

重度肺动脉高压产妇剖宫产围手术期发生肺动脉高压危象的术前危险因素分析

张春雷 刘亚光 卿恩明 马骏

100029 北京,首都医科大学附属北京安贞医院麻醉中心

通讯作者:马骏,Email:majun7689@163.com

DOI: 10.3760/cma.j.issn.2095-4352.2017.05.009

【摘要】 目的 分析重度肺动脉高压(PAH)产妇剖宫产围手术期发生肺动脉高压危象(PHC)的术前危险因素,探讨其临床价值。方法 采用回顾性分析方法,选择2008年1月1日至2016年12月31日在北京安贞医院接受剖宫产手术的152例重度PAH产妇作为研究对象,按照围手术期是否发生PHC分为两组。通过病例管理系统提取患者年龄、身高、体重、孕周、孕次、PAH类型、急诊手术、纽约心脏病协会(NYHA)心功能分级,术前超声左室射血分数(LVEF)、左室舒张期末内径(LVEDD)、超声TI法估测肺动脉收缩压(sPAP)、桡动脉收缩压(SBP)和舒张压(DBP)、心率、未吸氧时脉搏血氧饱和度(SpO₂),术前是否口服西地那非、是否放置漂浮导管、是否应用去甲肾上腺素,以及围手术期PHC发生情况和术后结局。对可能的术前危险因素进行两组间单因素比较和多因素logistic回归分析;绘制受试者工作特征曲线(ROC),分析各危险因素对PHC的诊断价值。结果 152例患者中排除10例全麻下同期行心脏手术患者、4例全麻下行剖宫产术患者,最终共138例纳入分析;围手术期发生PHC 27例(19.57%),死亡17例(病死率62.96%)。与非PHC组比较,PHC组患者年龄更小(岁:25.07±3.55比27.64±4.82),心功能更差[NYHA(级):3.22±0.64比2.85±0.53],术前LVEDD更小(mm:38.78±4.76比43.91±9.67),未吸氧时SpO₂(0.83±0.12比0.92±0.06)及口服西地那非患者比例更低(29.63%比56.76%),术前sPAP[mmHg(1 mmHg=0.133 kPa):113.41±24.73比99.35±21.10]、DBP(mmHg:79.63±13.23比75.23±12.14)及放置漂浮导管(85.19%比57.66%)、艾森曼格综合征(70.37%比37.84%)、急诊手术患者比例更高(48.15%比23.42%,均P≤0.1)。将单因素分析差异有统计学意义(取P≤0.1)的变量进行多因素logistic回归分析,结果显示,LVEDD[优势比(OR)=0.878,95%可信区间(95%CI)=0.796~0.968,P=0.009]、是否口服西地那非(OR=0.161,95%CI=0.051~0.515,P=0.002)、未吸氧时SpO₂(OR=0.882,95%CI=0.829~0.938,P=0.000)、是否放置漂浮导管(OR=6.186,95%CI=1.533~24.964,P=0.010)为重度PAH产妇剖宫产围手术期发生PHC的术前独立危险因素;ROC曲线分析显示,4个因素联合诊断PHC的ROC曲线下面积(AUC)为0.878(P=0.000),敏感度为88.89%,特异度为76.58%。结论 重度PAH产妇剖宫产围手术期PHC非常凶险,病死率极高。LVEDD、是否口服西地那非、未吸氧时SpO₂、是否放置漂浮导管为重度PAH产妇围手术期发生PHC的术前独立危险因素;4个术前因素对围手术期PHC的联合诊断价值较高。

【关键词】 肺动脉高压; 妊娠; 产妇; 肺动脉高压危象; 术前; 危险因素

基金项目: 国家自然科学基金(81471902);北京市卫生系统高层次卫生技术人才培养计划(2013-2-004)

Preoperative risk factors analysis of pulmonary hypertension crisis during perioperative period for caesarean section of woman with severe pulmonary hypertension Zhang Chunlei, Liu Yaguang, Qing Enming, Ma Jun
Department of Anesthesiology, Beijing Anzhen Hospital, Capital Medical University, Beijing 100029, China
Corresponding author: Ma Jun, Email: majun7689@163.com

【Abstract】 **Objective** To analyze preoperative risk factors of perioperative pulmonary hypertension crisis (PHC) for pregnant woman with severe pulmonary artery hypertension (PAH), and approach its clinical value. **Methods** A retrospective analysis was conducted. The clinical data from 152 pregnant women with severe PAH underwent cesarean delivery admitted to Beijing Anzhen Hospital from January 1st 2008 to December 31st 2016 was collected. The patients were divided into two groups according to with perioperative PHC or not. Through the case management system, age, height, weight, gestational age, pregnancy time, type of PAH, emergency or selective surgery, New York Heart Association (NYHA) cardiac function classification, and preoperative ultrasound left ventricular ejection fraction (LVEF), left ventricular diastolic final diameter (LVEDD), the pulmonary artery systolic pressure (sPAP) estimated by ultrasonic TI method, radial artery systolic blood pressure (SBP) and diastolic blood pressure (DBP), heart rate (HR), pulse oxygen saturation (SpO₂) without oxygen, oral sildenafil ingestion, having Swan-Ganz catheter placement or not, and whether used norepinephrine or not, as well as the occurrence of perioperative PHC and clinical outcomes were collected. Possible preoperative risk factors were compared between the two groups by single factor and multiple factors logistic regression analysis. The receiver-operating characteristic curve (ROC) was plotted to assess the diagnostic value of various risk factors. **Results** A total of 152 patients were screened. Ten patients got heart surgery under

general anesthesia at the same time, and 4 patients experiencing cesarean section with general anesthesia were excluded. 138 patients were enrolled finally, 27 patients underwent perioperative PHC (19.57%), and 17 patients died with a mortality of 62.96%. Compared with non-PHC group, the patients in PHC group were older (years: 25.07 ± 3.55 vs. 27.64 ± 4.82), had a poor cardiac function (NYHA cardiac function classification: 3.22 ± 0.64 vs. 2.85 ± 0.53), a smaller LVEDD (mm: 38.78 ± 4.76 vs. 43.91 ± 9.67), lower SpO₂ without oxygen (0.83 ± 0.12 vs. 0.92 ± 0.06) and oral sildenafil ingestion rate (29.63% vs. 56.76%), and higher sPAP estimated by ultrasonic TI method [mmHg (1 mmHg = 0.133 kPa): 113.41 ± 24.73 vs. 99.35 ± 21.10] and DBP (mmHg: 79.63 ± 13.23 vs. 75.23 ± 12.14), more having Swan-Ganz catheter placement (85.19% vs. 57.66%), more Eisenmenger syndrome (70.37% vs. 37.84%), and more emergency operation (48.15% vs. 23.42%, all $P \leq 0.1$). The variables with statistically significant differences showed by single factor analysis were collected, and it was shown by multiple factors logistic regression analysis that LVEDD [odds ratio (OR) = 0.878, 95% confidence interval (95%CI) = 0.796–0.968, $P = 0.009$], whether oral taken sildenafil (OR = 0.161, 95%CI = 0.051–0.515, $P = 0.002$) or not, SpO₂ at room air (OR = 0.882, 95%CI = 0.829–0.938, $P = 0.000$), Swan-Ganz catheter placement or not (OR = 6.186, 95%CI = 1.533–24.964, $P = 0.010$) were independent risk factors of perioperative PHC in pregnant women with severe PAH. It was shown by ROC curve analysis that the area under the ROC curve (AUC) of four factors mentioned above combined diagnosis for PHC was 0.878 ($P = 0.000$) with the sensitivity of 88.89% and specificity of 76.58%. **Conclusions** PHC is very dangerous for gravida with severe PAH, and the mortality rate is very high. LVEDD, oral sildenafil, SpO₂ at room air, Swan-Ganz catheter placement or not were independent risk factors of perioperative PHC for severe PAH maternal. Four preoperative factors of perioperative PHC joint diagnosis accuracy were higher.

【Key words】 Pulmonary artery hypertension; Pregnancy; Puerpera; Pulmonary hypertension crisis; Preoperation; Risk factor

Fund program: National Natural Science Foundation of China (81471902); High Level Health Technical Personnel Training Program of Beijing Health System (2013–2–004)

肺动脉高压(PAH)的特点为肺动脉壁慢性增生变厚,肺血管阻力逐渐增大,加重右心后负荷,最终导致右心功能衰竭。重度PAH患者妊娠期间的病情变化可能导致循环衰竭,孕产妇的病死率升高。肺动脉高压危象(PHC)是各种原因诱发的肺血管阻力急速升高,肺动脉压力接近或超越主动脉压力,导致右心功能急性衰竭的临床危象^[1]。PHC是造成妊娠合并重度PAH患者围手术期死亡的主要原因之一。本研究拟对重度PAH产妇剖宫产围手术期发生PHC的术前危险因素进行分析。

1 对象与方法

1.1 研究对象:采用回顾性分析方法,选择2008年1月1日至2016年12月31日在北京安贞医院行剖宫产术的152例妊娠合并重度PAH产妇为研究对象。

1.1.1 纳入标准:行硬膜外麻醉下剖宫产手术的重度PAH产妇;符合重度PAH诊断标准^[2]:超声心动图TI法估测肺动脉收缩压(sPAP) ≥ 60 mmHg (1 mmHg = 0.133 kPa);符合PHC诊断标准^[1]:肺动脉压急剧升高,肺动脉压力接近或超越主动脉压力,出现右心功能障碍的临床表现,伴有体循环低血压、低血氧,患者可主诉胸闷、呼吸困难,甚至出现休克、意识丧失、心搏骤停等。

1.1.2 排除标准:行其他非剖宫产手术的重度PAH产妇;全麻下行剖宫产手术的重度PAH产妇;术前

因非PHC死亡的重度PAH孕妇。

1.1.3 伦理学:本研究符合医学伦理学标准,经医院医学伦理委员会批准,所有治疗和检测均获得过患者或家属的知情同意。

1.2 资料收集:通过病例管理系统提取病史资料,包括患者年龄、身高、体重、孕周、孕次、PAH类型、急诊手术、纽约心脏病协会(NYHA)心功能分级,术前超声左室射血分数(LVEF)、左室舒张期末内径(LVEDD)、超声TI法估测sPAP、桡动脉收缩压(SBP)和舒张压(DBP)、心率、未吸氧时脉搏血氧饱和度(SpO₂),术前是否口服西地那非、是否放置漂浮导管、是否应用去甲肾上腺素,以及围手术期PHC发生情况和术后结局。

1.3 统计学方法:应用SPSS 17.0统计软件进行统计分析,采用Kolmogorov-Smirnov和Shapiro-Wilk法对计量资料进行正态性检验,符合正态分布的计量资料以均数 \pm 标准差($\bar{x} \pm s$)表示,两组间比较采用 t 检验;非正态分布的计量资料以中位数(四分位数)[$M(Q_L, Q_U)$]表示,两组间比较采用Mann-Whitney U 检验。计数资料以率表示,采用 χ^2 检验。对可能的术前危险因素进行两组间单因素比较和多因素logistic回归分析;用MedCalc 15.8软件绘制受试者工作特征曲线(ROC),分析各项危险因素对重度PAH产妇剖宫产围手术期PHC的诊断价值。 $P < 0.05$ 为差异有统计学意义。

表1 剖宫产围手术期是否发生PHC两组重度PAH产妇临床资料比较

组别	例数 (例)	年龄 (岁, $\bar{x} \pm s$)	身高 (cm, $\bar{x} \pm s$)	体重 (kg, $\bar{x} \pm s$)	孕周 (周, $\bar{x} \pm s$)	孕次 (次, $\bar{x} \pm s$)	心功能分级 (级, $\bar{x} \pm s$)	术前LVEF ($\bar{x} \pm s$)	术前LVEDD (mm, $\bar{x} \pm s$)	术前sPAP (mmHg, $\bar{x} \pm s$)
非PHC组	111	27.64±4.82	159.57±4.93	60.01±10.71	31.14±6.82	1.80±1.13	2.85±0.53	0.63±0.08	43.91±9.67	99.35±21.10
PHC组	27	25.07±3.55	160.30±5.75	60.78±8.74	30.59±5.93	1.93±1.30	3.22±0.64	0.65±0.08	38.78±4.76	113.41±24.73
t值		2.598	-0.667	-0.344	0.386	-0.495	-3.184	-0.925	3.960	-3.000
P值		0.010	0.506	0.732	0.700	0.621	0.002	0.357	0.000	0.003

组别	例数 (例)	术前SBP (mmHg, $\bar{x} \pm s$)	术前DBP (mmHg, $\bar{x} \pm s$)	术前心率 (次/min, $\bar{x} \pm s$)	术前SpO ₂ ($\bar{x} \pm s$)	术前口服西地那非 [% (例)]	术前应用NE [% (例)]	术前放置漂浮导管 [% (例)]	艾森曼格综合征 [% (例)]	急诊手术 [% (例)]
非PHC组	111	137.70±23.87	75.23±12.14	94.40±13.82	0.92±0.06	56.76(63)	54.95(61)	57.66(64)	37.84(42)	23.42(26)
PHC组	27	139.48±23.89	79.63±13.23	94.70±19.97	0.83±0.12	29.63(8)	51.85(14)	85.19(23)	70.37(19)	48.15(13)
t/χ ² 值		-0.349	-1.665	-0.076	3.842	6.398	0.084	7.063	9.319	6.548
P值		0.728	0.098	0.940	0.001	0.010	0.772	0.008	0.002	0.010

注: PHC为肺动脉高压危象, PAH为肺动脉高压, LVEF为左室射血分数, LVEDD为左室舒张期末内径, sPAP为超声心动图TI法估测肺动脉收缩压, SBP为桡动脉收缩压, DBP为桡动脉舒张压, SpO₂为未吸氧时脉搏血氧饱和度, NE为去甲肾上腺素; 1 mmHg=0.133 kPa

2 结果

2.1 一般情况: 共入选152例重度PAH产妇, 排除10例全麻下同期行心脏手术患者、4例全麻下行剖宫产术患者, 最终共138例患者纳入分析。年龄(27.14±4.70)岁, 孕周(31.03±6.64)周; 围手术期共发生PHC 27例(19.57%), 术中12例、术后15例, 死亡17例(病死率62.96%)。138例患者中以先天性室间隔缺损最多, 共55例, 发生PHC 12例(21.8%); 房间隔缺损35例, PHC 5例(14.3%); 原发性PAH 22例, PHC 5例(22.7%); 动脉导管未闭15例, PHC 4例(26.7%); 二尖瓣狭窄11例, PHC 1例(9.1%)。

2.2 单因素分析(表1): 对PHC组和非PHC组患者术前临床资料进行变量筛选, 结果显示, 与非PHC组比较, PHC组患者年龄更小, 心功能更差, 术前LVEDD更小, 未吸氧时SpO₂及口服西地那非患者比例更低, 术前sPAP、DBP及放置漂浮导管、艾森曼格综合征、急诊手术患者比例更高, 差异有统计学意义(均P≤0.1)。

2.3 logistic多因素分析(表2): 将单因素分析差异有统计学意义(取P≤0.1)的变量进行多因素logistic回归分析, 依次用进入法和前向LR法进行自变量筛选, 结果显示, LVEDD、是否口服西地那非、未吸氧时SpO₂、是否放置漂浮导管为重度PAH产妇剖宫产围手术期发生PHC的术前独立危险因素(均P<0.05)。

2.4 ROC曲线分析(表3; 图1): 术前LVEDD、口服西地那非、未吸氧时SpO₂、放置漂浮导管4个因素联合诊断重度PAH产妇围手术期PHC的AUC为0.878(P=0.000), 明显高于4个因素单独诊断的AUC(均P<0.01); 当患者术前LVEDD<39 mm、未

吸氧时SpO₂<0.91、未口服西地那非、未放置漂浮导管时, 其诊断围手术期PHC的敏感度为88.89%, 特异度为76.58%。

表2 重度PAH产妇剖宫产围手术期发生PHC术前危险因素的多因素logistic回归分析

进入法分析结果						
术前危险因素	β值	s _e 值	χ ² 值	P值	OR值	95%CI
年龄	-0.112	0.084	1.788	0.181	0.894	0.758~1.054
心功能分级	0.714	0.673	1.128	0.288	2.043	0.547~7.633
LVEDD	-0.136	0.055	6.042	0.014	0.873	0.783~0.973
sPAP	0.010	0.014	0.561	0.454	1.010	0.984~1.038
DBP	0.019	0.027	0.503	0.478	1.019	0.967~1.074
未吸氧时SpO ₂	-0.067	0.046	2.189	0.139	0.935	0.855~1.022
口服西地那非	-1.873	0.629	8.856	0.003	0.154	0.045~0.528
放置漂浮导管	1.957	0.789	6.144	0.013	7.076	1.506~33.249
艾森曼格综合征	0.467	0.789	0.351	0.554	1.595	0.340~7.484
急诊手术	0.020	0.709	0.001	0.978	1.020	0.254~4.097

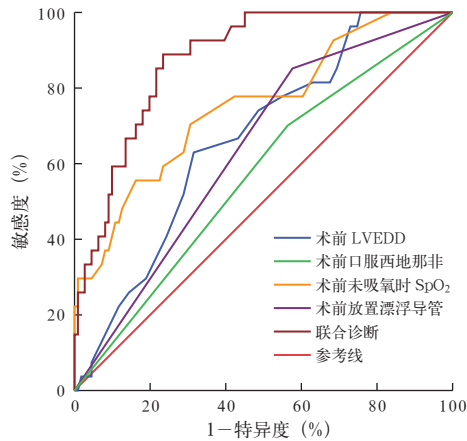
前向LR法筛选结果						
术前危险因素	β值	s _e 值	χ ² 值	P值	OR值	95%CI
LVEDD	-0.113	0.050	6.775	0.009	0.878	0.796~0.968
口服西地那非	-1.824	0.592	9.491	0.002	0.161	0.051~0.515
未吸氧时SpO ₂	-0.126	0.032	15.827	0.000	0.882	0.829~0.938
放置漂浮导管	1.822	0.694	6.554	0.010	6.186	1.533~24.964

注: PAH为肺动脉高压, PHC为肺动脉高压危象, LVEDD为左室舒张期末内径, sPAP为超声心动图TI法估测肺动脉收缩压, DBP为桡动脉舒张压, SpO₂为脉搏血氧饱和度, OR为优势比, 95%CI为95%可信区间

表3 术前LVEDD、口服西地那非、未吸氧时SpO₂、放置漂浮导管对重度PAH产妇剖宫产围手术期PHC诊断价值

变量	AUC	s _e	P值	95%CI	截断值	敏感度 (%)	特异度 (%)
LVEDD	0.666	0.054	0.007	0.581~0.744	≤39	62.96	68.47
口服西地那非	0.568	0.050	0.029	0.481~0.652	≤0	70.37	43.24
未吸氧时SpO ₂	0.753	0.055	0.000	0.672~0.822	≤91	70.37	69.37
放置漂浮导管	0.638	0.042	0.027	0.552~0.718	>0	85.19	42.34
联合诊断	0.878	0.031	0.000	0.812~0.928	0.184	88.89	76.58

注: LVEDD为左室舒张期末内径, SpO₂为脉搏血氧饱和度, PAH为肺动脉高压, PHC为肺动脉高压危象, AUC为受试者工作特征曲线下面积, 95%CI为95%可信区间



注：LVEDD 为左室舒张期末内径，SpO₂ 为脉搏血氧饱和度，PAH 为肺动脉高压，PHC 为肺动脉高压危象，ROC 为受试者工作特征曲线
图1 术前LVEDD、口服西地那非、未吸氧时SpO₂、放置漂浮导管对重度PAH产妇剖宫产围手术期PHC诊断的ROC曲线

3 讨论

PAH孕产妇病死率极高，国外报道病死率高达30%~50%，随着降低PAH药物的应用，围产期PAH患者病死率由38%降到25%^[3-5]。本研究中重度PAH产妇PHC病死率为12.32% (17/138)，发生PHC患者的病死率高达62.96%。

各种原因引起肺动脉压力长期升高可导致右心室肥厚、扩张，耗氧量增大，收缩力降低，当肺血管阻力急剧升高，平均肺动脉压升高超过40 mmHg时，可能发生右心功能衰竭^[6]。围手术期任何导致产妇肺动脉阻力升高的因素都能诱发PHC，如低氧血症、高碳酸血症、代谢性酸中毒、低体温、紧张疼痛导致的交感兴奋、羊水栓塞、肺栓塞等^[7-8]。

重度PAH产妇围手术期PHC的治疗包括：应用强心药，如多巴胺、肾上腺素增强心肌收缩，维持基本的心排量；吸入一氧化氮(NO)或伊洛前列素扩张肺动脉；给予苯海拉明或甲泼尼龙等抗过敏；应用去甲肾上腺素或垂体后叶素提高外周阻力，维持体循环血压，保证重要器官的灌注。持续危象状态可行体外膜肺氧合(ECMO)治疗。ECMO能减轻心脏负荷，减少肺血流量，从而降低肺动脉压力。胡春晓等^[9]对69例PAH的肺移植患者术中行ECMO辅助发现，术中sPAP较术前明显降低，有效避免了术侧肺动脉阻断导致的右心衰竭。

右心功能状态是重度PAH患者围手术期评估的重要内容。据报道，B型脑钠肽(BNP)与多普勒超声Tei指数能有效评价右心功能^[10-12]。长期的PAH导致右心室肥厚重构，可溶性ST2(sST2)能反映心肌纤维化和重构程度，有助于慢性心力衰竭的

诊断和预后判断^[13]。重度PAH患者右心室肥厚扩张，压迫左心室，使室间隔左移，LVEDD变小；右心功能减退导致肺血流减少，使左心室充盈不足，表现为LVEDD减小，因此LVEDD间接反映了右心功能状态^[14]。右心功能差，肺动脉压力突然升高，容易导致右心衰竭，发生PHC。本研究也显示，术前LVEDD是发生PHC的独立危险因素。

PAH患者术前未吸氧时SpO₂与右心功能和肺动脉阻力有关。存在右心向左心分流畸形的患者，肺动脉阻力增高导致右向左分流增加，左心氧合血被右心的未氧合静脉血混合稀释，SaO₂下降；没有右向左分流的患者，右心排血量下降，肺血减少，肺通气/血流比例失衡，SaO₂下降。未吸氧时SpO₂越低，患者肺动脉压力越高，右心功能越差。低氧血症及缺氧导致的酸中毒都能引起肺血管收缩，使肺血管阻力增高，增加PHC的风险^[15]。本研究也显示，术前未吸氧时SpO₂是发生PHC的独立危险因素。

PAH的药物治疗包括前列环素、吸入NO、血管紧张素转换酶2(ACE2)等^[16]。PAH的主要病理机制包括内皮细胞NO产生减少、5型磷酸二酯酶抑制剂(PDE-5)在肺血管平滑肌细胞中高度表达等。西地那非为PDE-5抑制剂，通过特异性抑制PDE-5可增加细胞内环磷酸鸟苷(cGMP)浓度，使内源性NO含量增加，起到舒张肺血管平滑肌、降低肺动脉压的作用^[17-18]。据报道，西地那非还具有增强肥厚右心室心肌收缩力的作用^[19]。一项前瞻性多中心研究显示，给予55例房间隔、室间隔缺损和动脉导管未闭患儿口服西地那非25 mg、8 h 1次，6 min步行距离均有不同程度提高，肺血管阻力和肺血流指数明显改善^[20]。西地那非对PAH孕妇疗效较好，能改善其临床症状、心功能分级、血流动力学指标^[21]。本研究也显示，术前是否口服西地那非是发生PHC的独立危险因素。

漂浮导管测量肺动脉压力是诊断PAH的“金标准”，其作用是超声等其他无创手段不能代替的；但导管放置操作和留置过程中的并发症难以避免，鞘管穿刺可导致局部血肿、血气胸、乳糜胸，导管漂浮到肺动脉的过程可引起肺动脉痉挛、心律失常，导管尖端摩擦肺动脉可导致肺动脉破裂出血，气囊破裂可导致肺动脉空气栓塞，导管术后留置可引起感染、静脉血栓，导管盘绕可导致拔除困难和三尖瓣损伤等^[22]。本组有1例PHC患者在漂浮导管置入肺动脉后发生肺动脉痉挛，造成PHC。重度PAH

产妇术前放置漂浮导管监测肺动脉压力可以观察扩张肺动脉和收缩血管药物的效果,监测麻醉、手术对肺动脉压力的影响,PHC发生时还能根据监测数据指导抢救^[23-25]。本研究结果也显示,术前是否放置漂浮导管是发生PHC的独立危险因素。

本研究ROC曲线分析显示,术前LVEDD、未吸氧时SpO₂、是否口服西地那非、是否放置漂浮导管对于围手术期PHC有诊断价值,且4个因素联合诊断价值更高。

综上,术前LVEDD、未吸氧时SpO₂、口服西地那非治疗、放置漂浮导管是重度PAH产妇剖宫产围手术期发生PHC的术前独立危险因素,但重度PAH产妇PHC属于少见病,阳性病例数少,术前危险因素还需要进行多中心大样本研究进一步证实。

参考文献

[1] Friesen RH, Williams GD. Anesthetic management of children with pulmonary arterial hypertension [J]. Paediatr Anaesth, 2008, 18 (3): 208-216. DOI: 10.1111/j.1460-9592.2008.02419.x.

[2] Galie N, Hoeper MM, Humbert M, et al. Guidelines for the diagnosis and treatment of pulmonary hypertension: the Task Force for the Diagnosis and Treatment of Pulmonary Hypertension of the European Society of Cardiology (ESC) and the European Respiratory Society (ERS), endorsed by the International Society of Heart and Lung Transplantation (ISHLT) [J]. Eur Heart J, 2009, 30 (20): 2493-2537. DOI: 10.1093/eurheartj/ehp297.

[3] Bédard E, Dimopoulos K, Gatzoulis MA. Has there been any progress made on pregnancy outcomes among women with pulmonary arterial hypertension? [J]. Eur Heart J, 2009, 30 (3): 256-265. DOI: 10.1093/eurheartj/ehn597.

[4] Hsu CH, Gomberg-Maitland M, Glassner C, et al. The management of pregnancy and pregnancy-related medical conditions in pulmonary arterial hypertension patients [J]. Int J Clin Pract Suppl, 2011, 65 (172): 6-14. DOI: 10.1111/j.1742-1241.2011.02711.x.

[5] 杨生岳,冯恩志,闫自强,等.红景天和葛根素对高原地区慢性阻塞性肺疾病急性加重期合并慢性肺源性心脏病患者肺动脉高压的干预作用研究[J].中国中西医结合急救杂志,2013,20(1): 20-23. DOI: 10.3969/j.issn.1008-9691.2013.01.007.

Yang SY, Feng EZ, Yan ZQ, et al. A study of intervention of rhodioid and puerarin on pulmonary arterial hypertension in patients with chronic obstructive pulmonary disease in acute exacerbation stage complicated by chronic cor pulmonale at high altitude areas [J]. Chin J TCM WM Crit Care, 2013, 20 (1): 20-23. DOI: 10.3969/j.issn.1008-9691.2013.01.007.

[6] Zamanian RT, Haddad F, Doyle RL, et al. Management strategies for patients with pulmonary hypertension in the intensive care unit [J]. Crit Care Med, 2007, 35 (9): 2037-2050.

[7] Sztrymf B, Souza R, Bertoletti L, et al. Prognostic factors of acute heart failure in patients with pulmonary arterial hypertension [J]. Eur Respir J, 2010, 35 (6): 1286-1293. DOI: 10.1183/09031936.00070209.

[8] 杜捷夫,雷永红,杨光,等.单中心医疗机构20年肺栓塞发病的回顾性分析[J].中华危重病急救医学,2011,23(5): 309-312. DOI: 10.3760/cma.j.issn.1003-0603.2011.05.016.

Du JF, Lei YH, Yang G, et al. Analysis of the occurrence of pulmonary embolism in 20 years in single medical center [J]. Chin Crit Care Med, 2011, 23 (5): 309-312. DOI: 10.3760/cma.j.issn.1003-0603.2011.05.016.

[9] 胡春晓,陈静瑜,王志萍,等.肺移植麻醉330例临床分析[J/CD].实用器官移植电子杂志,2015,3(6): 337-341. DOI: 10.3969/j.issn.2095-5332.2015.06.004.

Hu CX, Chen JY, Wang ZP, et al. Clinical analysis of 330 cases in lung transplantation anesthesia [J/CD]. Pract J Organ Transplant (Electron Version), 2015, 3 (6): 337-341. DOI: 10.3969/j.issn.2095-5332.2015.06.004.

[10] Abroug F, Ouanes-Besbes L. Detection of acute heart failure in chronic obstructive pulmonary disease patients: role of B-type natriuretic peptide [J]. Curr Opin Crit Care, 2008, 14 (3): 340-347. DOI: 10.1097/MCC.0b013e3282faa304.

[11] Baykan M, Baykan EC, Turan S, et al. Assessment of left ventricular function and Tei index by tissue Doppler imaging in patients with slow coronary flow [J]. Echocardiography, 2009, 26 (10): 1167-1172. DOI: 10.1111/j.1540-8175.2009.00939.x.

[12] 贾洪艳,武子霞,赵春玲. B型脑钠肽联合Tei指数评估慢性阻塞性肺疾病患者的右心功能[J].中华危重病急救医学,2013,25(8): 495-496. DOI: 10.3760/cma.j.issn.2095-4352.2013.08.012.

Jia HY, Wu ZX, Zhao CL. Clinical evaluation of right ventricular function in chronic obstructive pulmonary disease patients with Tei index combined with brain natriuretic peptide [J]. Chin Crit Care Med, 2013, 25 (8): 495-496. DOI: 10.3760/cma.j.issn.2095-4352.2013.08.012.

[13] 段勇,宋贵波. ST2:新一代心衰管理标志物[J].实用检验医师杂志,2016,8(1): 1-4. DOI: 10.3969/j.issn.1674-7151.2016.01.001.

Duan Y, Song GB. ST2: a novel biomarker of heart failure management [J]. Chin J Clin Pathol, 2016, 8 (1): 1-4. DOI: 10.3969/j.issn.1674-7151.2016.01.001.

[14] Hoeper MM, Granton J. Intensive care unit management of patients with severe pulmonary hypertension and right heart failure [J]. Am J Respir Crit Care Med, 2011, 184 (10): 1114-1124. DOI: 10.1164/rccm.201104-0662CI.

[15] Rabinovitch M. Molecular pathogenesis of pulmonary arterial hypertension [J]. J Clin Invest, 2008, 118 (7): 2372-2379. DOI: 10.1172/JCI33452.

[16] 肖红丽,李春盛.血管紧张素转换酶2治疗肺动脉高压的病理生理机制研究进展[J].中华危重病急救医学,2016,28(6): 569-572. DOI: 10.3760/cma.j.issn.2095-4352.2016.06.020.

Xiao HL, Li CS. Progress of pathophysiological mechanism of angiotensin-converting enzyme 2 in treating pulmonary arterial hypertension [J]. Chin Crit Care Med, 2016, 28 (6): 569-572. DOI: 10.3760/cma.j.issn.2095-4352.2016.06.020.

[17] Maharaj CH, O'Toole D, Lynch T, et al. Effects and mechanisms of action of sildenafil citrate in human chorionic arteries [J]. Reprod Biol Endocrinol, 2009, 7: 34. DOI: 10.1186/1477-7827-7-34.

[18] Palma G, Giordano R, Russolillo V, et al. Sildenafil therapy for pulmonary hypertension before and after pediatric congenital heart surgery [J]. Tex Heart Inst J, 2011, 38 (3): 238-242.

[19] Bassily-Marcus AM, Yuan C, Oropello J, et al. Pulmonary hypertension in pregnancy: critical care management [J]. Pulm Med, 2012, 2012: 709407. DOI: 10.1155/2012/709407.

[20] Zeng WJ, Lu XL, Xiong CM, et al. The efficacy and safety of sildenafil in patients with pulmonary arterial hypertension associated with the different types of congenital heart disease [J]. Clin Cardiol, 2011, 34 (8): 513-518. DOI: 10.1002/clc.20917.

[21] 孙晓媛,王克芳,王文静,等.枸橼酸西地那非治疗妊娠合并肺动脉高压的临床疗效观察[J].中华妇产科杂志,2014,49(6): 414-418. DOI: 10.3760/cma.j.issn.0529-567x.2014.06.004.

Sun XY, Wang KF, Wang WJ, et al. Clinical study on sildenafil in treatment of pregnant women with pulmonary arterial hypertension [J]. Chin J Obstet Gynecol, 2014, 49 (6): 414-418. DOI: 10.3760/cma.j.issn.0529-567x.2014.06.004.

[22] Gidwani UK, Mohanty B, Chatterjee K. The pulmonary artery catheter: a critical reappraisal [J]. Cardiol Clin, 2013, 31 (4): 545-565. viii. DOI: 10.1016/j.ccl.2013.07.008.

[23] 王腾科,卢家凯,陈晓,等.肺动脉导管在妊娠合并肺动脉高压患者围产期的应用[J].中华内科杂志,2015,54(9): 773-777. DOI: 10.3760/cma.j.issn.0578-1426.2015.09.008.

Wang TK, Lu JK, Chen Y, et al. The application of peripartum use of pulmonary artery catheter in pregnant patients with pulmonary hypertension [J]. Chin J Intern Med, 2015, 54 (9): 773-777. DOI: 10.3760/cma.j.issn.0578-1426.2015.09.008.

[24] 缪娟娟,史宏伟,赵雅梅,等.心脏术中肺动脉导管和食管超声监测对容量反应的敏感性及其特异性分析[J].临床麻醉学杂志,2014,30(7): 629-633.

Miao JJ, Shi HW, Zhao YM, et al. The analysis of the sensitivity and specificity by pulmonary artery catheter and transesophageal echocardiography regarding volume responsiveness in cardiac surgery [J]. J Clin Anesthesiol, 2014, 30 (7): 629-633.

[25] Richard C, Monnet X, Teboul JL. Pulmonary artery catheter monitoring in 2011 [J]. Curr Opin Crit Care, 2011, 17 (3): 296-302. DOI: 10.1097/MCC.0b013e3283466b85.

(收稿日期:2017-02-27)