

The 4-meter length of inked paper used to record each tetanus is relatively more permanent and vastly cheaper than an equivalent length of photographic medium.

The success of the technique is critically dependent on the ability of the multichannel direct writer to reproduce transients with sufficient fidelity. With the ordinary frequency response adjustments outlined in the manual, our Beckman-Offner Dynograph reproduced the form of a 1-cm-high square pulse introduced into the system (fig. 2a) with a real time rise to 90 per cent of value equivalent to less than 0.25 msec. The system band pass, including the P-15 preamplifier, was from 0.1 Hz to more than 2,500 Hz (6 db points) with the time expansion. The form of an EMC displayed from tape on a storage oscilloscope is compared with the system output in figure 2b.

In short, the system meets the criteria for faithful reproduction of these high-speed events, for ease of use, economy of material, and accessibility of large amounts of data. It comprises mostly laboratory instruments of general use and availability which need not be dedicated solely to this function. Therefore, the effective cost compares favorably with costs of other, less versatile, research equipment specifically committed to high-frequency recording. It has proved indispensable in following changes in the EMC under clinical conditions during periods of several hours following the administration of drugs.

#### REFERENCE

1. Lee ASJ: Technical aspects of monitoring systems, Patient Monitoring. Amsterdam, Excerpta Medica Monograph ISBN 90 219 2026 3, 1970, pp 30-44

## Accuracy of the Inspiratory Oxygen Tension with the Bennett MA-1 Ventilator

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Undesirable pulmonary complications characterized by atelectasis, pulmonary consolidation, and hyaline membrane formation are associated with prolonged mechanical ventilation with high inspired oxygen concentration.<sup>1</sup> Accordingly, the percentage of inspiratory oxy-

gen from a ventilator should be easily and predictably adjustable over a range from air to 100 per cent oxygen. The Bennett MA-1 ventilator is ideally suited in this respect, as it has a direct dial.

This study was designed to test the accuracy of inspired oxygen concentrations delivered by the Bennett MA-1 ventilator.

#### METHOD

Patients who needed prolonged mechanical ventilation and who were being ventilated with a Bennett MA-1 ventilator were selected for the study. The tidal volume and rate were approximately 15 ml/kg and 12/min, respectively, and P<sub>CO<sub>2</sub></sub> was maintained slightly be-

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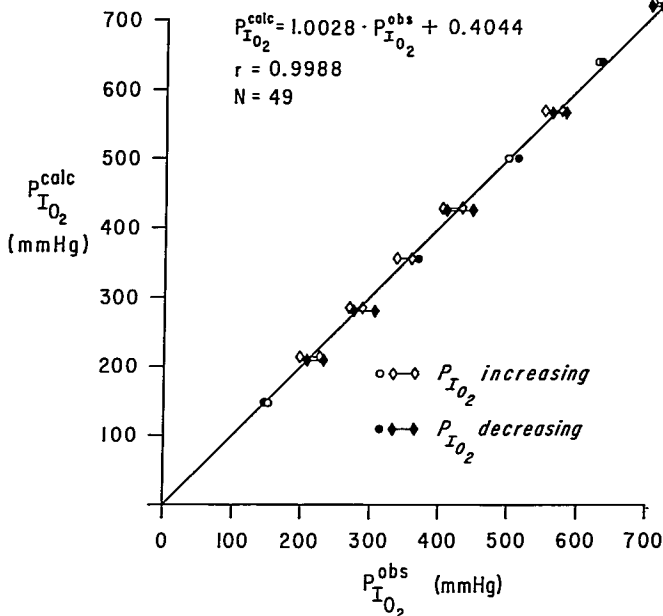


FIG. 1. Open diamonds refer to increasing  $P_{I_{O_2}}$  values for each calculated  $P_{I_{O_2}}$ , while solid diamonds reflect decreasing  $P_{I_{O_2}}$  values for each calculated  $P_{I_{O_2}}$ . A short line connecting two diamonds reflects the range, expressed as mean  $\pm 1$  SD of observed  $P_{I_{O_2}}$  values for the corresponding calculated  $P_{I_{O_2}}$  value. Circles represent individual data when only single determinations were made.

low 40 mm Hg by using an appropriate volume of deadspace. Four MA-1 ventilators were studied. Their serial numbers were recorded. Their average age was three years; they received major service by the company regularly after every 8,000 to 10,000 hours of use.

Initially, the  $P_{I_{O_2}}$  was adjusted so as to maintain adequate oxygenation in each patient, as judged by physicians directly in charge of the care of the patients. Then, the concentration of inspired oxygen was raised by 10 to 20 per cent increments at 3-6-minute intervals until 100 per cent oxygen was reached.

After 30 minutes of equilibration at 100 per cent, the procedure was reversed and the oxygen concentration lowered in 10 to 20 per cent decrements to the initial level.  $P_{I_{O_2}}$  in the airway was measured with a rapidly responding oxygen electrode (Radiometer Model 5047-0), applying a 3-mil-thick Teflon membrane described by Friesen and McIlroy.<sup>1</sup> The amplifier for the  $P_{O_2}$  electrode was made by using a FET operational amplifier (Mekco Model 1821) according to the diagram given by Severinghaus (personal communication). A 25-cm strip-chart recorder (Hewlett-Packard Model 7123A) was used to record  $P_{O_2}$  values.

The accuracy and stability of the oxygen electrode were periodically tested against known concentrations of oxygen. When calibrated with zero gas and 100 per cent O<sub>2</sub>, the oxygen electrode deviated less than 4 mm Hg from a linear relationship in the intermediate P<sub>O<sub>2</sub></sub> range.

#### RESULTS

The results are summarized in figure 1. The regression equation was

$$P_{O_2}^{calc} = 1.0028 P_{O_2}^{obs} + 0.4044$$

where P<sub>O<sub>2</sub></sub><sup>obs</sup> is the measured P<sub>O<sub>2</sub></sub> and P<sub>O<sub>2</sub></sub><sup>calc</sup> is the P<sub>O<sub>2</sub></sub> calculated from the barometric pressure and dial setting on the MA-1. The regression equation has a slope very close to one and a y intercept a fraction from zero. The correlation coefficient of 0.9988 is statistically significant at 0.0001 level. The largest discrepancy between calculated and observed P<sub>O<sub>2</sub></sub> values was 25 mm Hg.

#### DISCUSSION

A discussion of the mechanism of the MA-1 regulator is impossible at this time, as the company has not released this information.

However, as is evident from figure 1, the calculated P<sub>O<sub>2</sub></sub> values corresponded accurately to those observed, the regression line approximating very closely the ideal line. The dial setting of the Bennett MA-1 ventilator, therefore, is accurate within the commonly used range from 20 to 200 per cent oxygen.

The observed P<sub>O<sub>2</sub></sub>'s appear smaller than the calculated P<sub>O<sub>2</sub></sub>'s when the oxygen concentration is increasing, but greater when it is decreasing. This may reflect the transient state of the inspired oxygen change, the final concentration having not been achieved at the end of the 3-6-minute period. Though not detected, a play in the dial may induce a similar error.

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#### REFERENCES

1. Nash G, Blennerhasset J, Pontoppidan H: Pulmonary lesions associated with oxygen therapy and artificial ventilation. *N Engl J Med* 276:368-374, 1967
2. Friessen DO, McIlroy MB: Rapidly responding oxygen electrode for respiratory gas sampling. *J Appl Physiol* 29:258-259, 1970

## Evaluation of External Jugular Venous Pressure as a Reflection of Right Atrial Pressure

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Central venous pressure (CVP) is a valuable monitor, but the best approach for placement of the measuring catheter in the central venous circulation is unsettled. Subclavian<sup>1-3</sup> and femoral<sup>1,2</sup> vein catheterization are associated with significant hazards. Attempts to pass catheters into the superior vena cava from an external jugular<sup>2</sup> or antecubital<sup>2-4</sup> vein are often unsuccessful. A peripheral venous pressure that accurately reflected right atrial or central venous pressure would avoid

these problems. This study compares peripheral venous pressures measured in an external jugular vein with those pressures measured in the right atrium via a catheter in an internal jugular vein.

#### METHODS

Sixteen anesthetized patients whose tracheas were intubated were studied at the conclusion of elective operations. A 5-cm Teflon catheter † was placed percutaneously in either external jugular vein. The right internal jugular

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