

• 临床研究 •

## 快速康复病房腔镜下肺结节切除术患者术后肺部并发症危险因素分析

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**[摘要]** 目的: 分析快速康复病房行胸腔镜下肺结节切除术的患者发生术后肺部并发症(postoperative pulmonary complication, PPC)的危险因素。方法: 回顾性分析快速康复病房管理模式下首次行胸腔镜下肺结节切除术的624例患者的临床资料。根据患者出院后1个月内是否发生PPC分为PPC组和非PPC组。通过多因素Logistic回归分析筛选出独立危险因素, 构建列线图预测模型并进行内部验证。结果: 209例(33.5%)患者发生PPC。多因素Logistic回归分析结果显示, 术后胸腔引流管放置天数(OR=1.478, 95%CI: 1.043~2.094)、术后第1天引流量(OR=1.008, 95%CI: 1.006~1.011)、病理结果为恶性(OR=1.564, 95%CI: 1.037~2.359)是PPC的独立危险因素。预测模型受试者工作特征曲线下面积为0.716(95%CI: 0.673~0.760), 基于Hosmer-Lemeshow检验的校准曲线P值为0.105, 提示预测模型区分度和校准度均较好。结论: 术后胸腔引流管放置天数、术后第1天引流量、病理结果为恶性是快速康复病房管理模式下行胸腔镜肺结节切除术患者发生PPC的独立危险因素, 且根据其构建的预测模型有较好的区分度和校准度, 可为防治术后发生PPC提供个体化依据。

**[关键词]** 胸腔镜手术; 快速康复病房; 肺部并发症; 回顾性分析; 危险因素

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## Analysis of risk factors for postoperative pulmonary complications in patients undergoing video-assisted thoracic surgery under day surgery management model

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**[Abstract]** **Objective:** To analyze the risk factors of postoperative pulmonary complication (PPC) in patients undergoing video-assisted thoracic surgery (VATS) under day surgery management model. **Methods:** The clinical data of 624 patients who underwent the surgery of thoracoscopic pulmonary nodules for the first time in the Rapid Rehabilitation Care Unit were retrospectively analyzed. Patients were divided into two groups based on whether they developed PPC within one month after discharge: the PPC group and the non-PPC group. Multivariate logistic regression analysis were performed to identify independent risk factors, and a nomogram prediction model was constructed and internally validated. **Results:** A total of 209 patients (33.5%) developed PPC. Multivariate logistic analysis showed that days of postoperative thoracic drainage tube placement (OR=1.478, 95% CI: 1.043–2.094), drainage volume on the first day after surgery (OR=1.008, 95% CI: 1.006–1.011), and malignant pathological results (OR=1.564, 95% CI: 1.037–2.359) were independent risk factors for PPC. The area under the ROC curve of the prediction model was 0.716 (95% CI: 0.673–0.760), and the calibration curve based on the Hosmer-Lemeshow test had a P-value of 0.105, suggesting good discrimination and calibration of the prediction model. **Conclusion:** The days of postoperative thoracic drainage tube placement, the drainage volume on the first day

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after surgery and malignant pathological results are independent risk factors for PPC in patients undergoing VATS under day surgery management model. The prediction model constructed based on these factors shows good discrimination and calibration, providing a basis for personalized prevention and treatment of postoperative PPC.

[Key words] thoracoscopic surgery; day surgery management model; pulmonary complications; retrospective analysis; risk factor

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相比传统开胸手术,电视辅助胸腔镜手术(video-assisted thoracic surgery, VATS)具备创伤小、耗时短、恢复快等优势<sup>[1]</sup>。但目前VATS术后仍有较多并发症发生,对患者康复质量及生存品质造成严重影响。其中术后肺部并发症(postoperative pulmonary complication, PPC)为最常见<sup>[2]</sup>。研究表明,胸科患者PPC发生率约为35%,甚至超过心血管并发症<sup>[3]</sup>。随着加速康复外科(enhanced recovery after surgery, ERAS)理念在VATS围术期管理中的运用,大多数患者可在24~48 h内达到出院标准。PPC难以在较短住院期间得到全面的评估,而在出院后出现的PPC会严重影响行ERAS管理的胸科患者的安全及康复进程。目前关于影响ERAS管理模式下行VATS患者术后发生PPC的危险因素尚无定论。本研究通过回顾性分析快速康复病房管理模式下行VATS患者出院后1个月内发生PPC的危险因素,为优化此类患者围手术期管理提供临床依据。

## 1 对象和方法

### 1.1 对象

选取2021年1月—2022年12月南京大学医学院附属鼓楼医院快速康复病房首次行VATS的患者624例。纳入标准:年龄 $\geq 18$ 岁;美国麻醉医师协会(American Society of Anesthesiologists, ASA)分级I~III级;心、肺功能检查结果无明显异常。排除标准:合并非肺部恶性肿瘤及治疗史;全肺切除手术史;术后转入重症监护病房(intensive care unit, ICU);随访资料缺失。本研究获得南京大学医学院附属鼓楼医院伦理委员会批准(编号:2023-286-01)。

### 1.2 方法

#### 1.2.1 手术阶段

依照术者经验,对于部分结节位于肺实质内较深或实性成分较少的患者,术前2 h内在CT引导下应用Hookwire定位针穿刺定位结节。肺段支气管或动静脉变异较多者,术前还需行三维计算机断层扫描支气管血管成像重建以规划手术方案。患者术前均接受术侧超声引导下胸椎旁间隙阻滞。入

手术室后常规行心电图、脉搏血氧饱和度(percutaneous oxygen saturation, SpO<sub>2</sub>)、有创动脉压监测。麻醉方案均采用全凭静脉麻醉。术中采取肺保护性通气策略<sup>[4]</sup>。分别在气管插管后即刻和手术结束时行肺复张手法。患者从麻醉后监测治疗室(post-anesthesia care unit, PACU)转出时均配备患者静脉自控镇痛(patient controlled intravenous analgesia, PCIA)装置用于术后镇痛,成分包含舒芬太尼2  $\mu\text{g}/\text{kg}$ +昂丹司琼8 mg+地塞米松10 mg。

#### 1.2.2 术后阶段

患者返回快速康复病房2 h后开始口服液体。对于血栓栓塞的中高危人群,予以机械预防;患者自诉视觉模拟评分(visual analogue scale, VAS) $\geq 4$ 分时,予曲马多口服或氟比洛芬酯静脉推注作为补救镇痛措施。术后第1天早复查血常规、凝血功能、生化及胸部X线,每天至少3次6 min步行试验作为术后肺康复锻炼。患者拔除胸腔引流管后复查X线,如无特殊不适即可出院。嘱患者术后3~4周或期间出现不适时到医院复诊,并复查X线或CT。在出院后1个月时随访患者恢复情况及复诊情况。

#### 1.2.3 资料收集

资料均从本院电子病历系统和手术麻醉记录系统中采集,包括性别、年龄、体重指数(body mass index, BMI)、ASA分级、手术时间、插管方式、术中液体出入量、胸腔引流管放置时长、镇痛方式、术后恶心呕吐(postoperative nausea and vomiting, PONV)发生情况等信息,并随访出院后1个月内发生肺部炎症、胸腔积液、气胸、肺不张等并发症发生情况。

#### 1.2.4 PPC诊断标准

所有患者随访至出院后1个月。根据指南及既往研究的定义<sup>[5]</sup>,PPC的诊断可根据患者的临床表现、影像学表现及是否伴有需要紧急处理的呼吸道症状得出。PPC的类型包括:肺炎、肺不张、胸腔积液、气胸、急性呼吸窘迫综合征(acute respiratory distress syndrome, ARDS)、肺水肿、二次插管、支气管痉挛、呼吸衰竭等。所有结果均来自患者于门诊复诊时留存的病历、影像学或实验室检查数据。如果患

者在出院后1个月内发生任何一种PPC,则认为患者发生PPC,归为PPC组。

### 1.3 统计学方法

本研究收集的数据资料采用SPSS 26.0统计学软件和R 4.3.0进行分析。由于本研究中计量资料均不符合正态分布,因此以中位数(四分位数)[ $M(P_{25}, P_{75})$ ]描述,采用U检验比较;计数资料以频数(构成比)描述,采用 $\chi^2$ 检验比较。选择单因素分析中 $P \leq 0.2$ 的协变量进行多重共线性测试。通过Logistic回归分析筛选独立危险因素。绘制受试者工作特征(receiver operating characteristic, ROC)曲线,计算预测模型曲线下面积(area under the curve, AUC)。通过R语言软件绘制预测模型列线图、校准曲线和决策曲线。 $P < 0.05$ 为差异有统计学意义。

## 2 结果

### 2.1 一般情况

本研究初始纳入667例,剔除43例,最终纳入624例患者。有209例(33.5%)出院后1个月内至少发生1种PPC。其中肺部炎症36例、胸腔积液

182例、气胸23例、肺不张12例。两组患者一般情况比较见表1。

### 2.2 围术期资料情况

与非PPC组相比,PPC组手术时间更长,术后胸腔引流管放置时间更长,吗啡当量(按照10  $\mu\text{g}$  芬太尼或10  $\mu\text{g}$  瑞芬太尼相当于1 mg 吗啡静脉注射计算)更多,术中出血量更多,术后当天及第1天引流量更多,术后第1天晨间查房时VAS评分偏高,患者加泰罗尼亚外科患者呼吸风险评估(assess respiratory risk in surgical patients in Catalonia, ARISCAT)评分偏高,病理结果为恶性的占比更高,两组间差异有统计学意义( $P < 0.05$ ,表2)。

### 2.3 PPC的危险因素分析

对于单因素分析中 $P \leq 0.2$ 的协变量进行多重共线性测试,测试结果表明方差膨胀因子(variance inflation factor, VIF)值均 $< 3$ ,指标之间不存在多重共线性,继而采用多因素Logistic回归进一步分析。结果显示,术后胸腔引流管放置天数、术后第1天引流量、病理结果为恶性是快速康复病房行VATS患者发生PPC的独立危险因素( $P < 0.05$ 且 $OR \geq 1$ ,表3)。

表1 两组患者一般情况比较

Table 1 Comparison of general data between the two groups of patients

Parameter	Non-PPC( $n=415$ )	PPC( $n=209$ )	<i>P</i>
Sex(male/female)	152/263	72/137	0.593
Age[years, $M(P_{25}, P_{75})$ ]	52.00(36.00, 59.00)	54.00(46.00, 60.00)	0.003
BMI[ $\text{kg}/\text{m}^2$ , $M(P_{25}, P_{75})$ ]	23.66(21.78, 25.39)	23.44(21.26, 25.08)	0.636
Preoperative Hb [g/L, $M(P_{25}, P_{75})$ ]	142.00(136.00, 154.50)	140.00(131.00, 151.50)	0.531
Preoperative CRP[mg/L, $M(P_{25}, P_{75})$ ]	1.90(1.70, 2.30)	2.30(1.90, 3.35)	0.161
Cultural level[ $n(\%)$ ]			0.113
Under junior high	75(18.07)	49(23.44)	
Junior high and above	340(81.93)	160(76.56)	
Smoking history[ $n(\%)$ ]			0.732
No	392(94.46)	196(93.78)	
Yes	23(5.54)	13(6.22)	
Hypertension[ $n(\%)$ ]			0.221
No	348(83.86)	167(79.90)	
Yes	67(16.14)	43(20.10)	
Diabetes[ $n(\%)$ ]			0.732
No	392(94.46)	196(93.78)	
Yes	23(5.54)	14(6.22)	
ASA classification[ $n(\%)$ ]			0.064
I	169(40.72)	65(31.10)	
II	210(50.60)	122(58.37)	
III	36(8.68)	22(10.53)	

Hb: hemoglobin; CRP: C-reactive protein.

表2 两组患者围术期资料比较

Table 2 Comparison of perioperative data between the two groups of patients

Parameter	Non-PPC(n=415)	PPC(n=209)	P
Duration of surgery[h, $M(P_{25}, P_{75})$ ]	1.00(0.75, 1.33)	1.25(1.00, 1.75)	<0.001
Days of postoperative thoracic drainage tube placement [d, $M(P_{25}, P_{75})$ ]	2.00(2.00, 2.00)	2.00(2.00, 3.00)	<0.001
Hb of the first day after surgery[g/L, $M(P_{25}, P_{75})$ ]	132.00(123.00, 142.00)	130.00(120.00, 141.00)	0.598
CRP of the first day after surgery[mg/L, $M(P_{25}, P_{75})$ ]	25.30(13.30, 43.40)	25.80(14.55, 39.05)	0.470
Morphine equivalent[M( $P_{25}, P_{75}$ )]	91.00(73.00, 113.00)	100.00(79.50, 124.50)	<0.001
Intraoperative fluid infusion[mL, $M(P_{25}, P_{75})$ ]	1 000.00(1 000.00, 1 500.00)	1 000.00(1 000.00, 1 500.00)	0.120
Intraoperative urine volume[mL, $M(P_{25}, P_{75})$ ]	250.00(150.00, 400.00)	200.00(150.00, 400.00)	0.016
Intraoperative hemorrhage[mL, $M(P_{25}, P_{75})$ ]	30.00(10.00, 50.00)	50.00(10.00, 50.00)	0.001
Drainage volume on the day of surgery[mL, $M(P_{25}, P_{75})$ ]	50.00(10.00, 85.00)	50.00(10.00, 150.00)	0.005
Drainage volume on the first day after surgery[mL, $M(P_{25}, P_{75})$ ]	100.00(50.00, 146.50)	150.00(100.00, 250.00)	<0.001
VAS on the first day after surgery[mL, $M(P_{25}, P_{75})$ ]	3(2, 3)	3(2, 3)	0.017
ARISCAT[mL, $M(P_{25}, P_{75})$ ]	27(24, 27)	27(24, 27)	<0.001
Scope of resection[n(%)]			<0.001
Wedge resection	275(66.27)	91(43.54)	
Segmentectomy	89(21.45)	52(24.88)	
Lobectomy	51(12.28)	66(31.58)	
Pathological result[n(%)]			<0.001
Benignant	72(17.35)	22(10.53)	
Malignant	343(82.65)	187(89.47)	
PONV[n(%)]			0.976
No	334(80.48)	168(80.38)	
Yes	81(19.52)	41(19.62)	
Analgesic remediation[n(%)]			0.491
No	322(77.59)	157(75.12)	
Yes	93(22.41)	52(24.88)	
Intubation method[n(%)]			0.273
Laryngeal mask	58(13.98)	30(14.35)	
Single-lumen tube	27(6.50)	7(3.35)	
Double-lumen tube	330(79.52)	172(82.30)	

#### 2.4 PPC危险因素的列线图模型建立及验证

将 Logistic 回归分析中具有统计学意义的独立危险因素通过 R 语言软件绘制列线图(图 1), 该模型用于综合评估快速康复病房首次行胸腔镜下肺结节切除术的患者发生 PPC 的风险。根据回归系数得出预测模型方程为  $\text{Logit}(P) = -2.885 + 0.008 \times \text{术后第 1 天引流量} + 0.293 \times \text{胸腔引流管放置天数} + 0.538 \times \text{病理结果恶性(赋值为 1)}$ 。采用 ROC 分析其预测准确性。结果显示, 预测模型 AUC 为 0.716 (95%CI: 0.673~0.760), 提示该模型准确度较好(图 2)。基于 Hosmer-Lemeshow 检验绘制校准曲线(图 3)结果显示  $P=0.105$ , 说明该模型的预测风险与实际发生风险的一致性较高。决策曲线分析显示模型具有较好的临床应用价值(图 4)。

### 3 讨论

随着 ERAS 理念在胸科患者管理中的普遍运用, 患者术后的安全性及康复质量是临床医生需要关注的首要问题。本研究结果显示, 术后第 1 天引流量、术后胸腔引流管放置时间及病理结果为恶性是 VATS 患者出院后 1 个月内发生 PPC 的独立危险因素。根据危险因素构建的预测模型具有较好的区分度和校准度, 和较好的临床应用价值。

VATS 术后常规放置胸腔引流管可起到引流胸腔内残余气、液体的作用, 是观察胸腔内病情变化的重要窗口。术后胸腔引流量主要与手术时间、创伤范围、胸膜粘连程度、患者营养状态及术中止血材料的应用等因素相关<sup>[6]</sup>。手术操作破坏壁层胸

表3 PPC的多因素Logistic回归分析  
Table 3 Multivariate logistic regression analysis of PPC

Parameter	OR	95%CI	P
Age	0.996	0.976-1.016	0.695
Preoperative CRP	1.013	0.985-1.042	0.371
Cultural level( <i>vs.</i> Under junior high)			
Junior high and above	1.045	0.686-1.594	0.837
ASA classification( <i>vs.</i> I )			
II	1.034	0.654-1.634	0.886
III	—	—	0.999
Duration of surgery	1.266	0.614-2.608	0.523
Days of postoperative thoracic drainage tube placement	1.478	1.043-2.094	0.028
Morphine equivalent	1.004	0.996-1.012	0.351
Intraoperative fluid infusion	1.000	0.999-1.001	0.500
Intraoperative urine volume	1.000	0.999-1.001	0.821
Intraoperative hemorrhage	1.001	0.997-1.006	0.513
Drainage volume on the day of surgery	1.000	0.998-1.002	0.942
Drainage volume on the first day after surgery	1.008	1.006-1.011	<0.001
VAS on the first day after surgery	1.215	0.967-1.527	0.094
ARISCAT	0.994	0.938-1.053	0.832
Scope of resection( <i>vs.</i> Wedge resection )			
Segmentectomy	1.103	0.651-1.869	0.716
Lobectomy	1.217	0.603-2.454	0.584
Pathological result ( <i>vs.</i> Benignant )			
Malignant	1.564	1.037-2.359	0.033

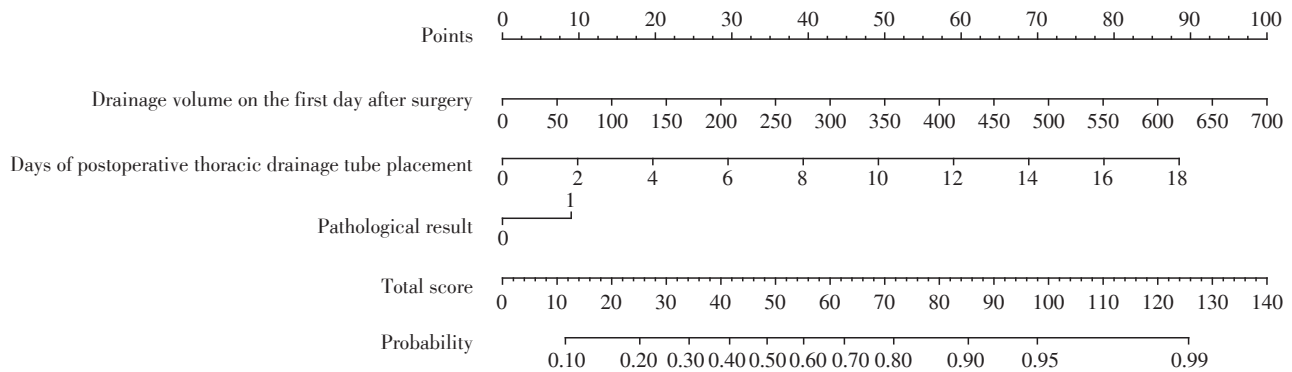


图1 VATS术后发生PPC的危险因素的列线图预测模型

Figure 1 Nomogram prediction model of risk factors for PPC after VATS

膜,胸腔内液体的重吸收和回流受到影响,从而使得胸腔内液体积聚。术后第1天引流量增多表明患者手术范围及术中创伤较大,若引流量持续增多可导致心律失常、呼吸衰竭甚至危及患者生命。既往有研究指出,术后第1天引流量较大为胸科患者术后并发症的独立危险因素<sup>[7]</sup>,与本研究结果相同。但该研究中并发症组术后第1天平均引流量为338 mL,而本研究为146.5 mL。可能原因为:①本研究中58.7%

患者行肺楔形切除术,手术时间短,创伤较小;②本研究患者身体基础状况较好,均为经麻醉门诊评估后可纳入ERAS管理的手术患者。本研究结果表明当胸腔引流管放置时间超过2.5 d时,PPC的发生概率显著增高。胸管放置带来的刺激性疼痛导致患者不敢下床活动,无法进行有效咳嗽咳痰,进而引起肺部感染、发热、皮下气肿、肺不张等一系列并发症<sup>[8]</sup>。同时胸管留置时间延长会使外界病原菌通过

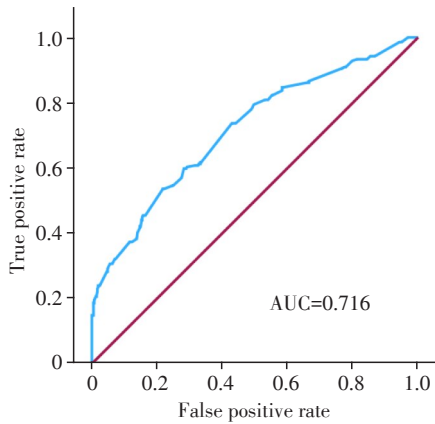


图2 预测 VATS 术后发生 PPC 的 ROC 曲线

Figure 2 ROC curve for predicting the occurrence of PPC after VATS

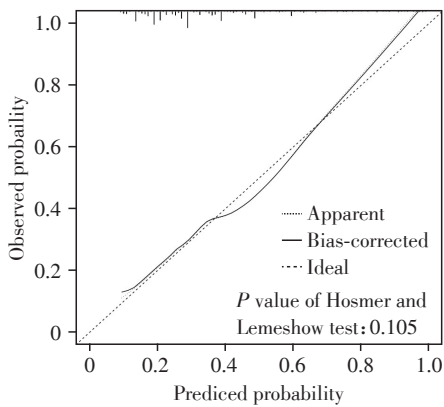


图3 预测模型的校准曲线

Figure 3 Calibration curve of prediction model

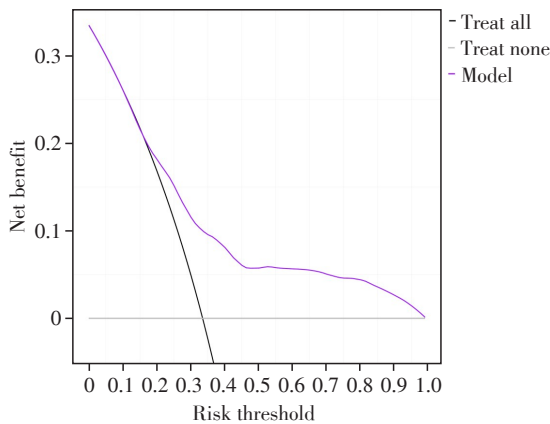


图4 预测模型的决策曲线

Figure 4 The decision curve of the prediction model

胸腔侵入机体的易感性增加。马世鑫等<sup>[9]</sup>研究表明,胸腔引流管放置时间 $\geq 3.5$  d,术后发生肺部感染的风险增加2.273倍。Dang等<sup>[10]</sup>分析表明,对于行胸腔镜下肺部分切除术的患者,术后不放置胸腔引流管可明显缩短住院时间,改善预后。本研究发生

PPC的患者中有56例未能在48 h拔除胸腔引流管,其中52%为胸腔积液所致,39%为漏气所致,其他考虑与手术创伤较大、患者自主意愿有关。对于行胸腔镜下肺部分切除后胸腔引流量 $< 300$  mL/d且无漏气患者,可考虑早期拔除胸腔引流管,减轻胸管带来的刺激性疼痛,鼓励患者早期下床活动,有效咳嗽咳痰,减少后期PPC的发生<sup>[11]</sup>。

非小细胞肺癌(non-small cell lung cancer, NSCL)为肺恶性肿瘤中较常见的病理亚型,占比80%以上<sup>[12]</sup>,且具有侵袭性高、转移快的特点。本研究结果表明恶性病理结果为PPC的独立危险因素。术中快速冰冻切片病理结果显示为恶性时会影响手术操作范围,不仅需要切除整个病灶区域,还需增加清扫周围淋巴结的操作步骤,也会相应延长手术时间,极有可能造成出血量增多,且会对水和电解质的转运功能造成影响,大量正常淋巴结的免疫功能受到损伤,更有可能导致PPC的发生<sup>[13]</sup>。

目前ARISCAT是临床工作中使用最为广泛的PPC预测模型,但其针对人群为所有行外科手术的患者,在胸科患者中的应用有局限性。Bevilacqua Filho等<sup>[14]</sup>纳入196例肺切除手术患者,结果表明ASA $\geq$  III级、术后肺一氧化碳弥散量预计值和年龄为手术后PPC的独立危险因素。Wang等<sup>[15]</sup>指出手术方式、手术时间、单肺通气吸入氧浓度、术后疼痛为肺切除术后7 d内肺部感染的独立危险因素。但以上研究针对人群均为普通病房胸科患者,鲜有针对快速康复病房管理模式下VATS患者的PPC预测模型。此外,有研究指出术后疼痛及肌松代谢为影响PPC的重要因素<sup>[16-17]</sup>,本研究在患者离开PACU时均确保肌松药已代谢完全,可排除术后肌松残留对患者呼吸功能的影响,且患者术后第1天VAS评分并无显著差异。在ERAS流程中引流管管理、疼痛管理、术后早期活动为围术期关注重点。但本研究仅为单中心回顾性研究,且患者住院时间短,术后很快脱离了严密的医疗观察,未能追踪远期预后,如需在更广泛人群中进行推广还需大量多中心前瞻性研究进行验证。

综上所述,术后胸腔引流管放置天数、术后第1天引流量、病理结果为恶性是快速康复病房行VATS患者发生PPC的独立危险因素。通过识别并对PPC高危患者进行积极干预,有望改善患者预后。对快速康复病房的患者进行精细化管理,如行肺局部切除术患者采取不放置或早期拔除胸腔引流管策略,术后引流增多且病理结果为恶性的患者

及时采取影像学检查明确胸腔情况,进而减少PPC发生,提高恢复质量。

#### 利益冲突声明:

所有作者声明无利益冲突。

#### Conflict of Interests:

All authors declare no conflict of interest.

#### 作者贡献声明:

倪爽:深度参与本次研究,对临床数据进行收集与整理。制定患者术后随访计划与方案,明确随访时间节点、随访内容与评估指标,确保能及时、准确地捕捉术后肺部并发症的发生情况。对数据进行统计学分析,确定合适的数据分析方法与统计模型。撰写文稿。路子蕴:参与文稿的审阅,提出修改建议。孙行:参与临床数据的收集与整理。史敏科、张楼乾、杨如松:从胸外科医师角度出发,提出专业的术后管理建议。李冰冰:作为通讯作者,构思了整个研究课题,规划研究的总体方向和策略,监督研究进展。参与解决研究实施中出现的关键技术和协调难题。对文稿进行了修订,并对整个项目进行了监督。

#### Author's Contributions:

NI Shuang: Deeply participated in this study, collected and collated clinical data. Formulated the postoperative follow-up plan for patients, clarified the follow-up time node, follow-up content and evaluation indicators, and ensured that the occurrence of postoperative pulmonary complications can be captured timely and accurate. Determined the appropriate data analysis methods and statistical models. Analyzed the data and made data figures. Wrote the manuscript. LU Ziyun: Participated in the review of the manuscript and made suggestions for revision. HANG Sun: Participated in the collection and collation of clinical data. SHI Minke, ZHANG Louqian, YANG Rusong: They contributed equally to this paper. As the thoracic surgeon, put forward professional postoperative management recommendations. LI Bingbing: As the corresponding author, he designed the experiments, planned the overall direction and strategy of the research, and supervised the research progress. Participated in solving the key technical and coordination problems in the implementation of the research. Revised the manuscript, and supervised the whole project.

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