A COMPARISON OF OESOPHAGEAL AND CENTRAL VENOUS PRESSURES IN THE MEASUREMENT OF TRANSPULMONARY PRESSURE CHANGE

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SUMMARY

Oesophageal (oes) and central venous pressure (CVP) were compared as indices of transpulmonary pressure change (Δp). The mean increase of Δp_{oes} over Δp_{CVP} was 2.8 cm H$_2$O. The size and variability of the increase were similar to the expected difference between oesophageal and pleural pressure fluctuations occurring in the supine patient. Central venous pressure may be more accurate and reliable than oesophageal pressure for estimations of transpulmonary pressure change in the supine position.

Dynamic lung compliance $C_{dyn}$ is the ratio of the tidal volume $V_T$ to the change in pressure $Δp$ between the points of zero flow at the extremes of $V_T$ (Mead, 1961). $C_{dyn}$ may be a useful index in the management of patients with pulmonary oedema, pleural or pericardial effusion, pulmonary artery occlusion and atelectasis (Comroe et al., 1970), and in the early detection of an increase of pulmonary extravascular water volume (Sladen, Laver and Pontoppidan, 1968; Eyal et al., 1975; Hauge, Bø and Waaler, 1975). It may be valuable also in the early detection of the "shock lung" (Rådegran, 1971).

The oesophagus is used commonly as a pressure reference point in the measurement of $C_{dyn}$. There is general agreement that the technique proposed by Milic-Emili and others (1964) is the most suitable. However, in patients in the supine position the weight of the mediastinal contents may influence the respiratory pressure swings as measured within the oesophagus. Mead and Gaensler (1959) have demonstrated that, during quiet breathing in the sitting position, the amplitudes of the oesophageal pressure swings were, on average, 1% (range +60% to −18%) less than the pleural pressure measured simultaneously. In the supine position there was a mean increase of 27% (range +60% to −15%) in the oesophageal pressure changes compared with the pleural pressure changes. These authors concluded that the use of oesophageal pressure in the supine position might result in false low values of $C_{dyn}$.

Oesophageal pressures have been shown to be unreliable in estimations of $C_{dyn}$ in the supine, curarized subject (Wildsmith, 1973). Clearly, there is a need for a more accurate reference point for the measurement of intrathoracic pressures.

We have compared "transpulmonary pressure" changes measured from the oesophagus (Δp_{oes}) and simultaneous changes measured from the respiratory component of the central venous pressure (Δp_{CVP}) in supine patients.

METHOD

Patients in the intensive therapy unit, receiving IPPV and with a central venous catheter in either the superior vena cava or the right atrium, were studied. Oesophageal balloon catheters were introduced whilst the patient was unconscious.

The oesophageal balloons (length 10 cm, perimeter 1.7 cm, wall thickness 0.04–0.08 mm) were made of rubber and were sealed over the end of a plastic catheter (Argyle feeding tube 8 F.G.; length 100 cm, i.d. 1.5 mm) into which holes had been cut in a spiral arrangement every 0.5 cm in that portion of the catheter enclosed by the balloon. The balloon catheter was introduced through the nose and into the oesophagus so that the balloon tip was 45 cm from the nares. The catheter was opened to atmosphere during the inspiratory phase of the ventilator; 0.2 ml of air was then introduced (Milic-Emili et al., 1964). The catheter was connected to one side of a differential pressure transducer (Pye Ether Ltd, Series U.P.). The other side was connected to a Cape ventilator by manometer tubing (length 100 cm, i.d. 1.52 mm, Portex Ltd) (fig. 1).

One of the following was used for measurement of CVP:

(a) Argyle feeding tube, introduced by cut-down in the antecubital fossa (length 100 cm, i.d. 1.5 mm).
FIG. 1. Schematic diagram of the equipment.

(b) Drum-Cartridge catheter inserted percutaneously to an antecubital vein (length 71 cm, i.d. 1.0 mm).
(c) Leader-Cath introduced by percutaneous puncture of the right internal jugular vein (length 18 cm, i.d. 1.4 mm, Vygon (UK) Ltd).
(d) Swan-Ganz catheter introduced by percutaneous puncture of the right internal jugular vein (length 80 cm, i.d. 0.98 mm, Cardiovascular Instruments Ltd).

The position of the oesophageal balloon catheter and the CVP catheters were checked radiographically.

The CVP catheter was connected to the liquid side of the second differential pressure transducer by a 100-cm manometer tube filled with sterile normal saline; gas bubbles were excluded. The other side of the second transducer was connected to the upper airway.

In some patients the transthoracic pressure was measured also. A three-way tap was incorporated into the ventilator tubing and airway pressures relative to atmosphere were measured using a transducer (Bell & Howell Type 4-327-L221), the electrical output of which was fed to a Devices MX4 amplifier and recorder. The scale was adjusted to give maximum deflection of the pens as an aid to accuracy in reading. Cardiac oscillations were sometimes superimposed upon the pressure changes, making accurate reading difficult (fig. 2). Where the beginning of the respiratory pressure change was not obvious, the reading was taken from a point opposite the middle of the cardiac artefact.

$V_T$ was calculated, by the physician in charge, as that which would be suitable for the ventilatory requirements at the time of study. In no study was the respiratory frequency less than 9/min or greater than 12/min. For each measurement of $\Delta p$, $V_T$ was reduced by approximately 200 ml, and pressure recordings were made during 10 respiratory cycles, $V_T$ being measured with a Wright respirometer attached to the expiratory port of the ventilator. $V_T$ and $\Delta p$ were calculated from the mean of 10 cycles. The readings were repeated following each increase of $V_T$, by approximately 100 ml, up to $V_T$ values of approximately 200 ml in excess of the original $V_T$. The time for measurement was 10–15 min.

RESULTS

Nine patients were studied on 12 occasions; the relevant details and the results are shown in table I. Typical pressure traces at different values of $V_T$ are shown in figure 2. Simultaneous readings of $\Delta p_{oes}$ and $\Delta p_{CVP}$ were compared on 640 occasions (fig. 3). When the percentage differences between each pair of readings were pooled, oesophageal pressures showed a mean increase over CVP pressures of 30.4% ± 31 ($t = 8.3$, $P < 0.001$).

DISCUSSION

There is no accurate method for measuring pulmonary dynamic compliance in the supine position because of the difficulty in measuring transpulmonary pressure. Oesophageal pressures are different from pleural pressures (Mead and Gaensler, 1959). They do not change in a parallel fashion during breathing, and the relationship between the two pressures is variable from individual to individual (Cherniack et al., 1967). The regional differences in pleural pressures related to atmosphere would not invalidate the accurate measurement of the transpulmonary pressures.
<table>
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<th>Subject</th>
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<th>Wt (kg)</th>
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<th>PEEP (cm H2O)</th>
<th>CVP cannula</th>
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* Estimated weight.

AVR = aortic valve replacement; CVP = central venous pressure; MVR = mitral valve replacement; LLL = left lower lobe; PAP = preoperative pulmonary artery pressure (mm Hg); PEEP = positive end-expired pressure. Type of CVP cannula: A = Argyle; D = Drum cartridge; S = Swan-Ganz; L = Leader-Cath.
pressure change, if the pressure changes during ventilation were the same over the whole lung surface. This does not appear to be so. In anaesthetized dogs, Coulam and Wood (1971) demonstrated that the ratio of maximal respiratory variations in pleural pressures recorded simultaneously over apical and caudal regions of the lung was 0.74 in the head-up position and 0.52 in the head-down position. It has been shown, in dogs in the supine position, that the end-expiratory pleural pressure becomes less negative from the apex to the posterior gutter, and that the respiratory excursions in pleural pressure increase from apical areas to the dependent, posterior gutter (Farhi, Otis and Proctor, 1957). If pressure changes in the oesophagus sometimes reflect local changes in pleural pressure, this observation would support the prediction of Mead and Gaensler (1959) that $\Delta P_{oeg}$ measured in the supine position would be falsely great if the oesophagus were used.

In this study, the values of oesophageal transpulmonary pressure change were usually greater than the CVP transpulmonary pressure change. The size and variability of the increase ($30.4\% \pm 31$) are similar to that of the increase in oesophageal pressure amplitudes compared with pleural pressure amplitudes ($26.4\% \pm 23$), calculated from the observations of Mead and Gaensler (1959) on patients breathing quietly.

If oesophageal pressure changes show a similar increase over both pleural and CVP changes, these should be approximately equal. This hypothesis is supported experimentally. When pressure changes occur within the thorax, it appears that alterations in CVP and intrathoracic pressure (ITP) are almost identical. Avasthey, Coulam and Wood (1970) studied dogs moved from supine, to head-down, to head-up position and concluded that there was no significant change in the mean right atrial filling pressure, the algebraic sum of CVP and ITP (Trichet et al., 1975), although there was a mean decrease of 9.6 cm H$_2$O in right atrial pressure related to the mid-lung level. These observations demonstrate that during changes in body position and consequent alterations of pressure within the thorax, ITP and CVP change in the same direction and with the same magnitude. This means that the observed alteration in CVP relates closely to the actual change in ITP and may explain why $\Delta P_{oeg}$ shows a similar increase over both $\Delta P_{CVP}$ and pleural pressure changes.

The respiratory component of CVP may be the best measure of mean pleural pressure change and the least invasive, because patients who are likely to benefit from dynamic compliance studies in the operating theatre or the intensive therapy unit may be expected to have a CVP catheter in position.

**ACKNOWLEDGEMENTS**

We would like to thank Mr Chris Bond, Miss Jean Drake and Mr Richard Innes for their technical assistance, and Miss Sue Foot for her help with statistics. We are indebted to London Rubber Industries for manufacturing the oesophageal balloons.

**REFERENCES**


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**COMPARAISON DE LA PRESSION OESOPHAGIENNE ET DE LA PRESSION VEINEUSE CENTRALE DANS LA MESURE DES VARIATIONS DE LA PRESSION TRANSPULMONAIRE**

On a comparé la pression oesophagienne (oes) et la pression veineuse centrale (CVP) en tant qu'indicateurs de la mesure des variations de la pression transpulmonaire (Δp). L'augmentation moyenne de ΔPoes par rapport à ΔPCVP a été de 2,8 cm H₂O. L'importance et la variabilité de l'augmentation ont été similaires à la différence attendue entre les fluctuations de la pression oesophagienne et de la pression pleurale se produisant sur le patient couché. La pression veineuse centrale peut être plus précise et plus fiable que la pression oesophagienne pour les estimations de variations de la pression transpulmonaire dans la position couchée.

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**COMPARACIÓN DE LAS PRESIONES ESOFAGICA Y VENOSA CENTRAL EN LA MEDICIÓN DEL CAMBIO DE PRESIÓN TRANSPULMONAR**

Las presiones esofágica (eso) y venosa central (PVC) fueron comparadas como índices del cambio de presión transpulmonar (Δp). El incremento medio de ΔPeso sobre ΔPCVP fue de 2,8 cm H₂O. El grado y variabilidad del aumento fue similar a la diferencia esperada entre las fluctuaciones de presión esofágica y pleural producidas con el paciente en posición supina. La presión venosa central pudiera ser más exacta y confiable que la presión esofágica para los cálculos del cambio de presión transpulmonar en la posición supina.