An Analysis of Flow Volume Curves during Artificial Ventilation

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Expiratory flow-volume curves during artificial ventilation (FV-av) were analyzed in 48 patients undergoing general anesthesia. They were divided into 4 groups according to preoperative respiratory disorders; obstructive type (group 1), restrictive type (group 2), small airway disease (group 3) and normal control (group 4). Expiratory flow rates and volumes during artificial ventilation were plotted on an X-Y recorder to calculate $\dot{V}_{50}/\dot{V}_{25}$, mean time constant ratio (MTCR), obstructive index (OI) and slope ratio (SR). FV-av values were compared among groups. FV-av values in groups 2 were significantly higher than those in group 4. The values in group 1 and those in group 3 were not significantly different from those in group 4. FV-av values may reflect restrictive respiratory dysfunctions but they are not sensitive enough to detect obstructive lung disease. (Key words: flow volume curve, artificial ventilation, monitoring)

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Maximum effort flow volume curves (MEFV) are well known to reflect small airway obstruction sensitively. Recently flow volume curves under artificial ventilation, which appear as FV-av on this paper, also have come to be known as useful respiratory parameters[1–3]. In order to know the value of FV-av, we examined the correlations between Fv-av values and preoperative respiratory functions in patients undergoing general anesthesia.

The protocol was approved by the Ehime University Ethical Committee and informed consent was obtained from each patient.

We studied 48 patients undergoing elective surgery under neuroleptanesthesia. The patients were divided into 4 groups according to types of preoperative respiratory disorders; obstructive type which had $FEV_{1.0\%}$ less than 70% (group 1), restrictive type with %VC less than 80% (group 2), smalll airway disease which had $\dot{V}_{50}/\dot{V}_{25}$ exceeding 3.0, normal $FEV_{1.0\%}$ and %VC (group 3), and control group with normal respiratory function values (group 4).

The patients were in the supine position paralyzed with i.v. vecuronium (0.1 $mg \cdot kg^{-1}$) and were intubated with a cuffed endotracheal tube. Artificial ventilation was instituted with a venti-

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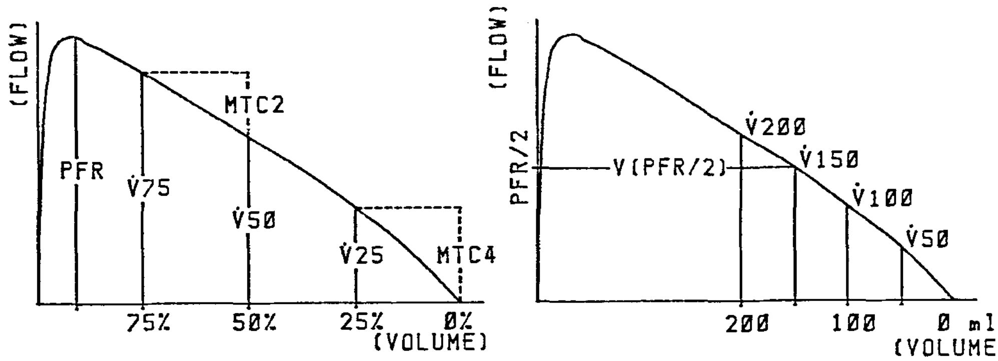

PARAMETERS
1. Peak Flow Rate (PFR)
2. $\dot{V}_{50}/\dot{V}_{25}$
3. MTCR=MTC2/MTC4
4. Obstructive Index (OI) = tidal volume/V (PFR/2)
5. Slope Ratio (SR) = $(\dot{V}_{200}-\dot{V}_{100})/(\dot{V}_{150}-\dot{V}_{50})$

Fig. 1. Flow volume values during artificial ventilation (FV-av)

lator (Servo 900C, Siemens-Elema) at an F_{IO_2} of 0.4 with a tidal volume of 8 ml·kg^{-1}, a rate of 12/min, and an I/E ratio of 1/3. Expiratory flow rates and volumes during artificial ventilation were measured with a respiratory flowmeter (RF-2, Minato ME^R) and plotted on an X-Y recorder to calculate FV-av values. These values included peak flow rate (PFR), $\dot{V}_{50}/\dot{V}_{25}$, mean time constant ratio (MTCR), obstructive index (OI) and slope ratio (SR). MTCR was the ratio of the slope between $\dot{V}_{75}$ and $\dot{V}_{50}$ to the slope between $\dot{V}_{25}$ and end-expiration. OI was the ratio of the tidal volume to expiratory volume at the time when the flow rate was half of PFR[4]. SR was the ratio of the slope between $\dot{V}_{200}$ and $\dot{V}_{100}$ to the slope between $\dot{V}_{150}$ and $\dot{V}_{50}$. $\dot{V}_{200}$, $\dot{V}_{150}$, $\dot{V}_{100}$ and $\dot{V}_{50}$ were the flow rates at the time when 200, 150, 100 and 50 ml of volumes were left in the lung, respectively, which still needed to be expired[1,2] (fig. 1).

Preoperative respiratory function values and FV-av values were compared among groups using one-way analysis of variance (ANOVA) with Bonferroni's multiple comparison. Statistical significance in this study was accepted as $P < 0.05$.

Mean values for age in group 2 was significantly higher than that in group 4. Significant differences between groups were observed in preoperative $FEV_{1.0\%}$, %VC and $\dot{V}_{50}/\dot{V}_{25}$ (table 1). As for FV-av values, $\dot{V}_{50}/\dot{V}_{25}$ and MTCR in group 2 were significantly higher than those in group 4. $\dot{V}_{50}/\dot{V}_{25}$, OI and SR in group 1 were also higher than those in group 4, however the differences were not statistically significant. None of the FV-av values were significantly different between groups 3 and 4 (table 2).

Recently, it is reported that FV-av has useful informations in estimating respiratory function in patients requiring artificial ventilation[1-3]. However, the value of this method has not been well appreciated yet, and we have no standardized application method of FV-av to evaluate respiratory function.

$\dot{V}_{50}/\dot{V}_{25}$, MTCR and OI are indices to evaluate the shape of MEFV. The higher the values are, the more serious is the airway obstruction. In this study we applied these indices both on MEFV and on FV-av. We also calculated SR, which had been advocated by Katsuya et al[2]. to evaluate FV-av. As we reported previously, changes in ventilatory mode can change FV-av

Table 1. Patients' characteristics and preoperative respiratory function values

groups	age (yrs)	sex (M/F)	$FEV_{1.0\%}$	%VC	$\dot{V}_{50}/\dot{V}_{25}$
1) Obstructive type	64.8 (12.6)	8/4	68.8** (9.9)	98.3 (10.8)	2.48 (0.88)
2) Restrictive type	69.1* (15.5)	7/5	78.9* (9.8)	71.4** (10.5)	3.21 (0.76)
3) Small airway disease	58.4 (15.0)	10/2	83.3 (5.8)	99.6 (12.7)	3.94** (0.92)
4) Control	48.3 (17.7)	5/7	89.4 (6.5)	100.6 (12.7)	2.13 (0.48)

mean (SD), $^{*}P < 0.05$, $^{**}P < 0.01$ between the control values.

Table 2. Flow-volume values during artificial ventilation

groups	$\dot{V}_{50}/\dot{V}_{25}$	MTCR	OI	SR
1) Obstructive	1.65 (0.12)	0.58 (0.08)	1.68 (0.28)	1.02 (0.28)
2) Restrictive	1.79 (0.23)*	0.81 (0.38)*	1.76 (0.36)	0.96 (0.20)
3) Small airway	1.60 (0.19)	0.61 (0.14)	1.58 (0.11)	0.89 (0.10)
4) Control	1.56 (0.12)	0.54 (0.12)	1.51 (0.11)	0.80 (0.19)

mean (SD), $^{*}P < 0.05$ between the control values.

values significantly[5]. Therefore the patients in our study were ventilated with the same ventilator settings to compare their FV-av values.

As a result, FV-av values were worse in those with restrictive respiratory dysfunction. A decrease in lung-thoracic compliance (C_{TOTAL}) accompanied with restrictive lung disease is suggested to be the mechanism for it. We speculate that in those with small C_{TOTAL} initial expiratory flow rate is large, while end-expiratory flow rate is small during artificial ventilation. Thus the curve is changed to make FV-av values higher. In order to confirm this speculation, simultaneous measurement of C_{TOTAL} and flow-volume curves is required.

FV-av values in patients with obstructive lung disease were not significantly higher than those in control group. In contrast with MEFV, FV-av is limited within a tidal volume range. This may be the reason why FV-av was not sensitive enough to detect large or smal airway obstruction in this study.

It is obvious that FV-av has some merits as a respiratory monitor; reproducibility and availability even for patients on ventilator. However, the diagnostic value of FV-av was only partially demonstrated in this study. We believe it worth further studying in order to clarify the mechanism from which the curves result, and to make the test more sensitive to detect existing respiratory diseases.

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