A Consideration on the New Classification of Latest Lung Ventilators

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Concerning the classification of ventilators, Elam (1958), Fairley (1959), and Hunter (1961) reported some simple ones such as pressure limited, volume limited, pressure preset, or volume preset models. Mapleson (1969) also classified them by the generating force or cycling together with the above-mentioned types.

The latest ventilators applicable to patients with respiratory failure usually have some cut-off function at high airway pressures as a safety measure. Therefore, all of them belong to the pressure limited type. Some ventilators are of two types such as the time cycled and pressure cycled type.

Therefore, we attempted to classify ventilators into four groups, i.e. the time cycled, volume cycled, pressure cycled and selective time-pressure cycled types according to the fundamental mode of ventilator function, the so-called change of cycling from inspiration to expiration. Each group was further divided into subgroups according to preset dials such as respiratory rate, I/E ratio, inspiration time, expiration time, tidal volume, flow rate and airway pressure.

By this method, fifty one ventilators on the market in Japan can be classified without overlapping. Although this clssification seems complex, it will be of use in selecting ventilators by emphasizing preset dials according to the user's needs, ability or both. (Key words: lung ventilator, new classification, pre-set dial, time-pressure cycled type)

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With the progress of respiratory control techniques, lung ventilators are playing a leading role and have become equipped with multiple functions. Many types of ventilators have been put on the market in keeping with increases in patient's needs. In practice, consideration must first be given to the basic type.

Many kinds of classification complicate the matter. A major division into the pressure preset and volume preset type according to the patient's requirements has been accepted so far, but is too general to be practical. There is another more up-to-date classification into three types: time cycling, volume cycling and pressure cycling, based on the concept of cycling according to the inspiration-expiration-conversion mode. Table 1 summarizes every kind of ventilator now on sale in Japan, especially those used for respiratory insufficiency. They are classified according to the three cycling types and the mode of the fundamental preset dials on the ventilator panel. This indicates that some ventilators are found in all groups or may belong to one or the other by a change of the dial.

We attempted to devise a more conve-

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nient and appropriate classification without overlapping to facilitate selection of the most suitable instrument from among the 51 in table 1. This is the aim of this report.

Method

The main lung ventilators for the treatment of respiratory insufficiency in table 1 were divided into groups according to the basic function of cycling, i.e., the trasition from the end-inspiratory to the expiratory phase. Each group was further divided into subgroups according to the fundamental preset dials on the ventilator panel to obtain a clear-cut classification without overlapping.

Results

In classifications by cycling, three groups have been used so far: time cycling, volume cycling and pressure cycling. Table 1 shows that overlapping occurs only in a combination of the time and pressure cycling groups and none in the others. Therefore, the problem of overlapping can be solved if a switchover group between time and pressure cycling is separated as a fourth group.

Each group was further subdivided according to the preset dials, which are determinants of each cycling among the principal parameters of ventilation and of preferential use at the trasition from the end-inspiratory to the expiratory phase; for example, "ventilatory frequency", "inspiratory time", "expiratory time" and "I/E ratio" for time cycling; "tidal volume" for volume cycling; and "airway pressure" for pressure cycling. Table 2 shows a clear-cut classification without overlapping.

Except for such determinant dials, each ventilator has preset dials which may often be altered in keeping with certain changes in the patients state or respiratory conditions, and a further division may be possible according to such preset dials. This new classification may be of practical use in automatically selecting the most appropriate type in each case taking into account the patients background, control capacity in the ward, medical staff arrangements and user's preference concerning cycling or deals. The

Table 1. List of latest ventilators for respiratory failure

Ventilators	cycling (I→E)	standard presetdial on panel: volume V_T	volume $\dot{V}_E$	frequency f	time T_I	time T_E	time I/E	flow $\dot{V}_I$	pressure Paw	control	required gas source for power and F_{IO_2} control
Acoma AR-2000D	Volume	■		■						Electric	O_2
Acoma ARF-850E	Volume	■		■				■		Electric	O_2
Acoma ARF-900E	Volume	■		■			■			Electric	O_2
Acoma ARF-1500E	Volume	■		■				■		Electric	O_2
Acoma ART-1500	Volume	■		■			■	■		Electric	O_2
Acoma ART-2000	Volume	■		■	■↔		■↔			Electric	O_2+Air
Aika EVA1200A	Volume	■		■			■			Electric	O_2
Aika CLV50	Volume	■		■			■			Electric	O_2
Aika EVW-1800weany	Volume	■		■	■					Electric	O_2+Air
Bear-1	Volume(m)	■		■				■		Electric	O_2
Bear-2	Volume(m)	■		■				■		Electric	O_2
Bear-5	Volume(m)	■		■	■			■		Electric	O_2
Bennett-7200	Volume(m)	■		■				■		Electric	O_2+Air
Bennett-MA 1	Volume	■		■				■		Electric	O_2+Air
Bennett-MA2+2	Volume	■		■				■		Electric	O_2
Bennett-PR 1	Time/Pressure			■↔				■	■↔	Pneumatic	O_2
Bennett-PR 2	Time/Pressure			■↔		■		■	■↔	Pneumatic	O_2
Bio-Med IC-2A	Time				■	■		■		Pneumatic	O_2+Air
Bird Mark 7	Pressure					■		■	■	Pneumatic	O_2
Bird Mark 8	Pressure					■		■	■	Pneumatic	O_2
Bird Mark 7A	Time/Pressure					■↔		■	■↔	Pneumatic	O_2
Bird Ventilator7001M	Time/Pressure					■↔		■	■↔	Pneumatic	O_2
Drager EVA	Volume	■		■			■	■		Electric	O_2+Air
Drager SIMV	Volume		■	■						Electric	O_2+Air
Drager UV-1	Volume	■		■				■		Electric	O_2+Air
Engstrom 2000	Volume		■	■			■			Electric	O_2+Air
Engstrom ERICA	Volume	■		■			■	■		Electric	O_2+Air
Hamilton Veolar	Volume(m)	■		■	■	■				Electric	O_2+Air
Kimura K550	Volume	■				■		■		Electric	O_2
Kimura KE101	Volume	■				■		■		Electric	O_2
Kimura KE202S	Volume	■				■		■		Electric	O_2
Kimura KE303S	Volume	■				■		■		Electric	O_2+Air
Kimura KE303SB	Volume	■				■		■		Electric	O_2+Air
IMI CV-3000	Time				■	■		■		Electric	O_2+Air
IMV-Bird	Time				■	■		■		Pneumatic	O_2+Air
Life-Products LP-4	Volume	■		■	■					Electric	O_2
Medishield CPU-1	Time/Pressure				■↔	■		■	■↔	Electric	O_2+Air
Newport Ventilator E100	Time/Pressure			■↔	■			■	■↔	Electric	O_2+Air
Origin CRV2000D	Volume	■		■						Electric	O_2
Origin CRV2000 M-2	Volume	■		■						Electric	O_2
Siemens Servo 900B	Volume(m)		■	■			■			Electric	O_2+Air
Siemens Servo 900C	Volume(m)		■	■			■			Electric	O_2+Air
(for Infant)											
Acoma ICV-60	Time			■	■			■		Electric	O_2+Air
Baby Bird	Time			■	■			■		Pneumatic	O_2+Air
Bear Cub	Time			■	■			■		Electric	O_2+Air
Biomed MVP-10	Time				■	■		■		Pneumatic	O_2+Air
Bp-200	Time			■	■			■		Electric	O_2+Air
Drager Baby-Log-1	Time				■	■		■		Pneumatic	O_2+Air
IMI CV-200	Time				■	■		■		Pneumatic	O_2+Air
Sechrist	Time				■	■		■		Electric	O_2+Air
Tohitsu PB800	Time			■			■	■		Electric	O_2+Air

(Symbols) V_T : tidal volume, f : ventilatory frequency, T : inspiratory time, $\dot{V}_E$: minutes volume, $\dot{V}$: inspiratory flow rate, T_E : expiratory time, I/E : I/E ratio, Paw : airway pressure.

Table 2. New classification of ventilators

⟨cycling (I→E)⟩		⟨Order of Priority of Preset-dial on Panel⟩	⟨Ventilators(48)⟩
Volume cycled	None Measured	V_T f	Acoma AR2000D, Origin CRV2000D, Origin CRV2000M2,
		V_T f T_I	Aika EVW1800Weany, Life Product LP-6,
		V_T f $\dot{V}_I$	Acoma ARF850E, Acoma ARF1500E, Bennett MA1, Bennett MA2+2, Dräger UV-1,
		V_T f I/E	Aika CLV50, Aika EVA1200A
		V_T f I/E $\dot{V}_I$	Acoma ART1500, Dräger EVA, Engström ERICA,
		V_T T_E $\dot{V}_I$	Kimura K350, KE101, 202S, 303S, 303SB,
		$\dot{V}_E$ f	Dräger SIMV,
	Measured	V_T f $\dot{V}_I$	Bear 1, Bear 2, Bennett 7200,
		V_T f T_I $\dot{V}_I$	Bear 5,
		V_T f T_I T_E	Hamilton Veolar
		$\dot{V}_E$ f I/E	Engström 2000, Siemens Servo 900B, Siemens Servo 900C,
Time cycled		f T_I $\dot{V}_I$	Acoma ICV60, Baby Bird, Bear Cub, Bp200,
		f I/E $\dot{V}_I$	Tohitsu PB800,
		T_I T_E $\dot{V}_I$	BioMed IC-2A, IMI CV3000, IMVBird, BioMed MVP-10, Dräger Baby-Log 1, IMI CV200, Sechrist,
Time/Pressure cycled	Low Generate Pressure	Paw↔f V_I	Bennett PR1
		Paw↔T_E $\dot{V}_I$	Bird Mark 7A, Bird Ventilator 7001M,
		Paw↔f T_E $\dot{V}_I$	Bennett PR2,
	High Generate Pressure	Paw↔f T_I $\dot{V}_I$	Newport Ventilator E100,
		Paw↔T_I T_E $\dot{V}_I$	Medishield CPU-1
Pressure cycled		Paw T_E $\dot{V}_I$	Bird Mark 7, Bird Mark 8,

⟨Symbols⟩ Measured : inspiratory volume measured (Servo controlled)
High Generate Pressure > 100cmH_2O
V_T : tidal volume, T_I : inspiratory time, $\dot{V}_I$: inspiratory flow rate
$\dot{V}_E$: minutes volume, T_E : expiratory time, Paw : airway pressure
f : ventilatory frequency, I/E : I/E ratio, ... : for infant

required gas source for power and F_{IO_2} control are recorded in an abbreviated form next, to each ventilator. In this classification we omitted items common to all ventilators such as PEEP, IMV or the minimum essential safety measures.

Discussion

Many kinds of artificial ventilators are now in use and differ with respect to mode of action, mechanism and composition. Classification of these ventilators has been attempted in various ways. Most of them concern the inspiratory phase alone, neglecting the expiratory phase, except for whether the pressure generated will be one of three categories: supraatmospheric, atmospheric and subatmospheric. For example, ventilators were classified by flow and pressure according to the generating object, by the mode of cycling and lastly by the extent of the effect induced by this power. Early attempts were reported by Elam et al. (1958)[1], Fairley (1959)[2], and Hunter et al. (1961)[3]. These classifications were simply based on what is applied to the airways, i.e. a general division into volume and pressure. Elam et al. postulated the following classification: volume limited with pressure variable and pressure limited with volume variable. Fairley's classification was volume constant with pressure variable and pressure constant with volume variable. Hunter et al. used volume preset and pressure preset types. Because they were very simple, they were widely used. There are, however, some instruments which belong to both groups or those partly adapted to one of the other groups. Recently almost all ventilators have the safety measure which cuts off inspiration at a certain level of airway pressure and changes over to expiration whether preset or not. In this sense all types are pressure limited, which must be strictly differentiated from that generally used so far in the classification.

Mapleson (1959 to 1969)[4,5] reported a classification by low or high pressure gas drive from the instrument to the lung. The former is a pressure generator which is affected. to a considerable extent by the properties of patient's lungs, and the latter is a flow generator hardly affected by such properties. This simple classification cannot draw the line between the pattern of driving force and the flow pattern in the airways which are different. Therefore, ventilators were further divided into three groups according to the differences in cycling at the end inspiratory point.

Norlander (1964)[6] described a detailed classification by the driving force of the instrument. He used pressure for a parameter, showing how the driving force was conducted through the airways. He divided ventilators into two groups according to a constant or a gradually increasing pressure during the inspiratory phase, and further divided each into two subgroups, but this was of no avail since some pressures gradually decreased and the mechanism at the end-inspiratory point was not included.

Analyzing the properties of artificial ventilators from three different point of view, the British Standards Institution (1964)[7] reported a classification of each instrument by three items. The ISO has accepted this proposition since 1968. Only the power of each instrument was not included.

Grogono (1972)[8] proposed a classification by stability or variability of minute ventilation, tidal volulme and inspiratory flow volume. Although stable in the normal state, they may become variable under pathological conditions. Moreover, there is no classification according to the mode of cycling, inspiratory flow curve and relative strength.

Baker et al. (1974)[9] proposed a classification by flow control and force with respect to the swithover of peak pressure by the ventilator and applied it to various ventilators.

Sawa (1970)[10] presented a new classification by three cyclings and preset values in combination. The variety of classifications reveals the impossibility of finding a simple and accurate expression of the overall function of artificial ventilators.

The classification in table 2 is primarily aimed at the user's convenience in operating ventilators; at first they are divided into four groups by cycling and then further subdivided by the order of priority of the fundamental preset dials on the panel of the ventilator. This classification may be of use in the selection of ventilators.

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