Each of these patients had had at least one surgical operation within 24 hours of wounding, but there were no reports of cardiac arrest or arrythmia during these procedures. Records are available, and each had been given 60 to 100 mg of succinylcholine in a single intravenous dose. Patient 3 was anesthetized 53 days after being wounded and was given 80 mg of succinylcholine intravenously without difficulty, although an ECG monitor was not used. Thirteen days later he had cardiac arrest after only 60 mg succinylcholine.

The reason the sodium concentration fell so markedly after the ECG values returned to normal in two of the patients but not in the other is not apparent. None of these patients exhibited the usual fasciculations that follow succinylcholine.

The patients reported here and the experiences of others with severely-burned patients and those with massive tissue injuries support the hypothesis that a sensitive period occurs sometime after severe injury, reaching a peak and then subsiding. Further studies are needed to define this period. I conclude that succinylcholine must be used cautiously, if at all, in paraplegics after the first 24 to 48 hours of injury.

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Intermittent Cuff Inflation during Prolonged Positive-pressure Ventilation

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The use of tracheostomy and prolonged intermittent positive-pressure ventilation (IPPV) in the care of patients with respiratory insufficiency has been accompanied by an increasing incidence of tracheal mucosal erosion, bleeding, and tracheoesophageal fistula.[1] It is becoming increasingly clear that the major contributing factor in these cases is prolonged inflation of the occlusive cuff, with high lateral pressures on the mucosa and resultant interruption its blood supply.

Various methods of alleviating this problem have been suggested, including frequent intermittent deflation of the cuff, prestretching the cuff, use of fluted cuffs and, recently, the use of long, large-residual-volume, low-pressure, large-contact-area, evenly-inflating cuffs. This last method, which has been studied intensively by Carroll *et al.*[1] and Hedden *et al.*[2] appears promising.

Another procedure which has been suggested is to inflate the cuff automatically during the inspiratory phase, allowing it to de-

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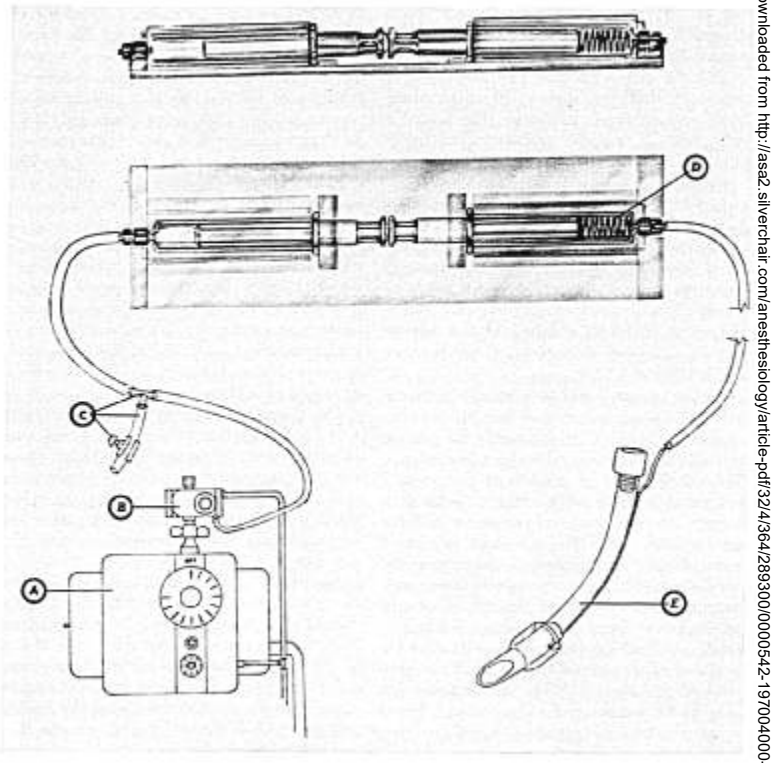

FIG. 1. Side and top views of specially-constructed plastic holder and opposed Luer-lock syringes. *A*, Bird respirator; *B*, inspiratory-flow cartridge; *C*, T-adaptor, pressure relief (pop-off) line, and thumbscrew clamp; *D*, recoil spring; *E*, tracheotomy tube.

flate during the expiratory phase.[3] In this way cuff inflation would be present during only about a third to half the total respiratory cycle, and intermittent mucosal capillary flow should be maintained. With proper humidification of the inspired gases, necrosis and infection should largely be prevented.

We have devised a simple, reliable means of providing automatic intermittent inspiratory cuff inflation and expiratory deflation with the Bird respirator. The apparatus is shown in figure 1. Two 10-ml glass Luer-lock syringes are placed in-line, but pointing in opposite directions, with their plungers in contact. The syringes are locked in place in a specially constructed plastic holder. Inside the syringe to be attached to the cuff of the tracheotomy tube is a spring, the exact characteristics of which are unimportant except that: 1) it should be approximately equal to the inside diameter of the syringe to prevent coil-binding during compression; 2) it should totally collapse to a distance on the syringe barrel equal to a volume between one and

two ml; 3) it should have sufficient recoil strength to return the syringe plungers to their original positions during the expiratory phase so that the cuff is deflated adequately. It is important that the syringe plungers move freely with minimal resistance. The use of a light-grade oil or liquid petrolatum will facilitate such movement.

One end of a nasal oxygen catheter is attached to the output jet of a standard Bird inspiratory-flow cartridge and the other end to the syringe facing away from the patient. A Bird T-connector is attached to this line and a second line connected to it which serves as a pop-off to dissipate excess pressure. A simple screw clamp is attached to this line to permit increasing or decreasing the pressure applied to the syringe.

As the operator gradually opens the needle valve in the inspiratory-flow cartridge, an increasing volume of air flows into the syringe forcing the plunger in the opposite direction. This plunger, since it is in direct contact with the plunger of the other syringe, causes it to inject a corresponding volume of air into the tracheotomy cuff. The rate and volume of cuff inflation are controlled by the amount the needle valve is opened and how much pressure is allowed to pop off through adjustment of the screw clamp. Incremental volumes as small as 0.5 ml are easily obtainable. The importance of not overinflating the cuff has been stressed previously.[1] When the respirator cycles off the inspiratory flow ceases, and the syringe plungers are returned to their original positions by the spring recoil.

Several advantages and safety features are inherent in this system: 1) The amount of air necessary to inflate the cuff just enough to provide an airtight seal can be determined easily and the inflating pressure adjusted so that only this amount will be provided. That an airtight seal does result has been demonstrated in two patients who required unusually high inspiratory pressures between 70 and 110 mm Hg to maintain adequate ventilation. 2) It is impossible to deliver more than 9 ml of air into the cuff since the volume available is limited by the syringe capacity minus the "deadspace" occupied by the compressed syringe. 3) Excessive intracuff pressures do not occur because once the cuff is inflated the excess pressure is dissipated through the pop-off line. This and the foregoing factor, in addition to preventing necrosis, should reduce the incidence of tracheal dilatation which may occur in patients undergoing prolonged IPPV. 4) If an inspiratory-flow cartridge is not available, intermittent cuff inflation using the Bird respirator may be obtained by placing a T-connector into the inspiratory drive line. The nasal oxygen catheter may then be connected to this T and to the syringe. Control of the volume delivered is achieved by applying a screw clamp to this line, and while it is less precise than that described above, it is adequate, and satisfactory intermittent inflation is readily achieved. 5) Cost of the entire unit is reasonable and it is a good investment in improved patient care.

One potential danger in the use of intermittent inspiratory cuff inflation is the aspiration of gastric contents during the deflation phase. For this reason we do not recommend this method for unconscious patients, in whom silent regurgitation and aspiration may occur, or for patients with nausea and vomiting from any cause.

Intermittent inspiratory cuff inflation has been well tolerated by our patients. If reflex coughing or bucking occurs it can almost always be eliminated by the instillation of 1 or 2 per cent lidocaine down the tracheotomy tube while the cuff is deflated. The resultant cough spreads the anesthetic over the tracheal mucosa and adequate topical anesthesia is readily achieved.

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§ The entire assembly, including the plastic holder, two Luer-lock syringes, and chromium-plated steel spring, costs less than $20.00. Further information and specifications may be obtained from Mr. Jimmie Schulz, 143 Hillsdale Drive, San Antonio, Texas 78227.