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_2, the oxygen electrode deviated less than 4 mm Hg from a linear relationship in the intermediate P_{O_2} range.

Results

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

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

where $P_{I_{O_2}}{}^{obs}$ is the measured P_{O_2} and $P_{I_{O_2}}{}^{calc}$ is the P_{O_2} 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 $P_{I_{O_2}}$ 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 $P_{I_{O_2}}$ 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 $P_{I_{O_2}}$'s appear smaller than the calculated $P_{I_{O_2}}$'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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Evaluation of External Jugular Venous Pressure as a Reflection of Right Atrial Pressure

ROBERT K. STOELTING, M.D.*

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[1-3] and femoral[1,2] vein catheterization are associated with significant hazards. Attempts to pass catheters into the superior vena cava from an external jugular[2] or antecubital[2-4] 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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† Deseret Pharmaceutical Co. Angiocath (16-gauge).

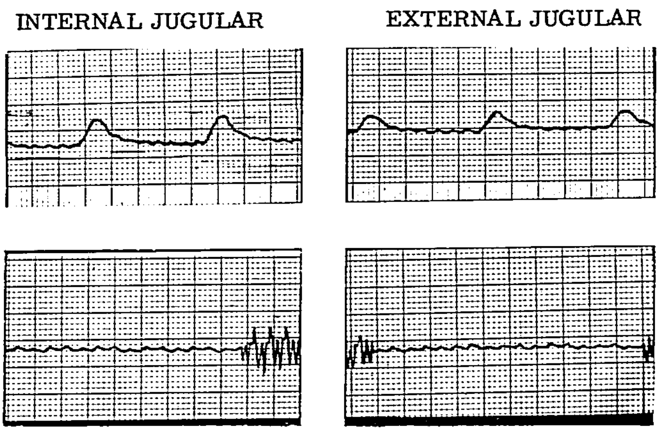

FIG. 1. Typical mean venous pressure recordings from a single patient. During controlled respiration (*upper panels*) there was greater variation of right atrial pressure with the ventilator cycle but peak pressure was nearly identical to that in the external jugular vein. This variation was decreased with spontaneous respiration (*lower panels*) and venous pressures from the two sites were nearly identical. The large amplitude deflections during spontaneous respiration represent phasic venous pressure recordings.

vein was catheterized percutaneously in the same patient using a 30 cm Teflon catheter.‡ A postoperative chest x-ray confirmed the right atrial position of the longer catheter. Respiration was controlled with a volume ventilator. Mean venous pressures were recorded from each catheter in succession by using a single transducer and turning the appropriate three-way stopcock. Spontaneous respiration was then allowed to resume and venous pressure measurements were repeated while the patient was still attached to the anesthesia circuit.

Blood samples were drawn from each venous catheter and an indwelling radial artery catheter simultaneously during controlled and spontaneous respiration for P_{O_2} and P_{CO_2} determinations.

RESULTS

Maximum venous pressures measured in the external jugular vein during controlled respiration and corresponding to end inspiration of the ventilator cycle averaged 10.6 ± 0.9 torr ($\pm$SEM). Right atrial pressures at this time averaged 10.0 ± 0.9 torr. The lowest venous pressures, recorded just before the start of the ventilator's inspiratory cycle, averaged 8.2 ± 0.9 torr in the external jugular vein and 6.0 ± 0.9 torr in the right atrium ($P < 0.01$). Venous pressure variation with the ventilator cycle was nearly eliminated during spontaneous ventilation, and external jugular vein pressure (9.6 ± 1.3 torr) was not significantly different from right atrial pressure (8.9 ± 1.2 torr).

Figure 1 illustrates typical venous pressure recordings from both venous sites during controlled and spontaneous ventilation.

Blood–gas data are summarized in table 1. During controlled respiration Pv_{O_2} was greater in the external jugular vein than in the right atrium ($P < 0.01$), while Pv_{CO_2}'s at the two sites were nearly identical and about 5 torr more than Pa_{CO_2}'s. Right atrial Pv_{O_2} increased with spontaneous respiration ($P < 0.02$), but external jugular Pv_{O_2} was still greater than

‡ Deseret Pharmaceutical Co. Angiocath (16-gauge).

TABLE 1. Blood-Gas Data (Averages ± SEM; n = 16)*

	Controlled Respiration			Spontaneous Respiration		
	Right Atrium	External Jugular Vein	Radial Artery	Right Atrium	External Jugular Vein	Radial Artery
P_{O_2} (torr)	44.1 ± 2.7	50.0 ± 3.5	186 ± 5.0	51.4 ± 1.4	56.3 ± 1.4	16.2 ± 5.0
P_{CO_2} (torr)	33.1 ± 1.5	33.8 ± 2.0	28.3 ± 1.8	46.0 ± 1.4	47.8 ± 1.3	42.6 ± 2.2

* Right atrial samples were obtained through the internal jugular vein catheter.

that in the right atrium ($P < 0.05$). Pv_{CO_2} increased during spontaneous ventilation and remained 4–5 torr higher than Pa_{CO_2}.

Discussion

These data indicate that venous pressures recorded from a 5-cm catheter in the external jugular vein accurately reflect right atrial pressures during anesthesia and controlled or spontaneous respiration. The only significant difference was the greater right atrial pressure variation during positive-pressure ventilation, but maximal venous pressures at the two sites were nearly identical. Previous investigators[5-6] have reported that external jugular venous pressure reflects right atrial pressure, but detailed measurements have not been presented.

Placing a short catheter in the external jugular vein avoids the difficulty of threading past the junction with the subclavian vein or lodgement in tributary veins.[2] Craig *et al.*[7] described valves at the termination of the external jugular vein but, if present, these did not interfere greatly with reflection of right atrial pressures. Additional advantages are its simplicity and safety—pneumothorax and intrathoracic bleeding are impossible with proper use of the technique. If one wishes to monitor CVP during anesthesia, a short catheter in the external jugular vein is a reliable approach. However, the external jugular vein has two important disadvantages. It does not accurately reflect right atrial P_{O_2}, and attempts to monitor adequacy of tissue perfusion may not be reliable. The major limitation of the external jugular vein approach is the positional nature of its function. In almost every instance it was necessary to turn the head to the opposite side to insure free blood withdrawal and subsequent reliable venous pressure readings. This becomes a significant disadvantage in the awake patient.

Percutaneous internal jugular vein catheterization reliably placed the catheter tip in the right atrium without the attendant hazards of the subclavian approach. Difficulty threading the catheter or subsequent difficulty withdrawing blood usually indicated a coiled catheter—this was confirmed radiographically in three such instances. The right internal jugular vein was used in this study, but catheterization of the left internal jugular vein was equally successful on other occasions. However, the added distance made right atrial placement of the catheter less assured. In addition, these catheters functioned in all positions and thus achieved greater acceptance.

Summary

Venous pressures recorded from a 5-cm catheter in the external jugular vein accurately reflected right atrial pressures during anesthesia with controlled or spontaneous respiration. Advantages were its simplicity and safety, but the positional nature of its function detracted from use in awake patients. Percutaneous catheterization of the right internal jugular vein reliably placed the catheter tip in the right atrium without the associated hazards of subclavian vein catheterization. Advantages of the internal jugular vein approach were its function in all positions and the ease of obtaining right atrial samples for blood–gas analysis.

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A New Disposable Spirometer

JOHN H. LECKY, M.D., J. KENNETH DENLINGER, M.D., ALAN J. OMINSKY, M.D.

The devices currently available for measuring vital capacity (V_c) and minute ventilation (V_E) usually suffer from one or more major deficiencies. These include: 1) cost; 2) fragility; 3) flow dependence; 4) lack of portability; 5) possibility for bacterial cross-contamination between patients. Recently, a disposable spirometer that appears to eliminate all of these deficiencies has become available.* This report assesses the accuracy and precision of this new device for measuring vital capacity and minute ventilation.

DESCRIPTION OF THE DISPOSABLE SPIROMETER

Figure 1 is a schematic diagram of the disposable spirometer. The device consists of a flexible 3-liter polyethylene bag calibrated in 25-ml increments. The bag is attached to a rigid polyethylene T tube which can be either used directly as a mouthpiece or attached to standard 15-mm anesthesia fittings.

METHOD OF USE

Measuring Vital Capacity. The patient breathes normally through the rigid tube while the bag entrance port is occluded with the operator's finger.† On command, a maximum inhalation is taken. The operator removes his finger from the bag entrance port and occludes the exhaust end of the T tube. The patient then exhales maximally into the calibrated bag. When the exhalation is completed, the bag entrance port is again closed with the operator's finger.

To measure the exhaled volume, the device is placed on a flat surface. Using the heel of the hand, the operator displaces the volume of gas distally (away from the rigid tube) until the bag lifts upward from the surface. When this lift produces an angle of 30 degrees between the flat surface and the bag, the volume is read directly from a scale printed on the bag (fig. 2).

Measurement of Minute Ventilation. For a patient on a ventilator, V_E is measured by attaching the device to the exhalation line of the ventilator and measuring the volume of three breaths. Respiratory frequency is recorded simultaneously. V_E is then determined using

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* Boehringer Laboratories, P.O. Box 18, Wynnewood, Pennsylvania 19096. Approximate cost: $4.50 each.

† When desired, supplemental oxygen can be provided through the T tube.