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Mechanical Ventilation in Prehospital Life Support

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Mechanical ventilation in the prehospital setting is used primarily for the treatment of acute respiratory failure (ARF), which may occur *de novo* as a result of illness or injury, or superimposed upon chronic respiratory insufficiency. Regardless of its cause, the immediate goal of therapy in ARF is the maintenance of adequate tissue oxygenation and pH.

The physiology of ventilation is considered by Gunderson in this issue. Standard definitions of ARF focus on blood gas values, which are unavailable to field personnel. Recognition of the need for artificial ventilation rests therefore, on clinical assessment. Physical signs such as restlessness, tachycardia, tachypnea, sweating, and cyanosis are indicative of hypoxia. Hypercarbia is suspected when somnolence develops. When doubt exists, it is preferable to err on the side of intervention, as hypoxia results in rapid and irreversible damage.

Once the airway is established, ventilation may commence. Several types of positive pressure ventilation units are currently available. Volume cycled units deliver a specific tidal volume at a specific rate, unless the pressure exceeds the set point of the pop-off valve. Pressure cycled units deliver gasses until a given airway pressure is reached, at which point inspiratory flow ceases and expiratory flow begins (2). Pressure cycled ventilators are not recommended for use in resuscitation or in cases with abnormal lungs (3).

Several commercial positive pressure, volume cycled automatic ventilators are on the market. They have the advantage of freeing personnel for other tasks (as opposed to bag-valve-mask units or demand valves). They can deliver 100% oxygen and may be used in patients of all sizes, infant to adult.

Mechanical ventilation may assume several modes (Figure 1):

1. Controlled Mechanical Ventilation (CMV): the ventilator delivers the preset tidal volume at the preset rate regardless of the patient's intubation effort
2. Assist Control Mechanical Ventilation (ACMV): the machine responds to the patient's respiratory efforts, but will deliver controlled ventilation in their absence.
3. Intermittent mandatory ventilation (IMV): this is essentially spontaneous ventilation with superimposed controlled ventilation.
4. Synchronized intermittent mandatory ventilation (SIMV): this mode combines spontaneous and assisted ventilation.

The bag-valve device permits manual ventilation in any of the above modes. It is inexpensive, easy to use, reliable and can deliver inspired oxygen contrations approaching 100% with a reservoir. Its primary disadvantage is that it is labor intensive, requiring a full time operator.

In an attempt to facilitate ventilation with 100% oxygen, the demand valve, a high flow manually triggered device permitting all four modes was developed. However, these devices may produce inadequate ventilation in the presence of high airway pressure, like the pressure cycled devices. This catastrophe may be unapparent to the operator (4).

A current third generation of prehospital ventilation units are now on the market. In this article we will discuss, as examples, the specifications for: the Impact *Univent®*, Life Support Products' *Autovent 2000®*, and the Ohmeda *Logic 07®*.

The *Univent*, Model 700 delivers controlled ventilation (CMV) only with adjustable tidal volumes from 0-1250 milliliters at fixed rates which vary from 12 to 20, depending on whether the adult child or infant setting is selected. The inspired oxygen concentration is fixed at 1.0 (5).

The LSP *Autovent* 2000 functions as an IMV ventilator, reverting to CMV in the non-breathing patient. The rate can be set from 8 to 20 breaths per minute, and the tidal volume is independently adjustable from 400 to 1200 milliliters. It also delivers 100% oxygen (6).

The Ohmeda *Logic 07* offers rates from 10-20 breaths per minute and tidal volumes which are set with a minute volume control (minute volume / respiratory rate = tidal volume). It functions in the IMV and CMV modes as does the LSP *Autovent*. Unlike the *Autovent* however, spontaneously breathing entrains room air and decreases the inspired oxygen concentration by a variable and uncertain amount. The inspired oxygen concentration during controlled breathing can be adjusted to 0.5 or 1.0 (7).

Any of the above devices will function acceptably in

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CPR, except the demand valve and pressure -cycled ventilators. Thus, depending on individual preference and budget, the bag valve device or any of the three commercial volume cycled ventilators may be used. In the spontaneously breathing patient requiring ventilatory assistance, the units offering IMV capability may be more useful, although known inspired oxygen concentration during spontaneous breathing is desirable. Finally, the use of inspired oxygen concentrations less than 1.0 in the ARF patient may be questionable if blood gas measurements such as pulse oximetry are not available. Lower inspired oxygen concentrations could presumably be used in transporting stable patients between facilities.

Standard settings for emergency ventilation include tidal volumes of 10-15 ml/kg and rates of 8 to 10 per minute for adults and up to 20 ml/kg for children and infants (8). This should maintain normocapnia. When hyperventilation is desired (e.g., for patients with increased intracranial pressure), this rate must be higher. Since arterial blood gasses and end-tidal capnography are not generally available in the prehospital setting, these "rules of thumb" must be relied upon.

To avoid barotrauma, volume cycled ventilators normally feature "pop-off" valves that vent a portion of the tidal volume to the atmosphere when a pre-set level of airway pressure is exceeded. The *Univent* can be set to a pop-off at 60 or 80 cm H_2O. The *Autovent* has an alarm which sounds above 45 cm H_2O, and the *Logic 07* may be adjusted from 20 to 90 cm H_2O pressure limits. Higher airway pressures than normal may be required in patients with cardiogenic pulmonary edema, ARDS, pulmonary contusion, bronchospasm, or other disorders.

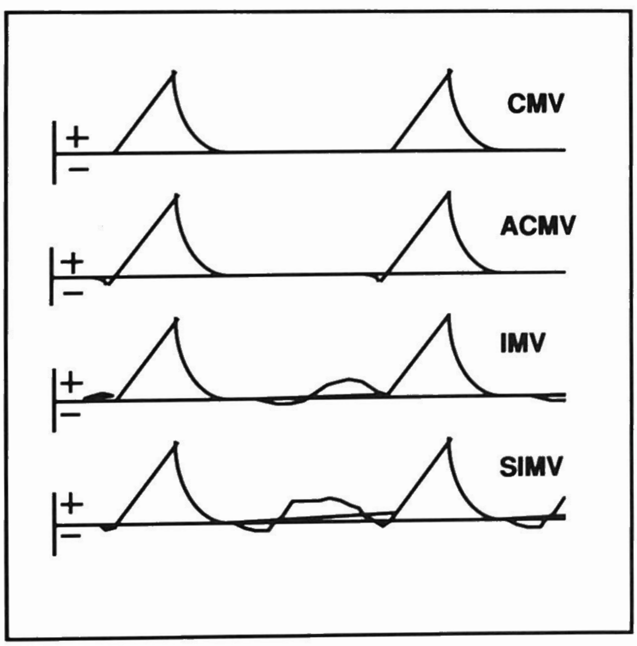

Figure 1 - Ventilatory Mode Waveforms - The pressure waveforms of the most common ventilator types are shown. With controlled mechanical ventilation (CMV) the ventilator delivers a breath regardless of patient effort. In assist-control mode (ACMV), the ventilator is triggered to deliver by the patients' inspiratory effort. Intermittent mechanical ventilation (IMV) will interpose mechanical breaths in addition to the patients' own breaths. Synchronized intermittent mechanical ventilation (SIMV) will allow some totally spontaneous breaths and the mechanical breaths are also triggered by spontaneous inspiratory effort.

Positive end expiratory pressure (PEEP) has become popular for treatment of hypoxic states secondary to cardiogenic or non-cardiogenic pulmonary edema (9). Although barotrauma, particularly pneumothorax, is a feared complication of PEEP, the incidence of pneumothorax is no higher in patients treated with PEEP than with mechanical ventilation alone (10). PEEP may also decrease venous return and cardiac output, particularly in the hypovolemic patient. Worsened ventilation-perfusion ratios may also be produced, decreasing arterial oxygen tensions (11). The use of PEEP in the prehospital arena must, therefore, be considered experimental at present.

Prehospital life support personnel, including EMT's, paramedics, and flight crews have an increased spectrum of ventilatory devices at their disposal. Selection of the appropriate devices can facilitate care. Those responsible for these choices should understand their capabilities and limitations, and personnel using them must be thoroughly trained and have periodic retraining.

REFEREE DISCUSSION

(This section was excerpted and edited from the discussion following presentation of this paper at the Protocol Roundtable Symposium on Airway Control and Ventilation, March 2, 1988, Tampa, Florida)

Gunderson: *(Michael R. Gunderson, REMT-P, Palm Harbor Fire Department / Pinellas County EMS; Tampa, FL)* Could you give us some additional comments on use of the manually triggered demand valve? What do you see as the pros and cons of it versus the bag and these other automatic ventilators?

Cobb: We've opened another whole can of worms there. The demand valve, when it first came out, was very attractive to a lot of us. It's simple to use, it's relatively compact, it is manually triggered. However, Dr. Melker and his colleagues in Gainesville (Florida) have demonstrated some real problems with the demand valve - that you may be delivering virtually no tidal volume with that device and you may not even know it. For that reason, I think the demand valve is best deleted from our inventory of equipment and I think that this newer generation of devices should replace the demand valve, really. I think it's just too fraught with problems.

Gunderson: Am I correct in assuming that the reason why they were finding inadequate tidal volumes from the demand valve was that when the pop-off valve was actuated, the operator wasn't aware of it. I notice the sound - it's a recognizable sound. When the pop-off valve isn't actuated and I'm getting chest rise, I haven't seen any problems with it. When the pop-off valve does start to actuate, I know that I can no longer use that device. The thing I like about the demand valve is it is small, it does deliver 100% oxygen, and it does put an upper limit on peak airway pressure. I've always been concerned in situations where I have to use less than optimally trained people to assist me on a code, and sometimes they end up on the airway. I'm concerned about a big, burly fireman who is handling the airway - maybe that isn't what I should do, but sometimes that happens. I'm worried that they can be over-aggressive in how fast they squeeze the bag and potentially generate dangerously high peak inspiratory pressures with the bag. At least if they're using the demand valve, there is an upper limit on it, so long as I listen for that pop-off valve actuation.

Cobb: To speak from an idealistic or ivory tower viewpoint, I think that the ideal solution to that problem is proper training of personnel. And again, that comes back to basics with any type of equipment that we use. We have to have well trained personnel who completely understand the equipment they are using - its limitations, and whatever problems can be generated with that equipment. I realize sometimes it's necessary in a field setting to use untrained or relatively untrained personnel because that's all that's available, but I think more training of personnel, if it can possibly be accomplished, is the best way to approach that problem. There is no piece of equipment that is completely idiot-proof.

Gunderson: How about if the demand valve was modified so that when the pressure relief valve becomes actuated, it would have a more distinct noise. Or, you could have an adjustable airway pressure relief valve, perhaps even distinct or separate from the device itself, just like hooking up an in-line manometer or respirometer?

Cobb: You could do that, but the demand valve is fairly labor intensive. Somebody has to sit there and push that button. And with this new generation of ventilators on the market, I just really don't see the need for it. I think with the newer more mechanized ventilator devices you can get better results more easily. So I don't really see the advantage.

Brown: *(Michael Brown, REMT-P, Hillsborough County EMS; Tampa, FL)* The demand valve still is about one tenth the cost of the average transport ventilator. The American Heart Association's latest report on emergency cardiac care and CPR did derive standards that are applicable to demand valve devices, but unfortunately at the present time they have only been incorporated into these transport ventilators. This includes a reduced flow rate of 40 L/min and the incorporation of a distinctly audible proximal airway pressure pop-off valve.

Cobb: If the improvements were made - But again, the reservations I have are based on the currently available equipment. The ones that are available now I would not recommend for use.

Walters: *(Cline Walters, Aero Products; Longwood, FL)* There are two situations that are being overlooked here with the demand valve. The demand valve you (Mr. Gunderson) currently use in your department, is it gated down to 40 L/min or is at the 100 L/min flow rate?

Gunderson: I believe it's still set at 100 L/min..

Walters: At the 100 liter per minute flow rate, we note problems with barotrauma, intracrainial pressure, and you could even run into ventilation/perfusion mismatching with that device at that setting. When you take a new generation device and gate it down to the JAMA recommended 40 L/min flow rate, you've got to look at what's going on there. Given your formula of 10-15 ml/kg, a seventy kilogram patient on the low end (10 ml/kg) is going to have a tidal volume of 700 ml. Now that's making no compensation for dead space or whatever. On the high end (15 ml/kg), its a tidal volume of 1,050 ml. Now let's take a real world patient, somebody like me. That would be a 110 kilogram patient times the low end, 10 ml/kg, is going to equal 1100 ml per breath. The demand valve, at 40 L/

min, is actually incapable of delivering that, because in the CPR setting we're limited now to a maximum inspiratory period of 1.5 seconds. The American Heart Association recommends pausing for up to a one and a half second period for ventilation time. At 40 L/min, that's 0.66 liters per second. Multiplied by one and a half seconds gives you less than a liter of gas - which is totally inadequate for a patient my size, not even compensating for mask leakage, dead space, things like that. So you've got to look at the demand valve from that aspect also.

Cobb: I think there are so many problems with the demand valve, that's a good point, and to me, it's hard to recommend it.

Scarberry: *(Eugene Scarberry, Respironics, Inc.; Monroeville, PA)* These things are very excellent points. I respectfully disagree with Dr. Melker. I know he has some strong biases against demand valves. In a face mask situation, where I loose a lot of tidal volume, the demand valve is not a volume limited device, it's a pressure safe device. It gives me the option of insuring reasonable tidal volume if I'm doing what I'm supposed to be doing, which is monitoring chest rise. With a bag valve resuscitator, to get 1200 cc stroke volume every time with one hand? - its also not real. So you're saying you can't use demand valves and you're saying the patient really needs a 1200 cc tidal volume, you're not going to even get close to that without a cuffed tube, so that's not going to work. You've just taken away the two existing devices.

Boothby: *(Charles Boothby, DO, Medical Director, Pasco County EMS; New Port Richey, FL)* If you haven't got a fixed rate, you can ventilate somebody with a bag-valve-mask just as fast as you can squeeze a bag to make up. So you've got the same tidal volume, the same minute rate.

Scarberry: The problem is if you take 500 cc's stroke volume and you do it twenty times a minute and then you take a 1000 cc's stroke volume and you do that ten times a minute you do not get alveolar ventilation that's equivalent.

Cobb: You doubled your dead space ventilation.

Scarberry: So that what you're finding is that the ideal breath is a large slow breath, fewer times a minute, rather than a high-frequency breath of short volume. Just doubling the ventilation rate is not going to buy you or necessarily improve alveolar ventilation.

Kinsey: *(Dave Kinsey, REMT-P, Clearwater Fire Department / Pinellas County EMS; Clearwater, FL)* I think that the other thing we're overlooking here is Stewart's study up in Pittsburgh. What were the tidal volumes they were achieving with a mask? It was not but 300 to 500 cc's.

Scarberry: In some cases, it was up to 800 cc's.

Kinsey They didn't really have an explanation as to why one person could achieve 800 cc and another person only 300 cc.

Gunderson: Did they look at the hand size?

Kinsey: They looked at the hand size. Unless we hired people with size 9 hands —

Cobb: Only basketball players need apply.

Kinsey: We're lucky to get 500 ml of ventilation on a bag. Realistically in the field, we're talking 300 ml.

Cobb: Again I think this points out the advantage of this new generation of transport ventilators is that they can reliably deliver large tidal volumes at reasonable rates. I think that they are currently the only devices available for prehospital ventilation that can do that.

Nelson: *(Joe A. Nelson, DO, Emergency Department, Carrollwood Community Hospital; Tampa, FL)* But you can't use them for cardiac arrest situations.

Cobb: Actually I don't mind doing that. I have just left the patient on the ventilator during a code, as long as the pop-off valve is turned up high enough. I don't mind that because I'm one of these people that doesn't believe in interposing ventilations between compressions. I realize that this is controversial.

Scarberry: But it assumes a protected airway.

Cobb: Yes - I've always intubated these people while they were on a ventilator or prior to their arrest or whatever. But let's face it, the vast majority of the time, either in the field or in the hospital, the patient is intubated very quickly after cardiac arrest. So in that setting, I don't feel that it's necessary to interpose the ventilations between compressions. I feel that there are some potential advantages of using other modes of ventilation. It's up to the individual clinician's preference or your protocols, depending on where you are. I think that the use of mechanical ventilators is perfectly acceptable in a CPR setting provided they have appropriate pop-off valve settings and that they're volume cycled rather than pressure cycled devices.

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ERRATA

In the January-March, 1988 issue, the proceedings for the Protocol Roundtable on Acute Congestive Heart Failure *(Protocol Roundtable: Acute Congestive Heart Failure. Tampa Bay EMS Journal 1(3):62-70, 1988)* contain errors in Figure 6 on page 69, listing items for the model protocol. Most significantly, the section on furosemide and the dosage for aminophylline were omitted. The corrected contents for the figure, with underlined changes, are shown below.

1. General Supportive Care
   - ECG monitoring
   - Venous access (IV D5W, t.k.o. or reseal)
   - History, physical assessment
2. Patient Positioning - Upright
3. High Flow O_2
4. Positive Pressure Ventilation
5. Intubation, if any of the following:
   - Decreased level of consciousness
   - Decreased ventilation (RR>36 or <10)
   - Hypotensive
6. PEEP (intubated cases)
   - 5-10 cm. H_2O
7. Nitrates
   - 2.5 mg. <u>isosorbide</u> or 0.4 mg. nitroglycerin, <u>sublingual</u>
8. Morphine
   - 2.5 mg. increments @ 5 min. intervals until diastolic 70-100 or systolic 120-160
9. <u>Furosemide</u>
   - <u>40 mg. (80 mg. if on oral furosemide); Repeat at double dose, if needed</u>
10. Aminophylline
    - <u>250 mg. in 50 ml. over 30 min.</u>
      <u>(if not on oral theophylline products)</u>

We apologize for the omission and any confusion it may have caused. Despite the very limited time and resources under which we produce the Journal, we make no excuses for such errors - We take our responsibility for the content of this publication very seriously. We appreciate the support of our readers and assure that as we grow, we will continue to improve the composition and academic quality of its contents.

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