·临床医学·

不同水平呼气末正压通气联合60%吸入氧浓度对单肺通气患者氧合及术后肺部并发症的影响

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[摘 要] **目的**:探讨单肺通气(one-lung ventilation,OLV)期间不同水平呼气末正压(positive end-expiratory pressure,PEEP)联合60%吸入氧浓度(inspired oxygen fraction,FiO_2)对OLV患者氧合及术后肺部并发症(postoperative pulmonary complication,PPC)的影响。**方法**:择期行经左胸食管癌根治术患者120例,随机分为A、B、C、D 4组,每组30例,OLV时各组均使用60%的FiO_2,通气侧分别采用0、5、8、10 cmH_2O PEEP。于OLV前即刻(T_1)、OLV 10 min(T_2)、OLV 15 min(T_3)、OLV 30 min(T_4)、OLV 60 min(T_5)、OLV 120 min(T_6)时分别经桡动脉与右颈内静脉中抽取动静脉血行血气分析,计算肺内分流率;记录各时间点的血流动力学与呼吸力学等指标;记录术后第2天的临床肺部感染评分(clinical pulmonary infection score,CPIS)和PPC的发生情况。**结果**:A组2例患者OLV中发生低氧血症而退出本研究,共118例患者完成试验。T_2~T_6时D组动脉血氧分压(PaO_2)明显高于A组、肺内分流率明显低于A组($P < 0.05$);T_3~T_4时C组PaO_2明显高于A组、肺内分流率明显低于A组($P < 0.05$)。T_4时B组PaO_2明显高于A组、肺内分流率明显低于A组($P < 0.05$)。T_2~T_5时D组PaO_2明显高于B组($P < 0.05$);T_2~T_4时D组肺内分流率明显低于B组($P < 0.05$)。T_5时D组PaO_2明显高于C组($P < 0.05$)。T_2~T_6时B、C、D组驱动压明显低于A组($P < 0.05$),T_2~T_5时C、D组驱动压明显低于B组($P < 0.05$)。T_4~T_6时C、D组肺动态顺应性(dynamic compliance,Cdyn)明显高于A、B组($P < 0.05$)。术后第2天B、C、D组CPIS明显低于A组。**结论**:OLV时FiO_2为60%条件下,联合5、8和10 cmH_2O PEEP均可改善氧合、降低肺内分流、增加肺动态顺应性,降低驱动压及CPIS,从而具有一定的肺保护作用,其中10 cmH_2O PEEP改善氧合的效应出现得更早,效果更佳。

[关键词] 单肺通气;吸入氧浓度;呼气末正压;氧合;术后肺部并发症

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The combined physiologic effects of using different positive end-expiratory pressure and inspired oxygen fraction of 0.6 during one lung ventilation

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[**Abstract**] **Objective**: To investigate the combined physiologic effects of different positive end-expiratory pressure (PEEP) and decreased inspired oxygen fraction (FiO_2) during one lung ventilation (OLV). **Methods**: This study is a prospective, single-blind, randomized controlled study. One-hundred and twenty patients were equally randomized into four groups of A (OLV with 0 cmH_2O), B (OLV with 5 cmH_2O), C (OLV with 8 cmH_2O), and D (OLV with 10 cmH_2O). All patients breathed an inspiratory oxygen fraction of 0.6. Arterial blood and venous blood were taken for gas analysism, and intrapulmonary shunt rate (Qs/Qt) were calculated before OLV (T_1), OLV 10 min (T_2), OLV 15 min (T_3), OLV 30 min (T_4), OLV 60 min (T_5), and OLV 120 min (T_6). Haemodynamics and respiratory

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mechanics parameters were monitored continuously. The clinical pulmonary infection score (CPIS) was recorded on the second day after the surgery and the incidence of postoperative pulmonary complication was recorded. **Results**: Among the 120 patients assessed for eligibility, 118 completed the study. At T_2~T_6, PaO_2 in group D was significantly higher than that in group A, Qs/Qt in group D was significantly lower than that in group A ($P < 0.05$). At T_3~T_4, PaO_2 in group C was significantly higher than that in group A, Qs/Qt in group C was significantly lower than that in group A ($P < 0.05$). At T4, PaO_2 in group B were significantly higher than that in group A, Qs/Qt in group B were significantly lower than that in group A ($P < 0.05$). At T_2~T_5, PaO_2 in group D were significantly higher than that in group B, At T2 ~ T4, Qs/Qt in group D were significantly lower than that in group B ($P < 0.05$). At T_5, PaO_2 in group D were significantly higher than that in group C ($P < 0.05$). At T_2~T_6, driving pressure (DP) in group B, C, and D were significantly lower than that in group A ($P < 0.05$). At T_2~T_5, DP in group C and D were significantly lower than that in group B ($P < 0.05$). At T_4~T_6, dynamic compliances in group C and D were significantly higher than those in group A and B ($P < 0.05$). The CPIS score was significantly lower in group B, C and D than that in group A on the second day after the surgery ($P < 0.05$). **Conclusion**: During one lung ventilation with 0.6 FiO_2, 10 cmH_2O PEEP improves pulmonary function without changing the hemodynamic parameters and reduces driving pressure, and plays an important role in lung protection.

[**Key words**] positive end-expiratory pressure; one-lung ventilation; inspired oxygen fraction; oxygenation; postoperative pulmonary complication

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单肺通气(one-lung ventilation,OLV)是现代胸外科手术麻醉中常用的呼吸管理方法。但OLV属非生理性通气方式,非通气侧肺因缺少气体交换而发生肺内分流,进而使机体氧合下降,易于发生低氧血症[1-3]。既往临床上通常使用较大潮气量、较高吸入氧浓度(inspired oxygen fraction,FiO_2)等方法预防低氧血症。但研究表明,使用较高的FiO_2会引起吸收性肺不张、肺部氧化应激损伤。目前研究倾向于围术期采用保护性通气策略[4-5],在保证氧供的前提下尽可能降低FiO_2。但OLV期间降低FiO_2会增加患者低氧血症的发生风险。通气侧肺呼气末正压(positive end-expiratory pressure,PEEP)通气的应用可以降低其肺内分流、改善患者氧合状况[6]。因此,OLV期间降低FiO_2同时联合使用适当的PEEP,理论上既能提高患者氧合又能减轻肺损伤,而究竟采取何种水平的PEEP对患者更加有益目前尚无定论。本研究拟在降低FiO_2至60%的条件下于OLV时联合使用不同水平的PEEP,以探讨该通气模式对OLV患者氧合及术后肺部并发症(postoperative pulmonary complication,PPC)的影响。

1 对象和方法

1.1 对象

本研究已获南京医科大学伦理委员会的批准[伦审号:(2017)550号],在中国临床试验注册中心注册(注册号ChiCTR1900024726),所有患者均签署知情同意书。本试验为随机、对照、单盲、前瞻性试验,选择2018年6月—2019年5月在南京医科大学附属肿瘤医院择期全麻下左剖胸行食管癌根治术患者136例,美国麻醉医师协会(ASA)分级Ⅱ或Ⅲ级,性别不限,49~76岁。排除标准:患者放化疗后;重度通气功能障碍(慢性阻塞性肺病3~4级);全身感染;术中输入血液制品;预计手术时间大于6 h或少于2 h。按照排除标准,最终共入组120例患者,采用随机数字表法将其随机平均分为4组,每组30例,设置FiO_2=0.6,A、B、C、D组OLV时PEEP分别为0、5、8、10 cmH_2O。

1.2 方法

患者入室后常规监测心电图、心率(heart rate,HR)、血氧饱和度(SpO_2)、呼气末二氧化碳($P_{ET}CO_2$),并使用气体监测仪(Datex-Ohmeda S/5)监测气道峰压(peak inspimtory pressure,P_{peak})、平台压(plateau airway pressure,P_{plat})、肺动态顺应性(dynamic compliance,Cdyn)。超声引导下行右颈内静脉穿刺置管测压,局麻下桡动脉穿刺置管持续监测动脉血压。所有患者采用全凭静脉麻醉,麻醉诱导方案为咪唑安定0.1 mg/kg、芬太尼4 μg/kg、丙泊酚1 mg/kg和顺式阿曲库铵0.2 mg/kg,3 min后可视喉镜辅助下行左侧双腔支气管导管插管(女F32号或F35号,男F37号或F39号),纤维支气管镜下确认导管位置。支气管插管后连接麻醉机行机械通气,设置通气模式为容量控制,FiO_2=0.6,潮气量(V_T)6 mL/理想体重(ideal body weight,IBW),呼吸频率(RR)12~14次/min,吸呼比=1∶2,维持$P_{ET}CO_2$在35~45 mmHg。IBW计算

公式：成年男性IBW=50 kg+0.91×[身高(cm)−152.4]；成年女性IBW=45.5 kg +0.91×[身高(cm)−152.4]。手术开始时追加芬太尼3 μg/kg，术中持续静脉泵注瑞芬太尼0.2 μg/(kg·min)、丙泊酚4~6 mg/(kg·h)和顺式阿曲库铵0.15 mg/(kg·h)，麻醉深度采用Narcotrend监测，维持在D_2~E_1水平。根据试验方案，开始OLV时，双腔管非通气侧与大气相通，B、C、D组分别给予通气侧肺5、8、10 cmH_2O PEEP，其余呼吸参数保持不变。实验期间，一旦患者SpO_2低于90%或动脉血氧分压(PaO_2)≤60 mmHg、低血压[平均动脉压(mean arterial pressure，MAP)≤65 mmHg或降低幅度大于20%]持续时间1 min以上或出现严重的心律失常，则停止使用PEEP并依次进行纯氧通气、非通气侧肺持续气道正压通气，必要时恢复双肺通气。开始关胸时静脉注射芬太尼2 μg/kg，手法膨肺恢复双肺通气(气道压力限制在30 cmH_2O以下，膨肺持续时间30~40 s)。手术结束后所有患者均送入ICU，同步间歇指令通气，待患者清醒，拔除双腔支气管导管。

记录手术时间、OLV时间、失血量、尿量、补液量；分别于OLV前即刻(T_1)、OLV 10 min(T_2)、OLV 15 min(T_3)、OLV 30 min(T_4)、OLV 60 min(T_5)、OLV 120 min(T_6)抽取桡动脉血和右颈内静脉血各2 mL，在采样后立刻进行血气分析并以患者PaO_2为主要结局指标。同时记录MAP、HR、中心静脉压(central venous pressure，CVP)、SpO_2、P_{peak}、P_{plat}、Cdyn，并按照公式[7]计算肺内分流率：$Qs/Qt=(CcO_2-CaO_2)/(CcO_2-CvO_2)$，$CaO_2=(PaO_2\times0.0031)+(Hb\times1.36\times SaO_2)$，$CvO_2=(PvO_2\times0.0031)+(Hb\times1.36\times SvO_2)$，$CcO_2=[FiO_2\times(P_B-P_{H2O})-PaCO_2/R]\times0.0031+(Hb\times1.36)$。其中$CcO_2$为肺毛细血管血氧含量、$CaO_2$为动脉血氧含量，$CvO_2$混合静脉血氧含量，$PvO_2$为混合静脉氧分压，$SvO_2$为静脉氧饱和度，$P_B$为大气压(760 mmHg)，$P_{H_2O}$为37 ℃水蒸气压(47 mmHg)，R为呼吸商(0.8)。计算气道驱动压(driving pressure，DP)[8]：对于无自主呼吸的机械通气患者，$DP=P_{plat}-PEEP$；记录患者ICU停留时间、术后第2天临床肺部感染评分(clinical pulmonary infection score，CPIS)[9]，记录术后7 d内包括肺部感染、肺不张、急性呼吸窘迫综合征(acute respiratory distress syndrome，ARDS)、胸腔积液等PPC的发生情况，并记录患者术后住院天数。

1.3　统计学方法

采用SPSS 24.0软件进行分析。正态分布的计量数据以均数±标准差($\bar{x}\pm s$)表示，组间比较采用单因素方差分析，LSD-t检验用于组间两两比较。组内重复测量数据采用重复测量的方差分析。计数资料采用例数(%)表示，组间比较采用χ^2检验或Fisher确切概率法。$P<0.05$为差异具有统计学意义。

2　结　果

本研究共入组120例患者，其中A组有2例患者因在OLV过程中发生低氧血症而退出本研究，低氧血症发生率为6.7%，B、C、D组均无低氧血症发生。最终共纳入118例患者统计分析，其中A组28例，B、C、D组各30例。在OLV即刻(T_1)，4组患者动脉血气、Qs/Qt、呼吸力学与血流动力学指标差异均无统计学意义。

2.1　一般资料

4组患者的年龄、性别比例、体重指数(body mass index，BMI)、手术时间、OLV时间、补液量、失血量及尿量差异均无统计学意义(表1)。

2.2　动脉血气与Qs/Qt指标

4组患者PaO_2在OLV开始后均呈快速下降，在T_4时降至最低点，而后缓慢上升。T_2~T_6时D组PaO_2明显高于A组、Qs/Qt明显低于A组($P<0.05$)；T_3~T_4时C组PaO_2明显高于A组、Qs/Qt明显低于A组($P<0.05$)；T_4时B组PaO_2明显高于A组、Qs/Qt明显低于A组($P<0.05$)。T_2~T_5时D组PaO_2明显高于B组($P<0.05$)；T_2~T_4时D组Qs/Qt明显低于B组($P<0.05$)。T_5时D组PaO_2明显高于C组($P<0.05$，表2)。

表1　4组患者围术期一般情况的比较

Table 1　Comparison of patients in general and baseline characteristics among the four groups

组别	例数	年龄(岁)	男/女(例)	BMI(kg/m²)	手术时间(min)	OLV时间(min)	失血量(mL)	补液量(mL)		尿量(mL)
								晶体量	胶体量	
A组	28	63.1 ± 6.0	23/5	23.8 ± 6.2	205.4 ± 52.1	171.3 ± 43.0	183.3 ± 57.7	1 116.7 ± 198.3	933.3 ± 172.9	230.7 ± 83.7
B组	30	63.9 ± 5.7	23/7	23.7 ± 3.5	193.6 ± 50.9	168.9 ± 48.3	160.0 ± 38.1	1 066.7 ± 253.7	883.3 ± 252.0	242.0 ± 135.3
C组	30	63.3 ± 6.5	26/4	23.7 ± 3.4	196.9 ± 48.6	165.4 ± 44.4	168.3 ± 72.5	1 116.7 ± 252.0	866.7 ± 224.9	233.3 ± 176.8
D组	30	64.4 ± 4.7	26/4	23.3 ± 2.3	213.2 ± 43.1	178.8 ± 47.8	187.9 ± 67.7	1 150.0 ± 325.6	833.3 ± 239.7	239.0 ± 110.4

表2 4组患者动脉血气结果及肺内分流率比较

Table 2 Comparison of the value of arterial blood gas, Qs/Qt among the four groups ($\bar{x} \pm s$)

指标	组别	例数	T_1	T_2	T_3	T_4	T_5	T_6
PaO_2 (mmHg)	A组	28	264.2 ± 52.3	121.6 ± 28.3	104.6 ± 24.3	93.2 ± 16.6	111.8 ± 32.7	141.4 ± 31.2
	B组	30	255.2 ± 48.6	122.6 ± 38.8	108.7 ± 25.6	106.8 ± 25.1[a]	115.5 ± 44.2	147.6 ± 34.7
	C组	30	262.7 ± 60.8	128.1 ± 39.0	122.3 ± 35.4[a]	110.5 ± 31.6[a]	116.7 ± 34.7	152.7 ± 34.3
	D组	30	245.6 ± 43.4	141.2 ± 35.5[ab]	124.2 ± 27.8[ab]	121.2 ± 27.1[ab]	139.0 ± 33.1[abc]	162.7 ± 33.9[a]
SaO_2 (mmHg)	A组	28	99.9 ± 0.3	98.1 ± 2.0	97.5 ± 2.0	96.4 ± 2.1	97.7 ± 1.7	98.7 ± 1.2
	B组	30	99.9 ± 0.3	97.5 ± 2.2	97.6 ± 1.9	96.9 ± 2.1	96.9 ± 2.5	98.6 ± 1.4
	C组	30	100.0 ± 0.2	98.2 ± 1.9	97.8 ± 2.1	97.0 ± 2.1	97.3 ± 2.3	98.8 ± 1.4
	D组	30	99.9 ± 0.3	98.1 ± 1.8	97.6 ± 1.7	96.9 ± 2.1	97.8 ± 1.8	99.0 ± 1.0
SpO_2 (%)	A组	28	99.5 ± 0.9	98.8 ± 2.0	98.1 ± 2.1	97.8 ± 2.1	98.5 ± 1.6	99.3 ± 1.2
	B组	30	99.7 ± 0.6	98.3 ± 2.0	97.8 ± 2.0	97.1 ± 2.5	97.7 ± 2.2	98.9 ± 1.2
	C组	30	99.8 ± 0.7	98.8 ± 1.8	98.6 ± 1.6	98.0 ± 2.0	98.2 ± 2.1	99.1 ± 1.3
	D组	30	99.7 ± 0.7	98.8 ± 1.6	98.2 ± 1.8	97.8 ± 1.7	98.6 ± 1.5	99.4 ± 1.0
pH	A组	28	7.4 ± 0.0	7.4 ± 0.0	7.4 ± 0.0	7.4 ± 0.0	7.4 ± 0.0	7.4 ± 0.1
	B组	30	7.4 ± 0.0	7.4 ± 0.0	7.4 ± 0.0	7.4 ± 0.1	7.4 ± 0.0	7.4 ± 0.0
	C组	30	7.4 ± 0.1	7.4 ± 0.0	7.4 ± 0.0	7.4 ± 0.0	7.4 ± 0.0	7.4 ± 0.0
	D组	30	7.4 ± 0.0	7.4 ± 0.0	7.4 ± 0.0	7.4 ± 0.1	7.4 ± 0.0	7.4 ± 0.0
$PaCO_2$ (mmHg)	A组	28	42.5 ± 4.4	41.3 ± 6.2	39.5 ± 3.7	41.3 ± 5.8	40.6 ± 6.3	39.8 ± 7.1
	B组	30	43.4 ± 4.8	43.3 ± 5.4	41.4 ± 5.9	41.7 ± 6.8	43.0 ± 4.4	42.4 ± 6.6
	C组	30	43.6 ± 6.1	42.3 ± 11.5	39.7 ± 3.6	39.3 ± 4.2	42.5 ± 4.3	39.7 ± 3.8
	D组	30	44.8 ± 5.7	40.3 ± 6.1	41.3 ± 6.0	40.5 ± 6.3	42.6 ± 4.0	40.4 ± 7.6
Qs/Qt (%)	A组	28	6.7 ± 2.8	17.9 ± 5.9	18.4 ± 4.0	20.1 ± 3.4	17.6 ± 3.1	16.3 ± 6.7
	B组	30	6.9 ± 2.7	17.9 ± 5.0	17.8 ± 3.1	18.2 ± 3.3[a]	17.2 ± 4.5	14.8 ± 3.8
	C组	30	6.5 ± 3.1	16.1 ± 3.9	16.3 ± 4.5[a]	17.6 ± 4.0[a]	17.1 ± 3.7	15.1 ± 3.0
	D组	30	7.3 ± 2.4	15.3 ± 4.3[ab]	15.8 ± 3.6[ab]	16.4 ± 3.5[ab]	15.5 ± 3.8[a]	13.8 ± 2.4[a]

与A组比较,[a]$P < 0.05$;与B组比较,[b]$P < 0.05$;与C组比较,[c]$P < 0.05$。

2.3 呼吸力学与血流动力学指标

T_2时B、C、D组P_{peak}、P_{plat}明显高于A组($P < 0.05$),D组P_{peak}、P_{plat}明显高于B组($P < 0.05$)。T_3~T_6时D组P_{peak}、P_{plat}明显高于A、B、C组($P < 0.05$)。T_2~T_6时B、C、D组DP明显低于A组($P < 0.05$)。T_2~T_5时C、D组DP明显低于B组($P < 0.05$)。T_4~T_6时C、D组Cdyn明显高于A、B组($P < 0.05$)。T_2~T_6时C、D组CVP明显高于A、B组($P < 0.05$)。4组间各时间点的MAP、HR差异无统计学意义(表3)。

2.4 预后指标

4组患者术后均无ARDS、急性呼吸衰竭等需非计划性使用有创或无创机械通气情况发生。B、C、D组术后第2天CPIS明显低于A组($P < 0.05$)。术后7 d内A组2例(7.1%)患者出现脓胸;B、C组各出现肺部感染1例(3.3%);D组1例(3.3%)患者出现肺部感染,1例(3.3%)患者出现胸腔积液,各组PPC发生率差异无统计学意义。ICU停留天数、术后住院天数差异无统计学意义(表4)。

3 讨 论

术中吸入较高浓度的氧气对患者的不良影响已经日渐引起临床医师的重视。研究表明,高氧性肺损伤与PaO_2的高低(尤其是$PaO_2 > 450$ mmHg或者$FiO_2 > 60\%$)和暴露时间的长短呈正比[10],而OLV期间较大潮气量、纯氧吸入、高气道压及OLV持续时间是患者术后发生ARDS的独立危险因素[11],本研究组既往动物实验显示,兔OLV时吸入60%氧气3 h后,兔肺组织病理组织学损伤评分较100% FiO_2有所减轻[12];进一步的临床研究发现,60%FiO_2应用于胸科手术麻醉OLV中时,有25%的患者因SpO_2降至90%~95%而恢复纯氧通气,但使用60%FiO_2实验组术后肺部感染的发生率较之纯氧组降低近50%[13],因此,我们认为降低OLV期间的FiO_2对胸科手术患者的肺保护很有价值。在此基础上,本研究继续选择60% FiO_2进行深入研究。数据显示A组有2例在OLV 15 min后发生低氧血症,再次提示OLV期间降

表3　4组患者呼吸力学及血流动力学结果比较

Table 3　Comparison of the value of respiratory mechanics, hemodynamics among the four groups　($\bar{x} \pm s$)

指标	组别	例数	T_1	T_2	T_3	T_4	T_5	T_6
P_{peak}	A组	28	15.4 ± 4.3	20.5 ± 2.1	21.8 ± 2.3	22.6 ± 3.1	23.7 ± 4.2	24.8 ± 4.6
(cm H_2O)	B组	30	15.0 ± 3.2	22.8 ± 3.7[a]	23.4 ± 4.4	23.5 ± 3.5	24.4 ± 3.8	23.5 ± 3.9
	C组	30	15.3 ± 2.3	23.0 ± 2.5[a]	23.1 ± 3.5	23.5 ± 3.1	24.5 ± 3.6	24.8 ± 3.7
	D组	30	15.4 ± 2.2	24.3 ± 3.2[ab]	26.2 ± 4.0[abc]	26.6 ± 3.8[abc]	27.4 ± 3.3[abc]	27.0 ± 3.5[abc]
P_{plate}	A组	28	14.3 ± 4.4	19.3 ± 2.0	20.8 ± 2.3	21.6 ± 3.2	23.6 ± 4.2	23.8 ± 4.5
(cmH_2O)	B组	30	14.0 ± 3.1	21.7 ± 3.8[a]	22.4 ± 4.4	22.5 ± 3.5	21.6 ± 3.8	22.5 ± 3.9
	C组	30	14.3 ± 2.3	21.9 ± 2.6[a]	22.2 ± 3.5	22.5 ± 3.0	23.6 ± 3.6	23.8 ± 3.7
	D组	30	14.4 ± 2.2	23.3 ± 3.2[ab]	25.2 ± 4.1[abc]	25.6 ± 3.7[abc]	26.4 ± 3.3[abc]	26.0 ± 3.5[abc]
DP	A组	28	14.3 ± 4.4	19.3 ± 2.0	20.8 ± 2.3	21.6 ± 3.2	22.7 ± 4.2	23.4 ± 4.4
(cmH_2O)	B组	30	14.0 ± 3.1	16.7 ± 3.8[a]	17.4 ± 4.4[a]	17.5 ± 3.5[a]	18.3 ± 3.8[a]	17.5 ± 3.9[a]
	C组	30	14.3 ± 2.3	13.9 ± 2.6[ab]	14.2 ± 3.5[ab]	14.5 ± 3.0[ab]	15.4 ± 3.6[ab]	15.8 ± 3.7[a]
	D组	30	14.4 ± 2.2	13.3 ± 3.2[ab]	15.2 ± 4.1[ab]	15.6 ± 3.7[ab]	16.3 ± 3.3[ab]	16.0 ± 3.5[a]
Cdyn	A组	28	39.6 ± 6.9	28.9 ± 6.7	30.8 ± 7.5	26.8 ± 4.2	27.0 ± 3.6	27.6 ± 3.5
(mL/cmH_2O)	B组	30	40.8 ± 8.9	28.5 ± 7.4	30.6 ± 7.7	28.4 ± 6.8	28.2 ± 7.0	26.8 ± 6.4
	C组	30	41.6 ± 7.6	31.8 ± 9.4	32.7 ± 8.1	32.9 ± 7.7[ab]	32.3 ± 7.4[ab]	31.3 ± 5.2[ab]
	D组	30	43.9 ± 10.0	30.3 ± 5.7	32.2 ± 5.9	33.8 ± 6.5[ab]	34.4 ± 6.9[ab]	33.6 ± 6.3[ab]
MAP	A组	28	97.9 ± 11.9	98.3 ± 13.1	93.7 ± 13.2	98.3 ± 11.0	101.6 ± 9.4	98.4 ± 12.4
(mmHg)	B组	30	99.8 ± 13.9	102.2 ± 12.7	98.3 ± 12.4	101.5 ± 14.3	97.7 ± 12.6	96.1 ± 12.4
	C组	30	97.4 ± 14.7	104.5 ± 10.2	98.9 ± 11.9	103.5 ± 12.6	98.9 ± 13.3	93.7 ± 10.8
	D组	30	95.8 ± 14.2	103.7 ± 14.1	99.6 ± 13.3	99.4 ± 14.0	101.0 ± 13.0	97.8 ± 11.6
HR	A组	28	74.2 ± 12.5	75.0 ± 12.2	77.3 ± 9.5	76.9 ± 10.8	73.6 ± 12.8	72.5 ± 18.8
(次/min)	B组	30	76.8 ± 11.8	77.8 ± 11.4	78.2 ± 11.6	78.3 ± 12.9	74.3 ± 11.0	69.2 ± 10.6
	C组	30	74.7 ± 9.9	76.3 ± 9.2	78.3 ± 9.4	77.3 ± 11.7	73.0 ± 10.8	67.6 ± 9.7
	D组	30	74.3 ± 13.0	75.5 ± 13.6	77.1 ± 15.5	73.9 ± 11.9	70.1 ± 11.4	68.3 ± 10.1
CVP	A组	28	13.2 ± 4.4	15.6 ± 4.5	15.8 ± 4.4	16.8 ± 3.6	17.4 ± 3.7	17.0 ± 3.5
(cmH_2O)	B组	30	13.5 ± 3.7	17.8 ± 4.7	17.8 ± 4.4	17.9 ± 3.8	18.1 ± 3.5	18.0 ± 3.4
	C组	30	13.8 ± 3.2	20.2 ± 5.7[ab]	21.1 ± 4.3[ab]	21.3 ± 4.0[ab]	21.1 ± 3.9[ab]	21.0 ± 3.7[ab]
	D组	30	13.9 ± 2.6	20.5 ± 2.3[ab]	21.2 ± 3.2[ab]	21.4 ± 3.1[ab]	21.5 ± 3.3[ab]	21.6 ± 3.3[ab]

与A组比较，$^aP < 0.05$；与B组比较，$^bP < 0.05$；与C组比较，$^cP < 0.05$。

表4　4组患者术后情况比较

Table 4　Comparison of prognosis among the four groups

组别	例数	CPIS（分）	PPC发生率[n(%)]	术后住院天数(d)	ICU停留时间(d)
A组	28	4.0 ± 2.3	2(7.1)	15.9 ± 5.0	2.1 ± 0.3
B组	30	2.5 ± 1.3[a]	1(3.3)	15.0 ± 5.2	2.0 ± 0.2
C组	30	2.3 ± 1.3[a]	1(3.3)	13.5 ± 1.2	2.0 ± 0.2
D组	30	1.6 ± 2.1[a]	2(6.7)	14.9 ± 4.5	1.8 ± 0.5

与A组比较，$^aP < 0.05$。

低FiO_2应当警惕低氧血症的发生风险增加。对通气侧肺使用PEEP通气，可通过扩张萎陷的肺泡、增加肺功能残气量而有效预防肺不张、降低肺内分流并改善氧合。因此，在降低FiO_2时联合适当的PEEP，从理论上来说可在维持患者满意氧合的基础上减轻肺损伤。

OLV时最适合患者的PEEP水平没有绝对的标准，过低的PEEP作用有限，过高的PEEP会增加胸腔内压，使静脉回流受阻，导致心输出量减少。OLV期间小潮气量、限制气道压力、增加PEEP等措施可以减轻患者急性肺损伤的风险[14]。Choi等[15]研究显示8 cmH_2O PEEP应用于胸腔镜手术OLV期间，能显著改善肺动态顺应性，对血流动力学无明显影响，且联合OLV前肺泡复张能明显改善患者氧合。Spadaro等[16]在V_T 5~6 mL/kg、纯氧条件下对41例OLV患者的研究结果显示，OLV后当逐渐提高PEEP至10 cmH_2O时，氧合及肺内分流明显改善，同时血流动力学较前无明显变化。本研究结果显示，D组患者自OLV 10 min后PaO_2便持续高于其他各

组,分流率也显著降低。随着时间的延续,C组、B组PaO_2与分流率也都相继明显改善,至OLV 30 min时,3个实验组均与对照组出现明显差异,提示在60% FiO_2条件下,5、8和10 cmH_2O的PEEP均可显著改善OLV期间的氧合和肺内分流;并且,随着PEEP水平的升高,其改善效应出现得更早,效应也更显著。同时,患者肺动态顺应性也有所改善,其中以使用8 cmH_2O和10 cmH_2O的PEEP改善效果较明显。在OLV 10 min后,C、D组CVP较A、B组显著升高,推测与剖胸侧病理生理改变以及PEEP的使用均有一定关系,各组其余血流动力学指标无显著差异,但D组有2例在关闭胸腔恢复双肺通气后出现短暂的血压下降(降幅超过20%),推测与关胸后胸腔压力进一步增加相关,停用PEEP通气后,血压回升至正常范围内,提示在使用10 cmH_2O的PEEP时需要密切关注其对血流动力学的影响。

CPIS综合了临床、影像学和微生物学标准等来评估感染的严重程度、疗效和预后,对早期肺部感染的诊断和预后评价有较大的临床应用价值[9]。围术期机械通气相关的肺部并发症多在术后5~7 d内发生。本研究中,4组患者7 d内PPC发生率无明显差异,但B、C、D组术后2 d的CPIS评分显著低于A组。Bluth等[17]一项多中心随机对照研究纳入了1 976例肥胖患者,根据机械通气时PEEP水平,分为低水平PEEP组(4 cmH_2O)和高水平PEEP组(12 cmH_2O),结果表明两组间PPC发生率并无明显差异,本研究结果与其一致。本研究中A组(0 cmH_2O)患者与其他3组PPC发生率无明显差异。其可能原因是既往OLV的相关研究通常是在吸入纯氧下进行,而本研究是在FiO_2为60%条件下进行,此保护性通气措施已降低患者PPC发生风险,且本研究以患者主要结局指标PaO_2来计算样本量,此样本量对于发生率较低的PPC而言尚不足以产生统计学差异。同时B、C、D组DP在OLV后均较A组降低,C、D组在OLV后60 min也较B组产生明显差异。DP是对抗呼吸系统的弹性阻力,驱动患者呼吸系统扩张的直接动力,回顾性分析显示DP的降低与ARDS患者病死率之间显著正相关,而V_T、PEEP或P_{plat}的个体变化与生存率无关,只有当其是导致驱动压力降低的影响因素之一时,PEEP等因素才与生存率有关[8]。也有研究表明,术中DP升高,术后肺部感染的风险也随之上升[18]。Neto等[19]的一项针对接受外科手术患者的Meta分析显示,DP增加是PPC的一个显著预测因素。本研究结果显示B、C、D组DP在OLV后均较A组降低,与CPIS评分趋势基本一致,并且DP随着PEEP水平的升高改善效应更显著。

本研究也有局限性。第一,本研究为单中心临床研究,且目前临床上已经采取多种措施综合预防围术期肺部并发症,其发生率较过去已经大幅度降低,同时本研究并未以PPC发生率或DP变化作为主要结局指标。因此以患者主要结局指标PaO_2来计算的样本量对于预后等指标的统计结果来说可能有一定偏倚。第二,现有结果显示增加PEEP的短期生理效应是有益的,但本研究并未进行远期随访,仍需进一步研究与长期随访证明OLV与10 cmH_2O PEEP联合应用是否会对患者的远期术后结局产生影响。

综上所述,OLV时FiO_2为60%条件下,联合5、8、10 cmH_2O PEEP均可改善氧合、降低肺内分流、增加肺动态顺应性,降低驱动压及CPIS,从而具有一定的肺保护作用,其中10 cmH_2O PEEP改善氧合的效应出现得更早,效果更佳。

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