

· 临床研究 ·

容量控制和压力控制通气模式在开腹手术老年患者中的比较

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【摘要】 目的 比较压力控制(PCV)模式和容量控制(VCV)模式肺通气策略对老年全身麻醉腹部开放手术患者术中及术后的影响。**方法** 入选解放军总医院接受腹部开放手术的老年患者70例, 男性39例, 女性31例, 年龄65~82岁。采用随机数字表法分为PCV组和VCV组, 每组35例。记录插管前(T_0)、插管机械通气3 min(T_1)、手术开始后(T_2)、手术2 h(T_3)、手术结束(T_4)和拔管后5 min(T_5)时间点的心率(HR)、血压(BP)、平均动脉压(MAP)、气道峰压(Ppeak)、气道平均压(Pmean)、潮气量(VT)和呼吸频率(RR), 并在 T_0 、 T_1 、 T_3 和 T_5 时间点采取桡动脉血行血气分析, 并记录患者住院期间并发症。**结果** 有8例患者被剔除, 共62例患者纳入研究, PCV组30例, VCV组32例。PCV组患者 T_2 、 T_3 、 T_4 时间点Ppeak显著低于VCV组($P < 0.05$)。手术开始后HR、MAP呈下降趋势, 相比VCV组, PCV组患者 T_2 、 T_3 、 T_4 时间点MAP较高, T_4 时间点最高, T_3 时间点乳酸水平较低, 差异有统计学意义($P < 0.05$)。相比 T_0 时间点, T_5 时间点两组患者pH、PaO₂和氧合指数(OI)均明显下降($P < 0.05$)。PCV组和VCV组患者住院时间差异有统计学意义(18.3 ± 5.3 vs 15.6 ± 4.5 , $P = 0.045$)。PCV组患者术后2例(6.7%)转入重症监护病房(ICU), VCV组患者9例(28.1%)转入ICU, 差异有统计学意义($P < 0.05$)。**结论** 老年开腹手术患者利用PCV模式的保护性肺通气策略可在术中以更低的气道压水平获得相似的OI及PaO₂, 提示PCV模式保护性肺通气策略可更利于老年全身麻醉下的开腹手术患者。

【关键词】 压力控制通气; 容量控制通气; 肺保护性通气; 术后并发症; 老年人

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Comparison of pressure-controlled and volume-controlled lung protective ventilation in elderly patients undergoing general anesthesia for laparotomy

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【Abstract】 Objective To investigate the effects of pressure-controlled ventilation (PCV) and volume-controlled ventilation (VCV) strategies for the patients undergoing general anesthesia for laparotomy. **Methods** A total of 70 patients (39 males and 31 females, aged from 65 to 82 years) who underwent general anesthesia for scheduled laparotomy were prospectively subjected in this clinical trial, and they were randomly assigned into PCV group ($n = 35$) and VCV group ($n = 35$). The hemodynamic and respiratory mechanic indices [including heart rate (HR), blood pressure (BP), mean arterial pressure (MAP), peak airway pressure (Ppeak), mean airway pressure (Pmean), tidal volume (VT) and respiratory rate (RR)] were measured at the following time points, pre-intubation (T_0), 3 min after intubation (T_1), immediately after surgery began (T_2), 2 h after surgery (T_3), end of surgery (T_4), and 5 min post-extubation (T_5). The radial arterial blood gas analyses were tested at T_0 , T_1 , T_3 and T_5 . Pulmonary and extrapulmonary complications during hospitalization were recorded. **Results** Eight patients were excluded and the other 62 patients were enrolled in this trial, including 30 patients for PCV group and 32 patients for VCV group. The level of Ppeak was significantly lower in the PCV group than in the VCV group at T_2 , T_3 and T_4 ($P < 0.05$). From the beginning of operation, HR and MAP were in a trend of decreasing. Compared with the group VCV, the PCV group had comparatively higher MAP level at T_2 , T_3 and T_4 , and reached the summit at T_4 , but the level of lactic acid was the lowest at T_3 ($P < 0.05$). The pH, PaO₂ and oxygenation index (OI) values were obviously decreased in the both groups at T_5 than at T_0 ($P < 0.05$). Significant difference was observed in the length of hospital stay in the PCV group and VCV group [(18.3 ± 5.3) vs (15.6 ± 4.5) d, $P = 0.045$]. There were 2 of 30 patients (6.7%) in group PCV and 9 of 32 patients (28.1%) in group VCV admitted to the intensive care unit (ICU), with significant difference between them ($P < 0.05$).

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Conclusion PCV model as lung protective ventilation strategy can lead lower airway pressure and obtain similar OI and PaO₂, and is beneficial to the aged patients undergoing general anesthesia for laparotomy.

[Key words] pressure-controlled ventilation; volume-controlled ventilation; lung protective ventilation; postoperative complications; aged

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腹部开放性手术创伤大,时间长,术后恢复较慢,并发症发生率高,老年患者由于肺功能退化及合并多种疾病,术后更易发生肺部并发症,发生率可高达9%~40%。合理的肺保护性通气策略能有效降低腹部手术患者术后肺部并发症的发生率^[1,2]。但是,国内外报道的保护性通气策略多采用容量控制(volume-controlled ventilation, VCV)模式,而压力控制(pressure-controlled ventilation, PCV)模式的优劣尚不清楚。因此,本研究对PCV和VCV模式肺保护性通气策略对老年开腹手术患者呼吸力学、血气和术后并发症的影响进行了比较,为临床优化麻醉呼吸管理提供理论支持。

1 对象与方法

1.1 研究对象

入选解放军总医院接受腹部开放手术的老年患者70例,男39例,女31例,年龄65~82岁。采用随机数字表法分为PCV组和VCV组,每组35例。纳入标准:美国麻醉医师协会(American Society of Anesthesiology, ASA) I~III级;体质量指数(body mass index, BMI) 18~30 kg/m²;择期全麻下腹部手术患者,预期手术时间>2 h。排除标准:严重心功能不全,恶性心律失常;各种原因导致的急性呼吸衰竭;败血症或感染性休克;胸片或CT显示肺大泡、气胸等有肺部损伤患者;合并严重肺动脉高压、颅内压升高等肺复张的禁忌证;近期接受过肺活检或肺切除术者;手术时间>8 h;出血量>1000 ml;术中发生严重的心脑血管意外或过敏反应。本研究已获医院的医学伦理委员会批准(批号:S2016-033-02),并与患者或家属签订知情同意书。

1.2 麻醉方法和通气策略

患者进入手术室后开放外周静脉通路,常规监测心电图(electrocardiogram, ECG)、心率(heart rate, HR)、血压(blood pressure, BP)、平均动脉压(mean arterial pressure, MAP)、血氧饱和度(blood oxygen saturation, SaO₂)和脑电双频指数(bispectral index, BIS),局麻下行桡动脉穿刺置管监测有创动脉血压。静脉注射咪达唑仑0.05 mg/kg、丙泊酚1~2 mg/kg、

罗库溴铵0.6 mg/kg、舒芬太尼0.4 μg/kg行麻醉诱导,气管插管成功后,连接麻醉机进行机械通气。麻醉维持采用静吸复合麻醉,静脉泵注丙泊酚2~4 mg/(kg·h)和瑞芬太尼0.1~0.5 μg/(kg·min),吸入七氟醚1%~2%,间断追加罗库溴铵,BIS维持在45~60。术中采用目标导向液体治疗,使脉搏压变异度<13。术后采用静脉镇痛泵模式镇痛。

术中调整吸气峰压,根据预测体重(predicted body weight, PBW)维持潮气量(tidal volume, VT) 6~8 ml/kg,呼气末正压通气(positive end-expiratory pressure, PEEP) 5 cmH₂O,每30 min进行一次肺复张(recruitment maneuver, RM)。术中通气均采用纯氧,氧流量为1.5~2.0 L/min,吸呼比(inspiratory: expiratory, I:E)为1:2,调节通气频率(respiratory rate, RR)使呼气末二氧化碳分压(partial pressure of end-tidal carbon dioxide, PETCO₂)维持在35~45 mmHg。

1.3 观察指标

记录患者插管前(T₀)、插管机械通气3 min(T₁)、手术开始后(T₂)、手术2 h(T₃)、手术结束后(T₄)和拔管后5 min(T₅)的HR和BP,并在T₁、T₂、T₃、T₄时间点记录气道峰压(peak pressure, P_{peak})、平均压(mean pressure, P_{mean})、VT和RR;在T₀、T₁、T₃和T₅时间点取桡动脉血进行血气分析(GEM Premier3000,美国IL),同时记录患者住院期间并发症。其中肺部并发症包括低氧血症、有创呼吸支持、肺炎、急性肺损伤(acute lung injury, ALI)和急性呼吸窘迫综合征(acute respiratory distress syndrome, ARDS)。系统并发症还包括全身炎症反应综合征(systemic inflammatory response syndrome, SIRS)、脓毒血症、肺外感染、心脑血管意外和胃肠功能障碍等。

1.4 统计学处理

采用SPSS17.0统计软件对数据进行处理。计量资料呈正态分布者以均数±标准差($\bar{x} \pm s$)表示,组间比较采用 t 检验,组内比较采用重复测量方差分析;呈偏态分布者用四分位数表示,组间比较采用Wilcoxon秩和检验。计数资料以率表示,组间比较采用 χ^2 检验。以 $P < 0.05$ 为差异有统计学意义。

2 结果

2.1 两组患者一般资料比较

PCV组2例手术时间 <2 h, 2例麻醉时间 >8 h, 1例术中出血 >1000 ml, 共排除5例, 最终30例纳入研究。VCV组1例手术时间 <2 h, 2例失访, 共排除3例, 最终32例纳入研究。两组患者基本资料差异无统计学意义($P>0.05$; 表1)。PCV组患者RM为8.0(7.8, 10.0)次, VCV组患者RM为8.0(6.0, 9.8)次, 其他术中情况差异无统计学意义($P>0.05$; 表2)。

表1 两组患者一般资料比较

Table 1 Comparison of baseline data between two groups

Item	PCV group (n=30)	VCV group (n=32)	P value
Male/Female	19/11	20/12	0.946
Age(years, $\bar{x} \pm s$)	70.6 $\pm$ 4.9	71.9 $\pm$ 5.9	0.348
Height(cm, $\bar{x} \pm s$)	163.8 $\pm$ 7.0	166.3 $\pm$ 7.7	0.185
Body mass(kg, $\bar{x} \pm s$)	62.7 $\pm$ 10.9	62.7 $\pm$ 12.9	0.988
BMI(kg/m ² , $\bar{x} \pm s$)	23.3 $\pm$ 3.5	22.6 $\pm$ 3.6	0.433
PBW(kg, $\bar{x} \pm s$)	58.4 $\pm$ 8.4	60.6 $\pm$ 8.9	0.328
ASA stage[n(%)]			0.779
II	27(90.0)	27(84.3)	
III	3(10.0)	5(15.7)	
Type of surgery[n(%)]			0.092
Gastrointestinal	26(86.7)	22(68.8)	
Hepatic	4(13.3)	10(31.2)	

BMI: body mass index; PBW: predicted body weight; ASA: American Society of Anesthesiology. Male: $PBW = 50 + 0.91 \times (\text{height} - 152.4)$; Female: $PBW = 45.5 + 0.91 \times (\text{height} - 152.4)$

2.2 两组患者呼吸参数和血流动力学比较

结果表明, PCV组患者 T_2 、 T_3 、 T_4 时间点气道峰

压显著低于VCV组($P<0.05$)。手术开始后HR、MAP呈下降趋势, PCV组患者 T_2 、 T_3 、 T_4 时间点MAP较VCV组高, T_4 时间点最高, 差异有统计学意义($P<0.05$; 表3)。

表2 两组患者术中一般情况比较

Table 2 Comparison of intraoperative data between two groups ($\bar{x} \pm s$)

Item	PCV group (n=30)	VCV group (n=32)	P value
Duration of anesthesia(min)	235.8 $\pm$ 60.1	213.4 $\pm$ 66.0	0.172
Duration of surgery(min)	181.0 $\pm$ 54.8	159.5 $\pm$ 57.9	0.138
Blood loss(ml)	208.6 $\pm$ 170.1	139.7 $\pm$ 89.5	0.058
Urine output(ml)	315.0 $\pm$ 204.7	296.9 $\pm$ 233.1	0.747
Fluid administration(ml)	2898.0 $\pm$ 810.4	2563.8 $\pm$ 452.8	0.053
Colloidal solution(ml)	620.0 $\pm$ 358.5	518.8 $\pm$ 230.6	0.188
Crystal solution(ml)	2130.0 $\pm$ 461.6	1946.9 $\pm$ 345.2	0.081

2.3 两组患者动脉血气指标比较

PCV组和VCV组患者 T_0 、 T_1 、 T_3 、 T_5 时间点动脉血氧分压(partial pressure of artery oxygen, PaO_2)、二氧化碳分压(partial pressure of artery carbon dioxide, $PaCO_2$)和氧合指数(oxygenation index, OI)差异无统计学意义。相比VCV组患者, PCV组患者 T_3 时间点乳酸水平较低, 差异有统计学意义($P<0.05$)。相比 T_0 时间点, T_5 时间点两组患者pH、 PaO_2 和OI均明显下降($P<0.05$; 表4)。

2.4 两组患者临床转归比较

PCV组和VCV组患者住院时间差异有统计学意义[(18.3 $\pm$ 5.3) vs (15.6 $\pm$ 4.5) d, $P=0.045$]。PCV组患者2例(6.7%)转入重症监护病房, VCV组患者9例(28.1%)转入重症监护病房, 差异有统计学意义($P<0.05$; 表5)。

表3 两组患者呼吸参数和血流动力学比较

Table 3 Comparison of respiratory parameters and hemodynamics between two groups

Index	PCV group (n=30)				VCV group (n=32)			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
VT(ml, $\bar{x} \pm s$)	423.3 $\pm$ 48.3	426.0 $\pm$ 49.1	419.7 $\pm$ 49.1	414.2 $\pm$ 50.8	413.8 $\pm$ 47.1	415.0 $\pm$ 50.4	419.7 $\pm$ 46.6	418.1 $\pm$ 49.0
MAP(mmHg, $\bar{x} \pm s$)	83.5 $\pm$ 10.1	81.2 $\pm$ 9.3*	82.0 $\pm$ 9.0*	86.8 $\pm$ 12.1*	78.1 $\pm$ 17.8	78.6 $\pm$ 17.6	76.1 $\pm$ 21.5	78.6 $\pm$ 16.4
HR(beats/min, $\bar{x} \pm s$)	74.0 $\pm$ 17.0	74.8 $\pm$ 11.1	63.7 $\pm$ 8.3	67.4 $\pm$ 11.5	71.4 $\pm$ 12.0	69.7 $\pm$ 11.2	65.7 $\pm$ 9.6	65.7 $\pm$ 8.7
PETCO ₂ (mmHg, $\bar{x} \pm s$)	32.0 $\pm$ 3.1	32.1 $\pm$ 3.0	31.5 $\pm$ 3.2	33.1 $\pm$ 3.4	32.0 $\pm$ 3.2	32.3 $\pm$ 3.2	33.1 $\pm$ 3.4	33.5 $\pm$ 3.0
Ppeak(cmH ₂ O, $\bar{x} \pm s$)	14.7 $\pm$ 2.3	16.2 $\pm$ 2.6*	15.9 $\pm$ 2.8*	15.8 $\pm$ 2.6*	15.0 $\pm$ 1.4	17.7 $\pm$ 3.0	17.8 $\pm$ 2.7	17.8 $\pm$ 2.5
Pmean(cmH ₂ O, $\bar{x} \pm s$)	7.7 $\pm$ 1.5	9.0 $\pm$ 1.1	8.9 $\pm$ 1.2	9.0 $\pm$ 1.8	9.0 $\pm$ 1.8	8.2 $\pm$ 1.7	8.5 $\pm$ 1.7	8.5 $\pm$ 1.6
RR(times/min, $\bar{x} \pm s$)	12.3 $\pm$ 0.5	12.0 $\pm$ 0.7	11.5 $\pm$ 1.2	11.7 $\pm$ 1.1	12.1 $\pm$ 0.4	12.0 $\pm$ 0.4	12.0 $\pm$ 0.7	11.9 $\pm$ 0.6
PEEP[cmH ₂ O, M(Q ₁ , Q ₃)]	0(0,0)	5(5,5)	5(5,5)	5(5,5)	0(0,0)	5(5,5)	5(5,5)	5(5,5)

VT: tidal volume; MAP: mean arterial pressure; HR: heart rate; PETCO₂: partial pressure of end-tidal carbon dioxide; Ppeak: peak airway pressure; Pmean: mean airway pressure; RR: respiratory rate; PEEP: positive end-expiratory pressure. T_1 : 3 min after intubation; T_2 : immediately after surgery began; T_3 : 2 h after surgery; T_4 : end of surgery. Compared with VCV group, * $P<0.05$

表4 两组患者血气指标比较

Table 4 Comparison of blood gas indices between two groups ($\bar{x} \pm s$)

Index	PCV group (n=30)				VCV group (n=32)			
	T ₀	T ₁	T ₃	T ₅	T ₀	T ₁	T ₃	T ₅
pH	7.37 ± 0.04	7.39 ± 0.05	7.38 ± 0.05	7.34 ± 0.05 [#]	7.37 ± 0.03	7.39 ± 0.04	7.36 ± 0.04	7.33 ± 0.05 [#]
PaO ₂ (mmHg)	91.21 ± 18.38	424.37 ± 88.09	396.72 ± 112.06	86.96 ± 40.23 [#]	87.89 ± 17.02	425.38 ± 117.56	390.28 ± 130.42	79.94 ± 15.31 [#]
PaCO ₂ (mmHg)	40.07 ± 9.22	38.90 ± 3.75	38.34 ± 3.56	41.62 ± 5.28	43.39 ± 4.45	38.59 ± 4.03	40.25 ± 4.27	43.30 ± 4.84
OI (mmHg)	434.34 ± 87.55	436.06 ± 79.71	429.05 ± 79.57	366.91 ± 53.87 [#]	418.53 ± 81.10	441.78 ± 113.28	440.14 ± 121.40	373.79 ± 94.02 [#]
Lactate (mmol/L)	1.31 ± 0.61	1.11 ± 0.52	0.91 ± 0.21 [*]	1.39 ± 1.04	1.32 ± 0.62	0.99 ± 0.28	1.27 ± 0.40	1.26 ± 0.54

PaO₂: partial pressure of artery oxygen; PaCO₂: partial pressure of artery carbon dioxide; OI: oxygenation index. OI = PaO₂/FIO₂ (FIO₂: fraction of inspiration O₂). T₀: pre-intubation; T₁: 3 min after intubation; T₃: 2 h after surgery; T₅: 5 min post-extubation. Compared with VCV group, ^{*}P < 0.05; compared with T₀, [#]P < 0.05

表5 两组患者临床转归比较

Table 5 Comparison of clinical outcome between two groups

[n(%)]

Clinical outcome	PCV group (n=30)	VCV group (n=32)	P value
Admission to ICU	2(6.7)	9(28.1)	0.027
Pulmonary complications [*]	4(13.3)	5(15.6)	1.00
Hyoxemia	4(13.3)	5(15.6)	1.00
Need for invasive ventilation	2(6.7)	5(15.6)	0.48
Pneumonia	2(6.7)	4(12.5)	0.73
ARF/ARDS	3(9.4)	4(12.5)	0.76
Systemic complications [*]	12(40.0)	16(50.0)	0.59
SIRS/Sepsis	4(13.3)	3(9.4)	0.61

ICU: intensive care unit; ARF: acute respiratory failure; ARDS: acute respiratory distress syndrome; SIRS: systemic inflammatory response syndrome. ^{*}The pulmonary complications are a composite of major pulmonary complications (defined as hyoxemia, need for invasive ventilation, pneumonia, acute respiratory failure or acute respiratory distress syndrome). ^{*}The systemic complications are a composite of major pulmonary complications and extrapulmonary complications (defined as systemic inflammatory response syndrome, sepsis, extrapulmonary infection, cardiocerebral events, gastrointestinal dysfunction)

3 讨论

肺保护性通气策略主要用于治疗 ALI 和 ARDS^[3,4],也有研究表明该策略同样能改善全麻患者肺功能,减少术后并发症^[1,5]。本研究两组患者均采用小潮气量机械通气,能减少肺泡过度扩张和高吸气压引起的肺损伤^[6],联合使用 PEEP 可提高肺组织顺应性,减少肺内分流和增加动脉氧合,而 RM 可增强 PEEP 对肺组织的有利作用^[7]。高水平 PEEP(12 cmH₂O)并不能预防术后肺部并发症,且术中低血压的发生率更高^[8],故本研究采用中等水平 PEEP(5 cmH₂O)和肺复张策略以对抗全麻后功能残气量下降,减少肺不张区域,改善通气血流比例和动脉氧合。也有研究推荐根据静态压力-容量曲线,

PEEP 值可设为高于拐点 2 cmH₂O,从而可因人而异^[9]。

Amato 等^[10]发现高驱动压可致 ARDS 患者预后恶化,驱动压与 ARDS 患者预后关系紧密。Neto 等^[11]也发现高水平驱动压可导致术后肺部并发症增多。驱动压为潮气量与呼吸系统静态顺应性 (compliance respiratory static, CRS) 之比,公式为 $\Delta P = VT/CRS$,可综合考虑潮气量和气道压的共同作用,也可简化为平台压与 PEEP 的差值。PCV 模式在吸气时采用减速气流,可防止局部肺泡过度充气及肺泡压过高,有利于肺泡复张^[12];VCV 模式在吸气时采用恒速气流,为克服气道阻力吸气初期会产生较高的吸气峰压和平台压。故相同 PEEP 水平时 PCV 模式的驱动压较低,对预后的不良影响更少。本研究表明,维持老年患者相似 OI 下,PCV 组患者 Ppeak 显著低于 VCV 组患者,证实 PCV 模式肺顺应性方面优于 VCV 模式^[13-15]。本研究未证实 PCV 模式在 OI 方面的优势,但 PCV 组动脉血乳酸水平明显低于 VCV 组,反映了 PCV 组患者细胞水平的能量代谢优于 VCV 组,这一结果表明 PCV 模式可能会改善老年开腹患者术中肺功能,并减少术后相关并发症。本研究表明,PCV 组患者术后转入 ICU 的患者例数远低于 VCV 组,但两组患者术后肺部并发症(包括低氧血症、肺炎、有创呼吸支持和 ALI/ARDS)差异无统计学意义。研究表明 PCV 和 VCV 模式较传统机械通气模式均有优势^[1],但相比 VCV 模式,PCV 模式可在获得相同通气及肺保护效应时使患者气道压更低。而气道压是机械通气产生肺损伤的重要因素之一,故上述结果提示 PCV 模式较 VCV 模式更具潜在优势。

本研究的不足之处是样本量较少,因此研究结果存在假阴性可能。另外研究未设立大潮气量通气模式作为对照,因此本研究中的两种肺保护性通气

模式对术后预后的影响缺乏比较对象。

总之,对于实施腹部开放手术的老年患者而言,在维持相似OI的前提下,PCV模式相比VCV模式,可使患者术中气道压更低,提供更好的肺顺应性,更有利于减少老年开腹患者术后肺部并发症的发生。

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