in children with CAP. The specificity, sensitivity, and area under the receiver operating characteristic curve (AUC) of the mPIRO scale for predicting poor prognosis were calculated for both pre-epidemic and post-epidemic periods to evaluate the scale's discriminatory ability. Evaluate the concordance between the changes in mPIRO score-reflected disease severity and the actual clinical severity of CAP in children before and after the COVID-19 pandemic. These two analyses were used to assess the impact of the public health emergency on the predictive performance of the mPIRO scale. Results: The mPIRO scale demonstrated consistently good performance in predicting various adverse outcomes in children with CAP before and after the epidemic. For mortality, the AUC was 0.87 vs. 0.84, specificity was 73.1% vs. 74.9%, and sensitivity was 86.3% vs. 78.6%. Similarly, the AUC for predicting ICU admission was 0.87 vs. 0.84, with specificity of 73.1% vs. 76.4% and sensitivity of 85.0% for both periods. The mPIRO scale also performed well in predicting invasive ventilator use, with AUCs of 0.88 for both periods, specificity of 75.25% vs. 76.4%, and sensitivity of 85.92% vs. 85.16%. Notably, the changes in mPIRO scores mirrored the changes in actual adverse outcomes. Conclusions: Our findings suggest that the mPIRO scale's predictive performance remains unaffected by public health emergencies. This indicates that even in the post-pandemic era, the mPIRO scale can continue to serve as a reliable decision-making tool for pediatricians. It can effectively guide them in implementing more aggressive treatment measures for children identified as high-risk for poor outcomes.

Keywords

Children, Community-Acquired Pneumonia, Prognosis, mPIRO Scale

1. 引言

社区获得性肺炎(Community-Acquired Pneumonia, CAP)是全球儿童入院和死亡的主要原因之一[1]。儿科医生致力于降低儿童 CAP 死亡率。评分或量表可以帮助医务工作者及时发现有不良预后风险的 CAP 患儿，从而降低死亡率。

改良 PIRO (mPIRO)量表是 Araya [2]等在成人版 PIRO 量表基础上[3]，利用巴西 860 名患儿资料开发的预测儿童 CAP 死亡风险的量表，预测性能优异。一个收集印度尼西亚某医院 80 名肺炎患儿资料的外部验证显示，mPIRO 量表预测肺炎患儿死亡风险性能优异[4]。田颖等人利用中国北方某医院重症监护室的 366 名 CAP 患儿资料，外部验证显示 mPIRO 量表预测重症肺炎患儿死亡风险性能一般[5]。

新型冠状病毒肺炎疫情导致许多疾病预后发生改变，包括导致了心血管疾病、意外伤害、肿瘤疾病、慢性下呼吸道感染、急性下呼吸道感染等疾病死亡率降低，其中尤其以急性下呼吸道感染的死亡率下降最明显[6]。另有许多研究进一步显示疫情对儿童 CAP 病情及诊疗的影响是多方面的。一方面，疫情后 CAP 患儿就诊人数有明显下降，包括急诊、门诊和住院部[7] [8] [9]。另一方面，疫情后由于 CAP 而导致的重症监护室(PICU)入住率[10] [11] [12] [13] [14]和死亡率[6] [15] [16]也有所降低。同时，疫情还导致在治疗 CAP 患儿时不必要抗生素使用的增加，从而导致抗菌药耐药性上升[17]。最重要的是，疫情防控措施导致了呼吸道常见流行病原谱发生了变化[17]。

临床预测模型的性能可能会随着时间的推移而减弱[18]，尤其是当疾病诊疗环境发生变化。结合之前研究显示出的疫情对儿童 CAP 诊疗的影响[19]，疫情发生后，mPIRO 量表对预测 CAP 患儿预测的性能令人担忧。目前，尚无研究评估疫情对上述评分或量表预测能力的变化。因此，本研究旨在通过比较疫情前后评分或量表的预测性能和预测结果的变化情况，来评估疫情对它们预测能力的影响。

2. 一研究对象及方法

2.1. 研究对象

我们回顾性地收集了 2016 年至 2021 年入住重庆医科大学附属儿童医院诊断为肺炎患儿资料。研究人群纳入标准为：1) 年龄小于 18 周岁；2) 满足《儿童社区获得性肺炎诊疗规范(2019 年版)》[20]对 CAP 诊断定义，入院后 24 小时内存在急性呼吸道感染症状(如发热、咳嗽、喘息)和阳性体检结果(如呼吸增快、固定湿性啰音)或阳性放射学结果。排除标准：排除 mPIRO 量表中任一指标有缺失的患儿。本研究关注的不良预后为 CAP 患儿在住院期间发生死亡、入住 ICU、使用无创通气辅助通气。本研究经重庆医科大学附属儿童医院医学伦理委员会批准(伦理批号：(2023)年伦审(研)第(277)号)，并经患儿监护人签署知情同意书。

2.2. 研究量表与方法

mPIRO 量表通过将 CAP 患儿划分为低风险(0~2 分)、中度风险(3~4 分)、高风险(5~6 分)和极高风险(7~10 分)四个风险分层，来评估不良预后风险。其中鉴于儿童血压不易测量，且血液培养结果无法及时获得本研究使用降钙素原(PCT)值升高代替菌血症，用毛细血管再充盈时间延迟代替低血压[2]。表 1 展示了 mPIRO 量表详细评分内容。

Table 1. The mPIRO scale
表 1. mPIRO 量表

	标准	得分
易感因素(P)		有该表现
年龄 < 6 月		1
伴随疾病	有以下任一表现：先天性心脏病，先天性气道发育异常，败血症，脓毒症，中毒性脑病，颅内感染，缺氧缺血性脑病	1
损伤(I)		1

续表

经皮血氧饱和度(SpO_2) < 90%		1
肢端毛细血管网延长	>3 s	1
降钙素原值升高	>0.5 ng/ml	1
炎症反应(R)		1
多叶肺炎	CT 报告显示多个肺叶受损	1
复杂肺炎	以下任一表现：气胸，肺大疱，胸腔积液	1
器官功能障碍(O)		1
肾功能障碍	血肌酐 > 60 μmol/L 或者血尿素氮 > 7.14 mmol/L	1
肝功能障碍	谷丙转氨酶 > 40 U/L 或者谷草转氨酶 > 45 U/L	1
呼吸衰竭(R)		1

将研究对象分为两部分，2016 年至 2019 年为疫情前，2020 年至 2021 年为疫情后，通过比较疫情前后量表的预测性能和预测结果的变化情况，来分析疫情对 mPIRO 量表的影响。

应用 SPSS25.0 进行数据分析，符合正态分布的计量资料组间比较采用独立样本 t 检验；非正态分布计量资料两组间比较采用 Mann-Whitney U 检验。计数资料用例(%)描述，组间比较采用 χ^2 检验、Fisher 确切概率法。

采用 MedCalc20.218 统计软件分析量表预测性能，计算此时的特异度、敏感度，并绘制每个评分或量表的受试者工作特征(Receiver Operating Characteristic Curve, ROC)曲线，计算 ROC 曲线下面积(Area Under the Curve at Curves, AUC)并把它作为量表区分性能评价标准，其中≥0.90 表示“区分性能极好”，0.80~0.89 表示“区分性能良好”，0.70~0.79 表示“区分性能中等”，<0.70 表示“区分性能差”。

3. 结果

3.1. 一般人口学及不良预后

纳入了 2016 至 2021 年符合诊断标准的 CAP 患儿共 26,039 名，他们的平均年龄为 18.9 月龄，女性有 10,105 (38.8%)名，男性有 15,934 (61.2%)名，15,790 名(60.6%)患者发生在疫情前，10,249 人(39.4%)发生于疫情之后。

疫情前后 CAP 患儿年龄分布有差异(表 2，$p < 0.05$)，疫情后 CAP 患儿平均年龄更大。而疫情前后 CAP 患儿性别差异不显著(表 2，$p > 0.05$)。并且，在 2020 年即疫情发生后第一年，CAP 患儿住院人数较 2019 年人数明显减少，然而到了 2021 年，CAP 患儿开始回升。

此外，疫情前后 CAP 患儿发生不良预后的人数也有差异。具体来说，疫情前 CAP 患儿年平均死亡人数为 46 (0.3%)，疫情后 CAP 患儿年平均死亡人数为 17 (0.2%)，疫情后 CAP 患儿死亡率降低(表 2，$p < 0.05$)。疫情前 CAP 患儿年平均转入 ICU 人数为 251 (1.8%)，疫情后 CAP 患儿年平均转入 ICU 人数为 151 (1.5%)，疫情后 CAP 患儿 ICU 转入率降低(表 2，$p < 0.05$)。疫情前 CAP 患儿年平均使用有创呼吸机人数为 410 (2.9%)，疫情后 CAP 患儿年平均使用有创呼吸机人数为 291 (2.7%)，疫情后 CAP 患儿有创呼吸机使用率降低(表 2，$p < 0.05$)。

3.2. 量表的预测性能

无论疫情前后，mPIRO 量表均显示出对 CAP 患儿不良预后良好的预测性能(图 1~3)。具体来说，

Table 2. Demographic and poor prognosis in patients included in retrospective study
表 2. 一般人口统计学资料及不良预后

	疫情前					疫情后			p
	2016 (%)	2017 (%)	2018 (%)	2019 (%)	2016~2019 (%)	2020 (%)	2021 (%)	2020~2021 (%)	
人数	2956	1516	3527	7791	15790	4592	5657	10249	
年龄(月)	16.29	16.02	16.68	23.33	18.08	18.68	20.75	19.72	p < 0.01
<30 天	39 (1.3%)	11 (0.7%)	33 (0.9%)	27 (0.3%)	110 (0.8%)	33 (0.7%)	14 (0.2%)	47 (0.5%)	
30 天~1 岁	1756 (59.4%)	949 (62.6%)	2149 (60.9%)	3758 (48.2%)	8612 (57.8%)	2620 (57.1%)	2763 (48.8%)	5383 (53.0)	
1 岁~3 岁	667 (22.6%)	331 (21.8%)	825 (23.4%)	1998 (25.6%)	3821 (23.4%)	1117 (24.3%)	1536 (27.2%)	2653 (25.8%)	p < 0.01
3 岁~6 岁	362 (12.2%)	155 (10.2%)	326 (9.2%)	1316 (16.9%)	2159 (12.1%)	528 (11.5%)	1035 (18.3%)	1563 (14.9%)	
6 岁~12 岁	120 (4.1%)	64 (4.2%)	167 (4.7%)	624 (8.0%)	975 (5.3%)	241 (5.2%)	270 (4.8%)	511 (5.0%)	
12 岁~18 岁	12 (0.4%)	6 (0.4%)	27 (0.8%)	68 (0.9%)	113 (0.6%)	53 (1.2%)	39 (0.7%)	92 (1.0%)	
女性	1086 (36.7%)	582 (38.4%)	1356 (38.4%)	3064 (39.3%)	6088 (38.2%)	1756 (38.2%)	2261 (40.0%)	4017 (39.1%)	p = 0.47
死亡	7 (0.20%)	11 (0.70%)	17 (0.50%)	38 (0.50%)	73 (0.48%)	8 (0.20%)	6 (0.10%)	14 (0.15%)	p < 0.01
转入 ICU	68 (2.30%)	97 (6.40%)	184 (5.20%)	265 (3.40%)	614 (4.33%)	142 (3.10%)	112 (2.00%)	254 (2.55%)	p < 0.01
有创呼吸机	53 (1.80%)	92 (6.10%)	184 (5.20%)	289 (3.70%)	618 (4.20%)	149 (3.20%)	107 (1.90%)	256 (2.55%)	p < 0.01

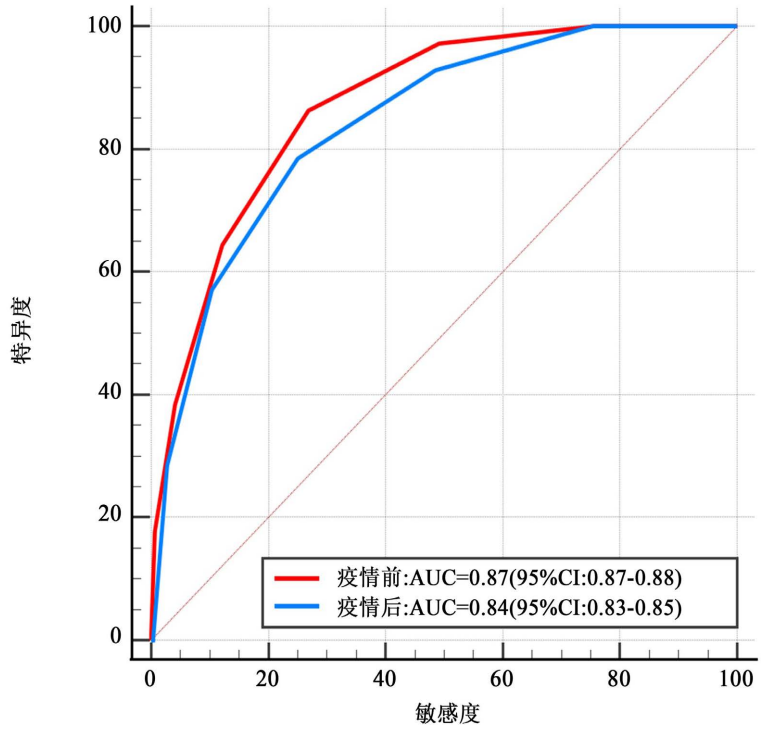

Figure 1. The ROC curve of the mPIRO scale predicting mortality in children with CAP before and during the COVID-19 pandemic
图 1. 疫情前后 mPIRO 量表预测 CAP 患儿死亡的 ROC 曲线

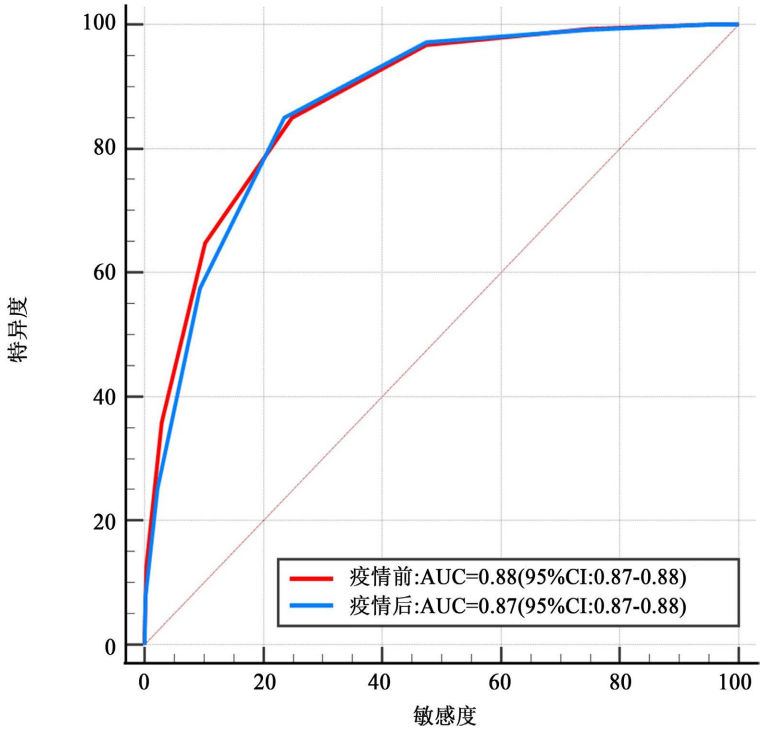

Figure 2. ROC curve of mPIRO scale predicting ICU admission in children with CAP before and during the COVID-19 pandemic
图 2. 疫情前后 mPIRO 量表预测 CAP 患儿转入 ICU 的 ROC 曲线

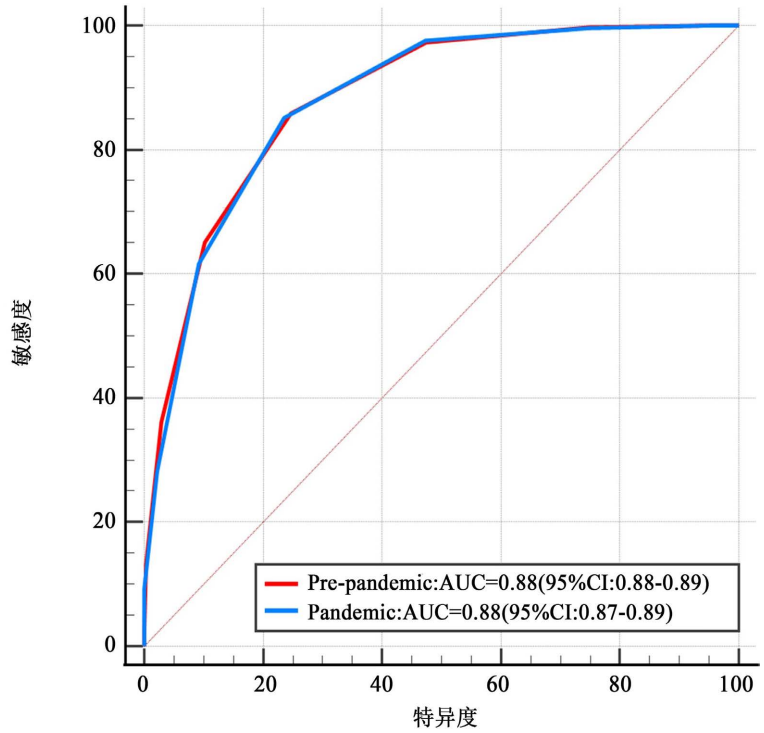

Figure 3. The ROC curve of mPIRO scale predicting invasive ventilation in children with CAP before and during the COVID-19 pandemic
图 3. 疫情前后 mPIRO 量表预测 CAP 患儿有创通气的 ROC 曲线

mPIRO 量表预测 CAP 患儿死亡风险的性能始终良好，疫情前预测死亡的 AUC 值为 0.87，特异度为 73.1，敏感度为 86.3；疫情后预测死亡的 AUC 值为 0.84，特异度为 74.9，敏感度为 78.6 (表 3)。mPIRO 量表预测 CAP 患儿转入 ICU 风险的性能始终良好，疫情前的 AUC 值为 0.88，特异度为 75.2，敏感度为 85.0；疫情后预测死亡的 AUC 值为 0.87，特异度为 76.4，敏感度为 85.0 (表 3)。mPIRO 量表预测 CAP 患儿使用有创呼吸机风险的性能始终良好，疫情前的 AUC 值为 0.88，特异度为 75.25，敏感度为 85.92；疫情后预测死亡的 AUC 值为 0.88，特异度为 76.4，敏感度为 85.16 (表 3)。

Table 3. Comparison of the predictive performance of the mPIRO scale for poor prognosis before and during the COVID-19
表 3. 疫情前后 mPIRO 量表预测不良预后性能的比较

	疫情前					疫情后		
	2016	2017	2018	2019	2016~2019	2020	2021	2020~2021
死亡								
AUC	0.95	0.84	0.87	0.86	0.87	0.79	0.90	0.84
Specificity (%)	76.2	65.9	70.1	74.8	73.1	72.5	76.9	74.9
Sensitivity (%)	100.0	81.8	88.2	84.2	86.3	75.0	83.3	78.6
转入 ICU								
AUC	0.88	0.84	0.90	0.87	0.88	0.86	0.89	0.87
Specificity (%)	77.4	68.8	73.1	76.5	75.2	74.3	78.1	76.4
Sensitivity (%)	82.4	82.5	89.1	83.8	85.0	84.5	85.7	85.0
有创通气								
AUC	0.89	0.85	0.90	0.88	0.88	0.87	0.89	0.88
Specificity (%)	77.09	68.78	73.11	76.74	75.25	74.41	78	76.4
Sensitivity (%)	84.91	82.47	90.22	84.08	85.92	85.91	84.11	85.16

3.3. 量表预测结果与实际不良预后比较

疫情前后 mPIRO 量表预测 CAP 患儿在不同风险分层的人数分布有差异(表 4，$p < 0.01$)。具体来说，疫情前被评为低风险分层的年平均人数为 1998 (50.6%)，而疫情后的年平均人数为 2631 (51.3%)；疫情前被评为中风险分层的年平均人数为 1459 (37.0%)，而疫情后的年平均人数为 1955 (38.2%)；疫情前被评为高风险分层的年平均人数为 459 (11.6%)，而疫情后的年平均人数为 520 (10.1%)；疫情前被评为极高风险分层的年平均人数为 32 (0.8%)，而疫情后的年平均人数为 19 (0.4%)。疫情后 CAP 患儿中低风险和中风险人数及占比增高，而高风险与极高风险人数及占比降低。

Table 4. Comparison of risk stratifications of the mPIRO scale before and during the COVID-19 pandemic
表 4. 疫情前后 mPIRO 量表不同风险分层的比较

分层	疫情前					疫情后			p 值
	2016 (%)	2017 (%)	2018 (%)	2019 (%)	2016~2019 (%)	2020 (%)	2021 (%)	2020~2021 (%)	
低风险	1524 (51.6)	660 (43.5)	1696 (48.1)	4111 (52.8)	7991 (50.6)	2136 (46.5)	3126 (55.3)	5262 (51.3)	$p < 0.01$
中风险	1143 (38.5)	589 (38.9)	1323 (37.5)	2781 (35.7)	5836 (37.0)	1895 (41.3)	2015 (35.6)	3910 (38.2)	
高风险	275 (9.3)	245 (16.2)	464 (13.2)	852 (10.9)	1836 (11.6)	540 (11.8)	500 (8.8)	1040 (10.1)	
极高风险	14 (0.5)	22 (1.5)	44 (1.2)	47 (0.6)	127 (0.8)	21 (0.5)	16 (0.3)	37 (0.4)	

进一步比较 mPIRO 量表反应的病情严重变化与实际不良预后变化发现，疫情发生后，疫情发生后不良预后人数及占比减少，mPIRO 量表评估的高风险与极高风险人数及占比也降低，两者的变化一致的。图 4、图 5 中详细展示了 2016 年至 2021 年间两者的变化趋势。

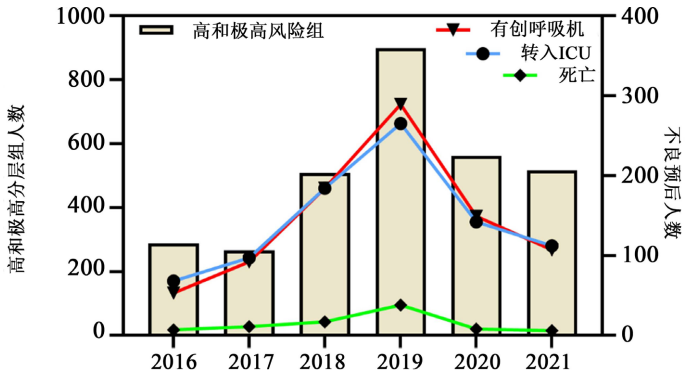

Figure 4. Illustrates the trends in the number of patients classified as high and very high risk by the mPIRO scale, as well as the trends in the number of actual deaths, ICU admissions, and invasive mechanical ventilation in CAP patients from 2016 to 2021

图 4. 展示了 2016 年至 2021 年间 mPIRO 量表预测的高和极高风险组人数的变化趋势，以及 CAP 患儿实际死亡、转入 ICU、使用有创呼吸机的人数变化趋势

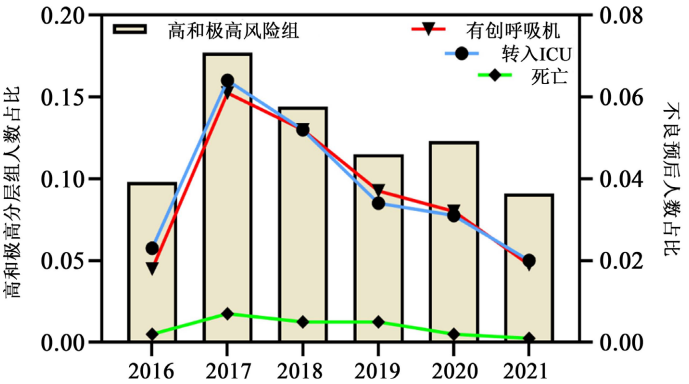

Figure 5. Illustrates the trends in the percentages of patients classified as high and very high risk by the mPIRO scale, as well as the trends in the percentages of actual deaths, ICU admissions, and invasive mechanical ventilation in CAP patients from 2016 to 2021

图 5. 展示了 2016 年至 2021 年间 mPIRO 量表预测的高和极高风险组人数占比的变化趋势，以及 CAP 患儿实际死亡、转入 ICU、使用有创呼吸机的人数占比变化趋势

4. 讨论

本研究使用了 2016 年至 2021 年间 26,039 名 CAP 住院患儿资料，证明了新冠疫情对 mPIRO 量表预测 CAP 患儿不良预后的性能没有影响，mPIRO 量表始终显示出对 CAP 患儿不良预后良好的预测性能。并且，mPIRO 量表反应的疫情前后 CAP 患儿病情变化趋势，与 CAP 患儿实际变化趋势是一致的。

这可能与 mPIRO 量表的科学性有关。PIRO 在 2003 年的国际重症急诊医学研讨会[21] [22] [23] [24]

被提出，并通过前瞻性队列研究证实 PIRO 量表可用于预测成人重症感染和 CAP 死亡率[3]。2016 年 Araya [2]等在成人版 PIRO 量表基础上，利用巴西 860 名患儿资料开发了针对儿童 CAP 的 mPIRO 量表，并且结果显示它预测性能优异(AUC = 0.94, 95% CI: 0.90~0.98)。后续有外部验证也显示出较好的预测性能。一个收集印度尼西亚某医院 80 名肺炎患儿资料的研究显示，mPIRO 量表预测肺炎患儿死亡风险的 AUC 为 0.92 (95% CI: 0.836~0.968) [4]。而田颖等人利用中国北方某医院重症监护室的 366 名 CAP 患儿资料，外部验证显示 mPIRO 量表预测重症肺炎患儿死亡风险性能一般(AUC = 0.762, 95% CI: 0.648~0.876) [5]。

同时，无论是本研究还是既往研究均显示，在疫情后 CAP 患儿的死亡率、ICU 入住率、有创呼吸机使用率降低，而这与疫情后呼吸道常见流行病原体检出显著降低是一致的[25]，具体来说，疫情后呼吸道常见流行病原包括肺炎球菌[26]、呼吸道合胞病毒[27] [28] [29]、流感[30] [31] [32]、副流感[33] [34]、腺病毒[35]、鼻病毒[36]等病原体的检出率均有明显降低。而这种呼吸道常见病原体的流行变化，与本研究中 CAP 患儿病情变化趋势，以及 mPIRO 量表反应的病情变化趋势，三者都是一致的。疫情导致儿童 CAP 整体疾病负担出现变化，但并未影响个体病情变化，mPIRO 量表通过评估每位 CAP 患儿预后风险并提供个性化指导，因此预测性能不受到影响。并且我们推测，即使面对新未知病原导致的突发公共卫生事件，mPIRO 量表对 CAP 患儿预后的预测性能仍能不被影响。

然而本研究也有一些不足之处。首先，我们的研究队列中没有新冠患者，新冠肺炎与常见病原所致肺炎的预后可能不同[37]，然而未来新型冠状病毒将与人类长久共存，因此，需要进一步研究以验证 mPIRO 量表对新冠肺炎患儿的表现。其次，本研究是一项回顾性研究，在分析 mPIRO 量表预测性能时只纳入了评价指标均可获得的病例，排除了它们任一指标有缺失的患儿，这可能导致我们纳入人群有偏倚，未来需要进一步前瞻性研究验证。最后，我们研究仅纳入了重庆医科大学附属儿童医院单中心肺炎患儿资料，我们的数据不能代表全中国儿童 CAP 的普遍特点，未来需要多中心的数据来进一步验证。

5. 结论

公共卫生突发事件不对 mPIRO 量表预测 CAP 患儿不良预后的性能造成影响，在后疫情时代，mPIRO 量表仍然可作为一种可靠的决策辅助工具，指导儿科医师对有高不良预后风险的患儿采取更积极治疗措施。

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