A NEW METHOD FOR MEASURING STATIC COMPLIANCE IN INFANTS AND YOUNG CHILDREN

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SUMMARY

1. A new method for measuring static compliance, which does not require general anaesthesia or a leak-free airway, is described for infants and young children.

2. Thoracic volume changes produced by static inflation pressures are measured by a respiratory jacket, and results compare well with those obtained by the syringe-inflation method.

3. This method can be used in the intensive care of sick infants, where it allows a new approach to the investigation of lung mechanics.

Key words: static compliance, children, thoracic-volume changes.

Supportive ventilatory therapy via an endotracheal or tracheostomy tube is well recognized in the treatment of infants and children with acute respiratory failure. In a small proportion of patients the lung disorder does not resolve and prolonged intermittent positive-pressure ventilation is required (Barnes, Glover, Hull & Milner, 1969). It may be difficult to remove the tracheostomy tube for many months after ventilatory support is withdrawn. Although serial blood-gas measurements help in the management of these patients the information they provide is limited. To evaluate the progress of the underlying lung disorder, some measure of lung mechanics is required.

We describe a method for measuring static compliance in these patients without the need for general anaesthesia. The method is not affected by leaks around the airway, and thus allows repeated measurements to be made with minimum disturbance to the child.

METHODS

The children were sedated with chloral (75 mg/kg) and an inflatable rubber jacket (Milner, 1970) was fitted so that it extended from the neck to below the pubis. After the jacket was
inflated to a pressure of 3–4 cmH₂O, the volume changes produced by the infant’s breathing were linearly related to the pressure changes within the jacket. The design and stretch characteristics of the rubber jacket were such that pressure changes of 1–2 mmH₂O occurred within it during tidal exchange. Pressure changes were measured by a differential pressure transducer (Ether, U.P.I.) and relayed to a hot-wire recorder (Devices M2). The system was calibrated by injecting and withdrawing known volumes of air from the respiratory jacket.

![Diagram of system for measuring static compliance](image)

**Fig. 1.** System for measuring static compliance. The respiratory jacket records thoracic-volume changes produced by sustained inflation pressures. The reservoir bag can be connected to either an endotracheal or tracheostomy tube. An air-tight seal in the trachea is not required.

![Graphs showing thoracic-volume change and inflation pressure](image)

**Fig. 2.** (a) Thoracic-volume change (respiratory jacket) and (b) inflation pressure during the measurement of static compliance. A 1 s time-marker is included.

The patient was ventilated manually by using an Ayres T-piece connected to the airway (Fig. 1). The inflation pressures were measured by inserting a F.G.21 thin-walled scalp-vein needle close to this connection. Airway pressure was recorded by a strain gauge pressure transducer (Bell & Howell 4-327-L221). The infants were hyperventilated until spontaneous respiratory efforts ceased. A constant inflation pressure was then produced by squeezing the reservoir bag of the T-piece while observing the inflation pressure trace, and compensating
for any leak around the airway. This pressure was maintained until the signal of the jacket volume had stabilized, which usually took 2–5 s. When the pressure was released the thoracic volume returned to its resting value. This manoeuvre was repeated at different inflation pressures (Fig. 2).

The airway pressure was plotted against thoracic volume change and the total static compliance calculated from the slope of the plot of best fit (Fig. 3).

To evaluate the accuracy, measurements of total static compliance with this new technique were compared with those using the standard syringe method in fourteen children between the ages of 7 weeks and 5 years, who required general anaesthesia and endotracheal intubation for a variety of minor surgical procedures. Written consent for anaesthesia was obtained from the parents, and the study was approved by the hospital ethical committee. After induction with methohexitone, a jacket was placed on the child, inflated and calibrated as described above. After paralysis with succinylcholine the child was intubated with an endotracheal tube which did not leak with inflation pressures of up to 35 cmH₂O. The lungs were inflated three times to a pressure of 30 cmH₂O to establish a reproducible volume history. A large glass syringe (500 ml) was then used to inflate and deflate the lungs in a stepwise manner allowing 3–5 s at each step for stabilization of the inflation pressure (Fig. 3) (Butler & Smith, 1957).

The respiratory jacket was then used to measure the static total compliance by using the technique described above.

In one infant with congenital heart disease, who was sedated but not anaesthetized, measurements of static total compliance were made on five occasions over a period of 90 min to assess the reproducibility of the technique.
RESULTS

All static compliance measurements obtained with inflation pressures below 10 cmH$_2$O or above 35 cmH$_2$O were ignored, because of possible errors caused by non-linearity of pressure-volume relationships at high or low lung volumes. In each child the static compliance was calculated from the slope of the regression line. However, a line drawn by eye through the observed values during inflation proved reliable. The mean values obtained visually by three of the authors individually differed from the calculated regression line by only 5.5%, with SD 0.48.

The comparison of static-compliance measurements obtained by the respiratory-jacket-reservoir bag method and the syringe technique during inflation and deflation are shown in Figs. 4 and 5. The respiratory-jacket method produced results which were slightly lower than those obtained by the syringe method. Agreement was closest to the deflation phase of the syringe method (Fig. 5).

The mean value for the five calculations of total static compliance measurements on one infant was 3.74 ml/cmH$_2$O with SD 0.20 cmH$_2$O.

DISCUSSION

Values have been reported for static-compliance measurements in health and disease in the newborn child (Reynolds & Etsten, 1966; Richards & Bachman, 1961; Smythe, 1963) and in
Static compliance in young children

These measurements have all been obtained by using the syringe-inflation method which requires general anaesthesia, muscle relaxation and a tight-fitting endotracheal tube. The use of general anaesthesia solely to measure static compliance in a sick child during intensive care hardly seems justifiable and the use of tight-fitting endotracheal or tracheostomy tubes introduces the hazard of tracheal damage.

The method we report in the present paper is a new and safe approach to the investigation of lung mechanics in critically ill children. Repeated measurements of static compliance may be made with minimal disturbance to the patient. If an oesophageal balloon is also used then respiratory resistance (Otis, Fenn & Rahn, 1950) and dynamic compliance (Neergaard & Wirz, 1927) can also be measured, but dynamic-compliance measurements are of little value when respiratory frequency or resistance are high (Comroe, Forster, DuBois, Briscoe & Carlsen, 1962). Reliable information about the elastic properties of the respiratory system can only be obtained by measurement of static compliance. Infants may require intermittent positive-pressure ventilation with high pressures because the compliance is low or the airway resistance is high or a combination of these factors. Measurement of static compliance by the described technique is now an established part of the clinical management of infants with chronic respiratory failure in this hospital.

When inflation pressure was outside the range 10–35 cmH₂O the values obtained were discarded because of possible errors caused by non-linearity of pressure–volume relationships at high or low lung volumes. Results obtained with the respiratory jacket compared well with

Fig. 5. Comparison of the results obtained for total static compliance by using the jacket method and the expiratory phase of the syringe method.

Total static compliance by jacket method (ml/cm H₂O)

Total static compliance by syringe method (expiration) (ml/cm H₂O)

0 4 8 12 16 20 24 28

Total static compliance by jacket method (ml/cm H₂O)

28 24 20 16 12 8 4 0

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those obtained by the syringe method and were more easily analysed. The subject must be
resting peacefully and care must be taken in the selection of jacket size and in ensuring that
the collar reaches the thoracic inlet.

Chest-wall and lung compliance can be separated by measuring transpleural pressure with
the oesophageal balloon. The chest-wall of the infant is usually so compliant, however, that
total and lung compliance are almost equal. We did not feel justified in using oesophageal
balloons in our comparison of the two methods of measurement of static compliance.

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