厚生連医誌 第12巻 1号 54～57 2003

Original Article

Changes in Respiratory Mechanics during General Anesthesia with Mechanical Ventilation for Aging

－The mechanical ventilatory tidal volume of 13 ml/kg for old patients is physiologically superior to tidal volume of 10 ml/kg in pulmonary mechanics－

Kariwagun General Hospital, Department of Anestheiology

Kappei Matsumoto

Objective: We studied to evaluate and compare changes in respiratory mechanics as expiratory tidal volume (Ve), inspiratory peak airway pressure (PIP), compliance of the total respiratory system (compliance), and partial pressure of end-tidal carbon dioxide (PETCO2) between young age (Y), middle age (M) and old age (O) patients group under general anesthesia and mechanically ventilated in supine position.

Study Design and Results: Patients were ventilated with a tidal volume (Vm) of 8, 10, 13 ml/kg, a respiratory rate of 8 breaths per minutes, an IE ratio of 2.0, and a fresh gas flow rate of 2.5l/min. We found that, with increasing age: Ve increased, PETCO2 decreased significantly. And Ve decreased between M and O group in Vm of 8 and 10 ml/kg. Compliance increased between Y and O group in Vm of 13 ml/kg , decreased between Vm of 10 and 13ml/kg in Y group and increased significantly between Vm of 10 and 13 ml/kg in O group. PETCO2 decreased significantly between M and O group in Vm of 8 ml/kg.

Conclusion: Vm of 13 ml/kg for O group is physiologically superior to Vm of 10 ml/kg in pulmonary mechanics rather than younger patients.

Key Words: Respiratory mechanics, aging, mechanical ventilation

Introduction

Elderly patients are at risk of hypoxemia during the general anesthesia, because of pre-existing alterations in lung and chest wall mechanics. Loss of tissue elasticity appears to be the primary mechanism by which age exerts its effect on pulmonary function, since elastic lung recoil decreases with age. Even without definable disease, elderly patients experience emphysema-like increases in lung compliance. It is usually admitted that during general anesthesia with mechanical ventilation in elderly patients, alterations of gas exchange are due to changes in lung volume and in the mechanical properties of the respiratory system. And elderly patients have decreased compliance of chest wall, increased compliance of lung and equal system compliance to the younger patients. The aim of this prospective study was to analyze the pulmonary mechanics during general anesthesia with mechanical ventilation in elderly patients by giving a specific figure.

Materials and Methods

After obtaining approval of the local Ethics Committee and informed written consent of patients, we studied ASA physical status I - II patients scheduled for elective surgery. We compared respiratory mechanics as expiratory tidal volume (Ve), inspiratory peak airway pressure (PIP), compliance of the total respiratory system (compliance), and partial pressure of end-tidal carbon dioxide concentration (PETCO2) of 27 young age group with a age of 19-40 years old (Y), 37 middle age group with a age of 41-64 (M) and 62 old age group with a age of 65-90 years old (O) in supine position[7].

After intramuscular premedication with atropine sulfate (0.5mg) and hydroxyzine hydrochloride (25 to 50 mg), anesthesia was induced by thiamylal sodium (4 to 5mg/kg) followed by paralyzed dose of vecuronium bromide (0.15mg/kg), and the trachea was intubated. Anesthesia was maintained with sevoflurane, nitrous oxide in oxygen and paralyzed by vecuronium bromide (0.08mg/kg/hour). Patients were mechanically ventilated with a tidal volume (Vm) of 8-13ml/kg and a respiratory rate of 8 breaths per minutes, an IE ratio of 2.0, a fresh gas flow rate of 2.5l/min (oxygen 1l/min and N2O 1.5l/min) without positive end-expiratory pressure. Respiratory mechanics were measured with a Capnomac Ultima anesthetic gas analyzer and a side-stream spirometry device (Datex instrumentarium Corp., Helsinki, Finland)[9].

Statistical Analysis: Correlation between continuous variables was described by Pearson's correlation coefficient and tested for significance by Fisher's r to z transformation and the other statistical analysis performed using two-way analysis of variance (ANOVA) followed

by Fisher's paired least significant difference test. A p-value less than 0.01 was considered statistically significant.

Results

The preoperatively profile data are presented in Table 1. Criteria were age 20-90 yr, height 1.40-1.90 m, weight 40-90kg, no history of smoking, and no previous cardiopulmonary disease. We found that, with increasing age: Ve (mean of Vm 8-10ml/kg) increased significantly (r=0.226; p<0.0001), compliance (mean of Vm 8-10ml/kg) was unaffected (r=0.11; p=0.0741), PIP (mean of Vm 8-10ml/kg) was unaffected (r=-0.175; p=0.0108), PETCO2 (mean of Vm 8-10ml/kg) decreased significantly (r=-0.313; p<0.0001) (Table 2). And Ve decreased significantly (p<0.0001) between M and O group in Vm of 8 and 10 ml/kg. Compliance increased significantly (p<0.0001) between Y and O group in Vm of 13 ml/kg, decreased significantly (p<0.0001) between Vm of 10 and 13ml/kg in Y group and increased significantly (p<0.0001) between Vm of 10 and 13 ml/kg in O group. PETCO2 decreased significantly (p<0.0001) between M and O group in Vm of 8 ml/kg. (Table 3-4).

Discussion

It is usually admitted that during general anesthesia with mechanical ventilation in elderly patients, alterations of gas exchange are due to changes in lung volume and in the mechanical properties of the respiratory system.[3, 5, 6, 10-12, 16] We found a linear relationship between the increase in age and the changes in Ve, PIP, compliance, and PETCO2. These alterations are mainly caused by loss of tissue elasticity appears to be the primary mechanism by which age exerts its effect on pulmonary function, since elastic lung recoil and tonus of diaphragm decreases and cartilages calcification of the ribs with age[2, 4, 14, 15]. We found that there is a significant difference between Y, M and O patients in Vm of 8, 10 and 13ml/kg. In Y patients: Compliance of Vm 10ml/kg increased significantly. In M patients: Compliance had no significant difference in any Vm. In O patients: Ve was significantly decreased in mean of Vm

Table 1 Patients Data and PLSD (p-Values)

Group	Y (N=27)	M (N-37)	O (N=62)	PLSD Y v.M	Y v.O	M v.O
Age (yrs)	27.2±8.3	52.7±6.7	73.6±5.8	<0.0001	<0.0001	<0.0001
Height (cm)	164.2±9.5	162.0±8.6	153.9±7.7	0.1244	<0.0001	<0.0001
Weight (kg)	62.8±16.7	61.3±9.1	54.9±9.6	0.4500	<0.0001	0.0002
BMI (kg/m2)	23.3±5.7	23.3±3.3	23.2±3.7	0.9955	0.8649	0.8583
VC (l)	3.66±0.75	3.56±0.91	2.80±0.67	0.6871	0.0003	<0.0001
VC (%)	103.4±12.2	111.9±15.8	100.7±20.3	0.1515	0.619	0.0024
FEV%	88.3±9.5	80.5±15.0	77.5±19.4	0.1623	0.0409	0.3795
Vs (ml)	559.2±148.9	825.3±302.9	852.8±321.2	0.0068	0.0016	0.6454
Ve (mean of Vm 8-13ml/kg)	572.8±129.7	576.7±99.6	508.5±93.0	0.8309	0.0001	<0.0001
PIP	14.6±5.05	13.8±3.03	12.9±4.13	0.2418	0.0100	0.1535
comp	40.59±9.72	43.95±10.47	42.57±11.19	0.0746	0.2498	0.3749
PETCO2	39.25±6.11	37.92±5.81	36.16±4.82	0.1656	0.0005	0.0276

Note : Values are means±Standard Deviation

Table 2 Correlation between Age and Respiratory Mechanics

Correlation	p-Value
Ve=-0.226*age+615.5	<0.0001
PIP=-0.157*age+15.4	0.0108
comp=0.11*age+39.3	0.0741
PETCO2=-0.313*age+42.5	<0.0001

Table 3 Changes in Age and Tidal Volume (Vm)

	Vm (ml/kg)	Ve	PIP	compliance	PETCO2
Y	8	459.9±89.6	11.7±2.01	42.47±8.77	37.8±5.55
	10	622.4±106.9	14.5±3.00	47.57±9.02	34.8±5.11
	13	696.7±95.6	17.0±2.48	41.28±9.23	32.0±4.75
M	8	520.7±98.9	11.0±1.92	48.79±8.64	38.2±8.31
	10	615.9±111.0	13.4±2.73	49.87±8.70	33.6±6.67
	13	756.8±119.9	16.1±3.04	50.61±9.64	30.5±5.61
O	8	414.6±87.4	10.1±1.97	43.25±10.00	36.7±3.74
	10	549.1±106.7	12.6±2.79	47.88±11.44	34.1±4.26
	13	715.5±115.1	15.5±3.36	52.07±13.07	31.3±4.19

Note: Values are means±Standard Deviation

Table 4 PLSD (p-Values) of Each Values

	Vm (ml/kg)	Ve	PIP	compliance	PETCO2
Y v.M	8	0.0111	0.1549	0.0046	0.0495
	10	0.0037	0.1305	0.4604	0.0002
	13	0.0025	0.2132	0.0044	0.0348
Y v.O	8	0.0045	0.0002	0.8060	0.0500
	10	0.0463	0.0007	0.0150	0.0452
	13	0.4399	0.0078	<.0001	0.1851
M v.O	8	<.0001	0.0216	0.0006	<.0001
	10	<.0001	0.0446	0.0658	0.0359
	13	0.0012	0.1106	0.1192	0.1984
Y	8v. 10	<.0001	<.0001	0.0019	0.0016
	8v. 13	<.0001	<.0001	0.4697	<.0001
	10v. 13	<.0001	<.0001	<.0001	0.0020
M	8v. 10	<.0001	<.0001	0.4247	<.0001
	8v. 13	<.0001	<.0001	0.1959	<.0001
	10v. 13	<.0001	<.0001	0.5311	0.0004
O	8v. 10	<.0001	<.0001	0.0038	<.0001
	8v. 13	<.0001	<.0001	<.0001	<.0001
	10v. 13	<.0001	<.0001	<.0001	<.0001

Abbreviations
compliance=compliance of the total respiratory system (ml/cmH20)
FEV%=percentage of the predicted value of the forced expiratory volume
M=middle age group (41-64yrs)
N=number of patients
O=old age group (65-90yrs)
PIP=inspiratory peak airway pressure (cmH20)
PETCO2=partial pressure of end-tidal carbon dioxide (mmHg)
PSLD=paired least dignificant difference
v.=versus
VC=vital capacity
VC%=percentage of the predicted value of the vital capacity
Ve=expiratory tidal volume (ml)
Vm=tidal volume of mechanical ventilator (ml)
Vs=spontaneous respiratory tidal volume (ml)
Y=young age group (19-40yrs)

but compliance of Vm 13ml/kg increased significantly. This means that loss of tissue elasticity appears to be the primary mechanism by which age exerts its effect on pulmonary function, since elastic lung recoil decreases with age[7, 8, 13]. We think that elderly people need more tidal volume than younger people for keeping the good compliance of respiratory system. In elderly patient we have to decide the mechanical ventilation settings precisely because of their low functional respiratory system. In conclusion, the mechanical ventilatory tidal volume of 13 ml/kg for old patients is physiologically superior to tidal volume of 10 ml/kg in pulmonary mechanics rather than younger patients and needs to avoid the derangement of pulmonary functions.

References

1. Matsumoto K. Changes in ventilatory mechanics with mechanical ventilation for old moderately obese patients. J Clin Anesthesia 2001;25:1541-4.
2. Wahba W. Influence of aging on lung function: Clinical significance of changes from age twenty. Anesth Analg 1983;62:764-76.
3. Pelosi P, Croci M, Ravagnan I, Tredici S, Pedoto A, Lissoni A, Gattinoni L. The effects of body mass on lung volumes, respiratory mechanics, and gas exchange during general anesthesia. Anesth Analg 1998;87:654-60.
3. Abrams WB, Beers MH, Berkow R. The Merck Manual of Geriatrics. 2nd ed. Whitehouse Stration (NJ): Merck and Co.; 1995.
4. Dauchot PJ, Lima AA. Risk and Outcome in Anesthesia. In: Brown DL, editor. Geriatic Anesthesi. 2nd ed. Philadelphia (PA): JB Lippincott Company; 1992;527.
5. Warner DO, Warner MA, Ritman EL. Human chest wall function while awake and during halothene anesthesia. Anesthesiology 1995;82:6-19.
6. Lynch S, Brand L, Levy A. Changes in lung-thorax

compliance during orthopedic surgery. Anesthesiology 1995;20:278-82.
7. Safar P, Agusto-Escarraga L. Compliance in apneic anesthetized adults. Anesthesiology 1995;20:283-9.
8. Huffman LM. AANA journal course: new technologies in anesthesia: update for nurse anesthetists-monitoring ventilation and compliance with Side Stream SpirometryTM. AANA J 1991;59:249-59.
9. Luce MJ. Respiratory complications of obesity. Chest 1980;78:626-31.
10. Bardoczky GI, Yernault JC, Houben JJ, d'Hollander A. Large tidal volume ventilation does not improve oxygenation in obese patients during anesthesia. Anesth Analg 1995;81:385-8.
11. Nunn JF. Nunn's applied respiratory physiology. 4th ed. Oxford: Butterworth-Heinemann; 1993;261-7.
12. Rehder K, Marsh HM. Respiratory mechanics during anesthesia and mechanical ventilation. In: Mead J, editor. Handbook of physiology: the respiratory system. Bethesda (MD): American Physiological Society; 1986;737-52.
13. Krayer S, Rehder K, Vetterman J.Position and motion of the human diaphragm during anesthesia and paralysis. Anesthesiology 1989;70:891-8.
14. Tobin MJ, Van de Graaff WB. Monitoring of lung mechanics and work of breathing. In Tobin MJ, editor. Principles and practice of mechanical ventilation. New York (NY): McGraw Hill; 1994; 967-1003.
15. Gerson G. Preoperative respiratory function tests and postoperative material. Br J Anaesth 1969;41:967.

和 文 抄 録

原著

陽圧換気下、呼吸器系メカニクスにおよぼす加齢の影響並びに至適設定一回換気量の検討

刈羽郡総合病院麻酔科
松本克平

目的：全身麻酔下、陽圧換気時の呼吸器系メカニクス（呼気1回換気量：Ve、吸気時最大気道内圧：PIP、呼吸器系コンプライアンス：compliance）ならびにPETCO2の変化を若年、壮年、老年者で比較し、加齢による至適設定1回換気量（Vm）の検討を行った。

方法・成績：加齢によりVeの有意の上昇、PETCO2の有意の低下が見られた。壮年、老年者間でVm 8ml/kgと10ml/kgにVeの有意の低下がみられた。complianceは若年、老年者間でVm 13ml/kgで有意の上昇がみられ、若年者でVm10ml/kgと13ml/kg間に有意の低下、老年者でVm10ml/kgと13ml/kg間に有意の上昇が見られた。PETCO2は壮年、老年者間でVm 8ml/kgで有意の減少がみられた。

結論：以上より、老年者では初期一回換気量設定としてVmを13ml/kgとするのが10ml/kgとするより若壮年者にくらべ換気条件として有利であると思われた。

キーワード：呼吸器系メカニクス、一回換気量、加齢