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B. J. Stenson
R. A. Wilkie
I. A. Laing
W. O. Tarnow-Mordi

Reliability of clinical assessments of respiratory system compliance (Crs) made by junior doctors

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B. J. Stenson (✉) · I. A. Laing
Neonatal Unit, Simpson Memorial Maternity Pavilion, Edinburgh EH3 9EF, UK

R. A. Wilkie · W. O. Tarnow-Mordi
Ninewells Hospital and Medical School, Dundee, UK

Abstract *Objective:* To assess the reliability of estimates of static respiratory system compliance (Crs) made by junior hospital doctors caring for ventilated newborn infants.
Design: A prospective comparison of junior doctors' estimates of Crs to the Crs measured immediately afterwards.
Setting: A regional neonatal intensive care nursery in Edinburgh, Scotland.
Patients: 46 ventilated newborn infants.
Measurements and results: Crs was estimated by three grades of junior doctor (Senior House Officer, Registrar and Research Fellow) using two different methods, (i) based on visual assessment of tidal volume in relation to inflation pressure (optical Crs) and (ii) directly using a visual analogue scale (analogue Crs). The Crs was then measured immediately afterwards using the single breath passive expiratory flow technique. The differences between the estimates and the measurements were calculated for each grade of observer and plotted against the corresponding measurements. The relationship between estimates and measurements was also expressed in terms of the coefficients of determination r^2 calculated by least squares regression. With both methods of estimation observers tended to overestimate the Crs of infants with lower measured Crs and underestimate that of infants with higher measured Crs with many estimates differing from the measurements by more than 50%. Values of r^2 ranged from 0.086 to 0.481 indicating a weak relationship between the estimates and the measurements.
Conclusions: Junior doctors' estimates of Crs were unreliable and did not represent a useful method of assessing respiratory function. The clinical use of compliance measurements merits wider evaluation.

Key words Pulmonary function testing · Lung compliance

Introduction

Whenever an infant is mechanically ventilated the person adjusting the ventilator makes an informal appraisal of the lung mechanics by visually estimating the chest inflation. Estimates of static respiratory system compliance (Crs) based on clinical assessment of chest inflation have been proposed as a useful aid to ventilator management in neonatal intensive care [1, 2]. The reliability of clinical judgements is likely to vary with clinical experience and estimates made by the junior doctors who provide much of the care to ventilated infants may be less reliable than those of their seniors. It can be difficult to make an accurate diagnosis from a chest radiograph [3]. Blood gas analysis measures the effect of the current ventilator set-

tings rather than what they might ideally be and over-ventilation can substantially worsen gas exchange [4]. Given the subjective nature of the clinical information available, objective lung function data such as Crs measurements might help to optimise ventilation strategy. But if junior doctors could reliably judge Crs then the additional infant handling and equipment costs associated with the measurements however minimal would be hard to justify. This study was designed to determine whether the junior doctors in a regional neonatal intensive care unit can make reliable clinical estimates of static respiratory system compliance.

Materials and methods

A total of 46 ventilated newborn infants were studied prospectively in the Simpson Memorial Maternity Pavilion, Edinburgh between September 1992 and June 1993. Infants were eligible for inclusion if on the first day of life the Senior House Officer (SHO), Registrar and Research Fellow were simultaneously available to estimate Crs and no preceding Crs measurements had been made. Written parental consent was obtained in all cases. The study was conducted according to the principles established in Helsinki and with the approval of the local ethics committee. Crs was estimated using two methods and the estimates were compared to the measured Crs obtained immediately afterwards.

Crs estimates

The methods of estimation were: (a) optical Crs, and (b) analogue Crs. Optical Crs is based on assessment of tidal volume [1, 2]. The examiner placed the chest inflation observed with each ventilator breath into one of three categories: less than normal and barely visible, approximately normal, or greater than normal and distinctly visible (normal being that observed in a healthy newborn infant breathing spontaneously). A tidal volume of 5, 7.5, or 10 ml/kg body weight was assigned accordingly. The values obtained were divided by the inflation pressure (peak inspiratory pressure minus positive end-expiratory pressure) to give the optical compliance (units ml/cmH_2O/kg body weight). Analogue compliance was estimated by marking a point on a linear scale corresponding to what the observer thought the Crs would be (Fig. 1). The scale described Crs values ranging from 0.4 (severely abnormal) to 2.5 ml/cmH_2O/m body length (functionally normal). Crs values were expressed on the analogue scale in relation to body length as Crs is routinely corrected for length in our unit [4–6]. In our experience infants recovering from lung disease can usually be extubated and are often breathing air by the time their Crs has reached 2.5 ml/cmH_2O/m but newborn infants with entirely normal lungs have a Crs of around 5–8 ml/cmH_2O/m [7–10] or 1–1.6 ml/cmH_2O/kg [11]. The optical estimates and measurements were compared to one another using their actual values. For the purposes of comparison to the analogue scale all measured Crs values that were greater than 2.5 ml/cmH_2O/m were called 2.5. Each observer was blind to the estimates made by the others.

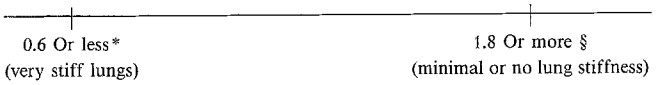

Fig. 1 Analogue scale for estimating Crs. *Crs ≤ 0.6 ml/cmH_2O/m means high risk of death from lung disease [4]. § Crs ≥ 1.8 ml/cmH_2O/m implies normal lung phospholipid profile [5]

Crs measurements

Immediately following the estimates, Crs was measured by the research fellow (BJS) using the single breath passive expiratory flow technique as previously described [4–6, 12]. This was then divided by the infant's crown-heel length measured with a tape measure (±1.5 cm) or birth weight in kg for comparison to the estimates.

Statistical methods

The difference between each Crs measurement and the corresponding Crs estimate was calculated (measurement minus estimate) and plotted against the measurement. In addition, the relationship between the estimates and measurements was assessed by the coefficients of determination (r^2) calculated from least squares regression. Statistical calculations were made by computer using Statview II.

Results

Complete data were obtained from 46 infants. Their characteristics are described in Table 1.

Figures 2 and 3 show the differences between each measurement and the corresponding estimates plotted against the measurements. The observations of all 3 grades of examiner are combined in each plot as the patterns were similar between observers. Both methods of estimation produced a similar distribution of observations with a tendency for examiners to overestimate the compliance of the infants with the lowest measured compliance and underestimate the compliance of the infants with the highest measured compliance. The estimates often differed by considerably more than 50% of the measured compliance. Table 2 shows the coefficients of determination (r^2) of the relationships between the measurements and estimates for each grade of examiner and each method of estimation. In all cases the measurements and estimates were only weakly related with r^2 values ranging from 0.086–0.481. Of the 46 infants, 6 (13%) had measured Crs values > 2.5 ml/cmH_2O/m. The values were 2.6, 2.8, 3.3, 3.5, 5.4, and 7.9.

Table 1 Patient characteristics expressed as median (range)

n	46
Gestational age (weeks)	31 (25–41)
Birth weight (kg)	1.496 (0.533–4.050)
Length (cm)	40 (29–57)
Crs (ml/cmH_2O)	0.518 (0.191–3.782)
Crs (ml/cmH_2O/kg)	0.358 (0.188–1.15)
Crs (ml/cmH_2O/m)	1.3 (0.5–7.9)

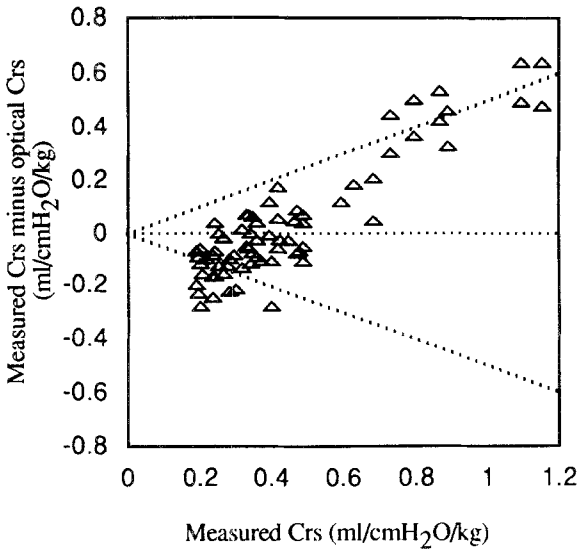

Fig. 2 Difference between measured and optical Crs. *Dotted diagonal lines* denote±50% of the measured Crs

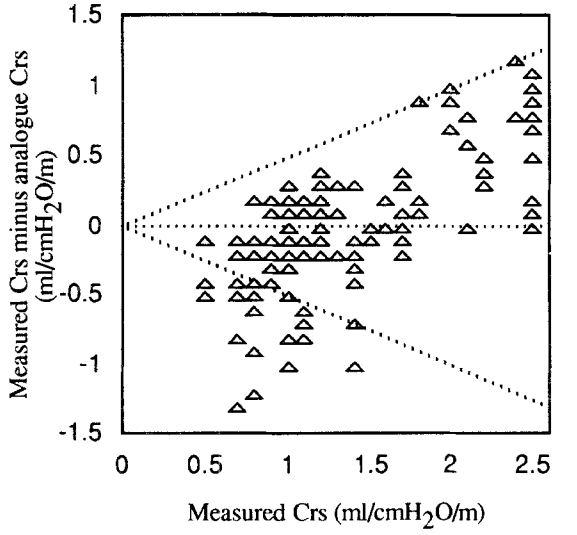

Fig. 3 Difference between measured and analogue Crs. *Dotted diagonal lines* denote±50% of the measured Crs

Table 2 Relationship between optical or analogue estimates and measurements of static respiratory system compliance. The coefficients of determination (r^2) from least squares regression analysis are shown

Observer	Measured and optical Crs	Measured and analogue Crs
SHO	$r^2 = 0.086$	$r^2 = 0.400$
Registrar	$r^2 = 0.184$	$r^2 = 0.194$
Research fellow	$r^2 = 0.254$	$r^2 = 0.481$

Discussion

In this study junior doctors' estimates of static respiratory system compliance were unreliable. Neither method of estimating Crs performed within sufficient limits of accuracy to represent a realistic alternative to direct measurement.

The single breath passive expiratory flow technique for measuring Crs has been used in ventilated infants by many investigators and the Crs values in this study fell within the published ranges of diseased and normal infants. Although the scatter plots suggest that neither method for estimating Crs was clearly superior the r^2 values favoured the analogue estimates. This may be largely attributable to the upper limit of the analogue scale being at a Crs of 2.5 ml/cmH_2O/m. By assigning a value of 2.5 to the six measured Crs values above 2.5, inaccuracies that may have occurred over a wider range were avoided. If the results are reanalysed excluding these 6 datapoints the r^2 values are much closer to those of the optical estimates (SHO $r^2 = 0.342$, Registrar $r^2 = 0.081$, Research Fellow $r^2 = 0.267$).

The two other studies in the literature examining the abilities of doctors to estimate compliance [1, 2] concluded that estimates of optical compliance were closely correlated with measured compliance and may therefore be clinically useful. Both studies used correlation coefficients to describe the relationship between the measurements and estimates and neither expressed the Crs values in relation to the size of the infants. The second study also used the mean difference between the estimates and measurements plus or minus one standard deviation as a measure of agreement. Of the 45 data points in that study 15 fell outside those limits (as would be expected). Of the differences between the estimates and measurements 95% should lie between the mean difference±2 standard deviations. These limits would have been approximately −55% to +41%. The estimates were made by a senior neonatologist and the limits of agreement were considerably narrower than those achieved by the junior doctors in this study but they are still quite wide.

Expression of compliance values in relation to infant size is important for two reasons. Firstly, in normal individuals compliance is proportional to lung and body size so large infants have a higher compliance than small infants. Only by expressing the compliance values in relation to infant size do they truly become a comparative measure of disease severity. Many investigators correct compliance measurements to body weight. We have found in other studies in this age group that correction to body length may be of marginally greater predictive value [4–6], hence the development of the analogue scale corrected for length. Secondly the correlation coefficient between two variables will improve as the range of observations widens [13]. Compliance values are spread over a much wider range if they are not expressed in relation to

body size. If the optical estimates and measurements in this study were considered without correcting them for body weight the range of observations would have been more than 3 times as broad and the r^2 values would have been 0.491 (SHO), 0.587 (Registrar) and 0.572 (Research Fellow). The ranges of observations for the Crs measurements corrected to body length (0.5–2.5, i.e. five fold) and weight (0.188–1.15, i.e. six fold) were similar.

The trend for the compliance of the sickest infants to be overestimated and of the healthiest infants to be underestimated by both methods is a reflection of the tendency of the observers to select values in the middle of the range in the majority of infants. 105/138 (76%) of the optical estimates were for the middle tidal volume option and the standard deviation of the analogue estimates was considerably narrower than that of the compliance measurements. This was also the finding of Aufricht et al. in an inexperienced observer [2]. If the poor reliability of the estimates is due to lack of clinical expertise or confidence it is difficult to speculate on ways of improving the methods of estimation to overcome this.

The measured Crs may not be the gold standard. The more important question is what gives the best indication of disease severity and is most useful in clinical practice. It should be stressed that there is as yet no data which clearly demonstrates that Crs measurements can improve the outcome of neonatal intensive care. In 1982 Crs measurements were found to measure reliably disease severity and predict outcome [14]. Another study has confirmed these findings although the Crs value associated with a high risk of death has lowered with time. This study also suggested that Crs may be a better measure of disease severity in ventilated infants than oxygen requirements [4]. Crs measurements can identify biochemical lung immaturity [5] and measure the response to surfactant treatment [6, 15]. They have been used to measure the effects of bronchodilators [16] and may identify infants suitable for extubation [17]. Automated systems for measuring pulmonary function are becoming increasingly available. If Crs measurement is to become more widely used to assist clinical management then substantial evidence that it can improve clinical outcome is required. This should be properly assessed in the context of a randomised controlled trial.

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