LETTERS TO THE EDITOR

SIR:

It was with great pleasure that I read in the current [July, 1966] issue of your journal the article entitled "Respiratory Insufficiency and Its Treatment Following Paediatric Cardiovascular Surgery." My friends in Toronto have continued their exemplary work in the treatment of their little patients. I agree with them that "the Engstrom respirator has several features which make it most satisfactory for ventilating postoperative cardiac patients." Unfortunately, I do not agree with the comments numbered 3 and 4 on page 351. Although the patient may be considered to be in direct communication with the bag, spontaneous breathing between inspiratory phases of the respirator is not always possible. Examination of Figure 3 A & B on page 19 of Engstrom's thesis¹ will illustrate this fact. In Figure 3, Dr. Engstrom has divided the respiratory cycle into 30 parts. In his example there are 20 cycles per minute, each breath being three seconds in duration. The active inspiratory phase covers one third of this time. The curve for "low resistance" inspiration occurs in seven and a half of the one-tenth-second intervals, leaving two and a half one-tenth-second intervals that could be considered part of the expiratory phase that lies within (in the example) the inspiratory phase of the cycle. The bag is then empty after three fourths of a second with low resistance, and after one second with increased resistance. The bag does not start filling until over seventeen of the one-tenth-second intervals have elapsed. This means that in a patient with a low resistance there is one second in which he is connected to an empty bag. In a patient with so-called increased resistance there is about three-quarters of a second in which he is connected to an empty bag. Quite probably the patient could develop enough negative pressure to pull air through the dosing valve which would add extra gas to the system. Although this is possible, a great deal of negative pressure must be developed to accomplish this end. In the illustration provided by Dr. Engstrom in his book, the period from slightly over the seventeenth one-tenth-second interval to the twenty-fifth one-tenth-second interval is listed as filling time for the bag. I believe the negative pressure around the bag is -35 cm. H_2O . This negative pressure is necessary to draw air through the dosing valve into the bag. If the patient inspires during this period he must overcome the negative pressure around the bag in order to remove air from the bag. This leaves one-half second at the end of the expiratory phase when a patient may inhale from the bag without undue resistance. Although the term "undue resistance" has been used, what is "undue" depends on the patient's condition. As inspiration will be through the wet double layer sponge humidifier screen, the patient must draw at least -6 cm. H_2O pressure to move air (on our two machines). Those who are curious can set up the Engstrom instrument, put a mask on, and try to inspire against the machine during the expiratory pause. They will find that it is very difficult to inspire and that they will draw a great negative pressure on the monometer unless they wait until the end of the expiratory pause.

The ventilator is equipped with an "additional inspiration valve." If this is left opened, the patient may inspire without fighting the machine. In this way an additional breath may be inspired without "undue resistance," but again there is some resistance to inspiration because the patient must pull air through the wet foam rubber wick of the humidifier. If the patient does inspire this extra volume, the next breath delivered by the machine will then act like a "sigh." This is non-deleterious; in fact it may be to the patient's advantage. In clinical usage I have the patient "sighed" every fifteen minutes by having the dosing valve turned up to increase the tidal volume at least 50 per cent. Others achieve the same end by having the patient detached from the ventilator and "sighed" with an ambient air breathing unit. In clinical use, I believe that the Venturi system should only be run at enough negative pressure to ensure a zero oesophageal pressure during expiration. In Engstrom's Figure 3 one wonders about the small passive inspiratory flow of gases shown at the end of the "active expiratory phase." The active expiratory phase is correlated with the Venturi effect, so one might consider the chest to be subjected to undue negative pressure in Engstrom's example. Perhaps the passive inspiration is a springback of air into the chest after release of the Venturi. One suspects that this would not be a healthy situation.

Although minute volume and oxygen concentration can be well controlled on the Engstrom machine, the concentration would be still easier to control if there were a reservoir system for the oxygen. If the oxygen is accidentally disconnected from the machine the tidal volume will fall, since there is no way for the machine to compensate for the lack of gas. There is also a flow effect that will make the flow meter readings inaccurate during the negative pressure filling phase of the bag. The system adopted by Mr. J. H. Emerson in his ventilator, that of using an open-ended reservoir, allows more accurate metering of oxygen. It also prevents the catastrophe of a low tidal volume if the oxygen is accidentally disconnected. Another factor affecting accuracy of delivered oxygen concentration is the use of the Venturi with an open "additional inspiration valve." If the Venturi pulls over a few centimetres of negative pressure, air will be entrained at the "additional inspiration valve," diluting any additional oxygen in the inspiratory tubing and over the water in the humidifier.

The Toronto group has used "intermittent controlled ventilation" for weaning their patients from the ventilator. The dyspnoeic index can be modified to the patient on the ventilator. The patient is disconnected from the ventilator and allowed to respire an oxygen-enriched atmosphere (with added humidity). After the patient has become adjusted to breathing on his own, a Wright respirometer is attached to the end of the patient's endotracheal or nasotracheal tube. The minute volume is then measured. The patient is then instructed in maximum breathing. With a great deal of oral encouragement from the physician, a maximum breathing capacity for one minute is measured. If the patient can double his previous minute volume, we find that he can be extubated. If he cannot double it, he is returned to ventilator therapy. This prevents prolonged periods of muscular and physical exhaustion. Blood gas and pH studies confirm that if the patient can double his minute volume in the maximum breathing exercise,

he will maintain a low P_{CO_2} . After extubation the patient is maintained in a high-humidity atmosphere, generally with an ultrasonic nebulizer. Oxygen is added to the atmosphere in a percentage necessary to assure a blood P_{O_2} of 100 to 150. Although a nasotracheal tube assures a patient airway, at times in a small child or infant it may increase respiratory work because the cross-sectional area of the airway is diminished. For this reason, we extubate as soon as possible after the patient is removed from ventilator therapy.

In the small child, there is the added problem of determining an accurate minute and maximum breathing capacity with the Wright respirometer. The commercial model loses sensitivity below a tidal volume of 150 ml. Dr. Conn's group in Toronto has perfected a more sensitive Wright respirometer, but unfortunately it is not commercially available. Drs. Brown, Johnston, and Conn are to be complimented on their excellent clinical results. It is hoped that the preceding comments will encourage further discussion and publications on the postoperative care of the paediatric patient.

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REFERENCE

1. ENGSTROM, CARL GUNNAR. The Clinical Application of Prolonged Controlled Ventilation. Stockholm, 1963 (also published as Suppl. XIII, Acta Anaesth. Scandinav. (1963)).