fitting, was elevated to reduce kinking in the connector hose. At this time, breath sounds were noted to be markedly diminished and an audible leak noted as the ventilator bellows descended. With return of the reservoir bag to the anesthesia circuit, no significant leaks were detected and effective ventilation was easily reestablished. Thorough examination of the ventilator fittings revealed several fine, longitudinal cracks in the machine connector pipe (fig. 1). Raising the ventilator and applying the screw clamp caused displacement of the fatigued metal pipe. This appeared as a variable leak in the ventilator system, depending upon the pressure and location of clamp application.

In retrospect, we speculate that this problem may have been present in previous cases but with no obvious cause or a variable leak of any great magnitude. The ventilator had been in active use and had passed all routine equipment checks. In fact, the area of metal fatigue was not obvious unless the connector pipe was deformed by a clamp or other pressure over the precise area of vulnerability; but there were several such areas along the length of the pipe. We hope that this report will serve to reemphasize the need to carefully reexamine all metal fittings which are prone to fatigue. Furthermore, it represents a major design flaw when a part of the ventilator circuit is also used as a structural mount and thereby subjected to the recurrent stress of daily operating room usage.

STEVEN WOLF, M.D.
Assistant Professor of Anesthesiology

CHARLES B. WATSON, M.D.
Assistant Professor of Anesthesiology

PHYLLIS CLARK, DDS,
Resident, Oral Surgery
Department of Anesthesiology

School of Medicine
Department of Anesthesiology
The University of North Carolina at Chapel Hill
Burnett-Womack Building
Chapel Hill, North Carolina 27514

REFERENCE

1. Dorsch JA, Dorsch SE: Understanding Anesthesia Equipment: Construction, Care and Complications. Baltimore, Williams and Wilkins, 1975, pp 68–70

(Accepted for publication December 30, 1980.)

Anesthesiology
55:84–85, 1981

Factors Affecting Rebreathing in T-piece Circuits

To the Editor:—The article by Byrick and Janssen on the effect of respiratory waveforms on rebreathing in T-piece circuits[1] provides useful and provocative information. But like many papers on the subject,[1] the authors' interpretation of their own results is flawed.

If a patient's respiratory waveform does affect rebreathing in a T-piece system—and it probably does[3]—this article fails to prove it. Unfortunately, the authors did not take into account a variable known to affect the amount of rebreathing in a Mapleson-D system:[4,5] the ratio of fresh gas flowrate ($\dot{V}_F$) to minute volume ventilation ($\dot{V}_E$). For instance, in their table 1, they report (in the upper left hand cell) that when $\dot{V}_F$ was 100 ml·kg^{-1}·min^{-1}, mean $\dot{V}_E$ was 4.34 l/min in their enflurane group, and 8.83 l/min in their halothane group. Assuming that the patients' body weights were comparable between the two groups and averaged 70 kg (and therefore $\dot{V}_F$ averaged 100 ml·kg^{-1}·min^{-1} × 70 kg = 7.0 l/min) then the ratio $\dot{V}_F/\dot{V}_E$ was 1.6 in the enflurane group, but only 0.8 in the halothane group, a twofold difference. On this basis alone one would expect to see little rebreathing in the enflurane group, but quite a lot in the halothane group. This is just what was found.

One could argue, in support of the authors' hy-

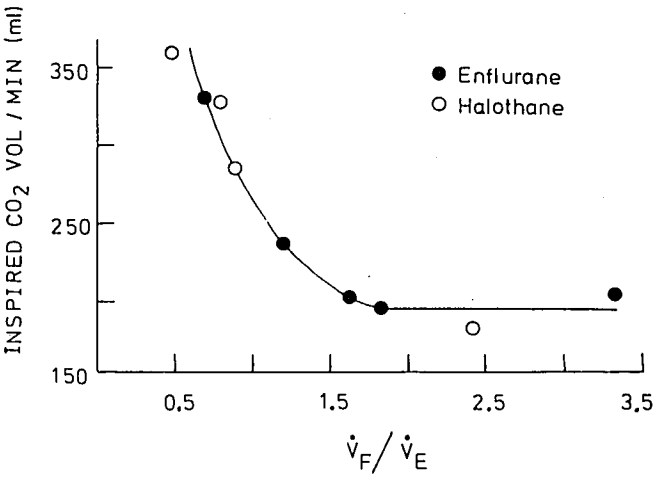

FIG. 1. Calculated $\dot{V}_F/\dot{V}_E$ ratios for both anesthetic groups at each fresh gas flowrate plotted against the inspired CO_2 volume per minute.

pothesis, that the larger values of $\dot{V}_E$ consistently seen with halothane was the effect, rather than the cause, of greater rebreathing in that group. But this is unlikely. Even when rebreathing was minimal or absent ($\dot{V}_F$ = 200 ml·kg^{-1}·min^{-1}) $\dot{V}_E$ was larger in the halothane group. Moreover, end-tidal CO_2 concentrations were consistently lower in the halothane group despite the presence of a greater degree of rebreathing. This suggests that less respiratory depression was present with halothane than with enflurane, and that the $\dot{V}_E$ was always larger in the halothane group on that basis. Obviously a larger $\dot{V}_E$ at a given $\dot{V}_F$ will result in a smaller ratio of $\dot{V}_F$ to $\dot{V}_E$, and therefore more rebreathing will be seen.

It should be noted in fairness to the authors that controlling for differences in $\dot{V}_E$ during spontaneous ventilation, especially with different anesthetics, is extremely difficult. Nevertheless, the differences in $\dot{V}_E$ between patients breathing enflurane and those breathing halothane seen in this study can explain the observed differences in rebreathing. One could argue that the respiratory waveforms played no role at all.

It may be possible to get at the precise role of the respiratory waveform from the data presented by Byrick and Janssen, if a way could be found to adjust the data for differences in the $\dot{V}_F/\dot{V}_E$ ratios between the two groups. To this end, I calculated $\dot{V}_F/\dot{V}_E$ ratios for both anesthetic groups at each fresh gas flowrate, using the mean values of minute volume from their table 1 and assuming a body weight of 70 kg. I then plotted these against the inspired CO_2 volume per minute (their measure of rebreathing) and found that the results from both groups fell amost exactly along the same curve (see fig. 1). Perhaps with the original data, the authors might be able to see differences, presumably due to variation in respiratory waveform. My own guess is that if there is a difference due to waveform, it is small.

This paper implies that the Bain circuit is unpredictable in its performance because of the wide and uncontrollable variability of respiratory waveforms seen during spontaneous ventilation. The data presented by Byrick and Janssen—useful as they are—do not support this implication.

RICHARD L. KEENAN, M.D.
Department of Anesthesiology
Medical College of Virginia
Richmond, Virginia 23298

REFERENCES

1. Byrick RJ, Janssen EG: Respiratory wave form and rebreathing in T-piece circuits: A comparison of enflurane and halothane waveforms. ANESTHESIOLOGY 53:371–378, 1980
2. Keenan RL, Boyan CP: Confusion regarding the Bain Circuit (letter). Can Anaesth Soc J, 28:90–91, 1981
3. Harrison GA: the effect of the respiratory flow pattern on rebreathing in a T-piece system. Br J Anaesth 36:206–211, 1974
4. Mapleson WW: The elimination of rebreathing in various semi-closed anaesthetic systems. Br J Anaesth 26:323–332, 1954
5. Willis BA, Pender JA, Mapleson WW: Rebreathing in a T-piece: Volunteer and theoretical studies of the Jackson-Rees modification of the Ayere's T-piece during spontaneous respiration. Br J Anaesth 47:1239–1246, 1975

(Accepted for publication January 13, 1981.)

Anesthesiology
55:85–86, 1981

In reply:—The aim of our study,[1] as the title suggested, was to analyze and compare the respiratory waveform of anesthetized patients during halothane and enflurane anesthesia, and to relate these waveform differences to rebreathing in T-piece circuits. The key role of minute volume ($\dot{V}_E$) and the $\dot{V}_F/\dot{V}_E$ ratio has been experimentally verified as Dr. Keenan suggests. Indeed, our hypothesis assumed that this relationship would exist, although presenting data in this manner would seem to verify our technique of measuring the inspired CO_2 load. The impact of respiratory waveform on rebreathing can only be analyzed when one considers the basic components of $\dot{V}_E$ which characterize a waveform, that is the inspiratory flow rate and the timing of each phase.

Milic-Emili et al.[2] introduced the concept of analyzing a given minute volume ($\dot{V}_E$) in terms of inspiratory drive (V_t/T_i) and the effective timing ratio. This relationship,

$$\dot{V}_E = V_t/T_i \times T_i/T_{tot} \times 60$$

characterizes the interdependence of $\dot{V}_E$ and the components of the respiratory waveform. By plotting the ratio $\dot{V}_F/\dot{V}_E$, Dr. Keenan is including the waveform characteristics on the x-axis which he wishes to isolate for examination. There are many variables (including dead-space, end-tidal CO_2 levels, and waveform) which will influence the relationship between inspired CO_2 volume and the $\dot{V}_F/\dot{V}_E$ ratio. The key finding of our study was that when halothane-anesthetized patients increased V_t/T_i, the fraction of CO_2 inspired increased. When enflurane was used, the exact opposite