Intraobserver variation in Doppler ultrasound assessment of pulmonary artery pressure

N V Subhedar, N J Shaw

Abstract

Intraobserver variation associated with the non-invasive assessment of pulmonary artery pressure (PAP), using measurement of pulmonary artery Doppler derived systolic time intervals, was investigated. Forty pairs of independent ultrasound examinations of the pulmonary artery were performed by a single observer in 20 preterm infants, median gestation 27 weeks (range 24-31 weeks). Median age at study was 17 days (range 1-47 days). Paired measurements of acceleration time (AT), ratio between acceleration time and right ventricular ejection time (AT:RVET), corrected AT, and corrected AT:RVET were compared to assess intraobserver agreement.

For the corrected AT:RVET ratio, the mean percentage difference between observations was -0.9% (95% confidence intervals -5.0 to 3.1%). The limits of agreement for the two measurements were -26.3 to 24.5%. The coefficient of repeatability was 25.4%. Variation for other indices was similar.

Non-invasive assessment of PAP using Doppler derived systolic time intervals is associated with considerable intraobserver variation.

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Keywords: pulmonary artery pressure, Doppler ultrasound, intraobserver variation, AT:RVET ratio.

Pulmonary artery Doppler ultrasound is being used increasingly to follow changes in pulmonary artery pressure (PAP) in the neonatal period and beyond. PAP has been assessed non-invasively using right ventricular systolic time intervals in healthy term and preterm infants, and those with cardiorespiratory disease. Various indices of pulmonary flow velocity correlate with PAP measured directly at cardiac catheterisation in infants and older children. Time intervals most commonly used include the acceleration time (AT) and the acceleration time to right ventricular ejection time (AT:RVET) ratio. Further correction for variation in heart rate may be made to give the corrected acceleration time (ATc) and corrected acceleration time to right ventricular ejection time ratio (ATc:RVETc). An accurate and reproducible non-invasive method of assessing PAP would allow the role of pulmonary hypertension in respiratory disease and the effects of pulmonary vasodilator treatment to be studied in greater detail.

Although the reproducibility of other Doppler ultrasound measurements has been investigated, there are, to our knowledge, no published studies assessing the variation associated with pulmonary artery Doppler measurements. The aim of this study was to determine the intraobserver variation inherent in using this technique to assess PAP in the newborn period.

Methods

Preterm neonates were studied during either the acute or recovery phase of respiratory distress syndrome (RDS). Doppler examination of the pulmonary artery was performed using a duplex Doppler ultrasound system (Advanced Technical Laboratories, Ultramark IV) incorporating a 7.5 MHz multifrequency imaging transducer combined with a 5 MHz pulsed wave Doppler transducer. A real time two dimensional image of the main pulmonary artery was obtained using either a parasternal short axis or a modified long axis view. The sample volume was placed in the centre of the artery just distal to the pulmonary valve leaflets. Before the Doppler signal was recorded, further manipulation of the transducer was necessary to align properly the ultrasound beam to ensure the angle of insonation was below 20° and to obtain an optimal flow velocity pattern. Using a sweep speed of 100 mm/second, between three and five consecutive systolic waveforms with clearly defined spectral envelopes were selected for measurement of time intervals.

The integrated electronic calipers of the system were used to measure time intervals directly from the frozen ultrasound image on the screen. The R-R interval was measured from a simultaneous ECG trace displayed on the screen. AT was defined as the interval between onset of ejection and time of peak velocity. RVET was the interval between onset and cessation of systolic blood flow. AT:RVET was the ratio between these two intervals. Correction for heart rate was performed by dividing AT and AT:RVET by the square root of the R-R interval to give ATc and ATc:RVETc, respectively.

One or more pairs of examinations were performed on each infant studied by a single observer (NVS). The initial measurement was made "blind" by obscuring the measurement obtained on the screen and printing a hard copy for subsequent analysis. This was immediately followed by a repeat examination on the same baby. Satisfactory Doppler signals were obtained in all infants studied and right
ventricular function, as assessed subjectively by
two dimensional echocardiography, was nor-
mal in all cases. All infants had stable oxygen
saturation throughout the study.

Data from paired observations was analysed
using the method described by Bland and Alt-
man.1 Intraclass correlation coefficient was assessed
by plotting the difference between each pair of
measurements (expressed as a percentage of
their mean value) against the mean value itself.
The study was approved by the local paedi-
actic research ethics committee and
informed parental consent was obtained.

Results
Forty pairs of measurements were made in 20
infants studied. Their median birthweight was
897 (range 680-750) g and gestation 27 (range
24-31) completed weeks. Median age at the
time of study was 17 (range 1-47) days.
Thirteen infants were receiving assisted ven-
tilation and a further two infants were receiving
only supplemental oxygen.

A Bland-Altman plot of the 40 pairs of mea-
surements for the AT:RVET(c) is shown (fig
1). The overall mean percentage difference
between each pair of measurements of
AT:RVET(c) was -0.9% (95% confidence
intervals -5.0 to +3.1%), suggesting that there
was no overall systematic bias between paired
measurements. The limits of agreement, which
included all values between plus and minus 2
SD from the mean, were -26.3 to +24.5%. The
coefficient of repeatability4 was 25.4%. Values
for the other time intervals were similar (table
1).

Discussion
Pulmonary artery pressure may be assessed
non-invasively using Doppler ultrasonography
using one of three methods. Measurement of
the maximal velocity of the tricuspid regur-
gitant jet and subsequent application of the
modified Bernoulli equation,3 or analysis of
maximal ductal flow velocity in a similar way,10
both permit quantification of PAP. Pulmonary
artery systolic time intervals are more widely
applicable in neonatal practice, because the
technique of pulmonary artery Doppler ultra-
sound is more straightforward and satisfactory
recordings can be obtained in almost all infants
by anyone familiar with using a conventional
ultrasound scanner. Such measurements from
the pulmonary artery velocity waveform and
their derived ratios cannot be used to deter-
mine an absolute value of PAP.

This study shows that there is an intraob-
server variation when using Doppler derived
pulmonary artery systolic time intervals which
we believe is clinically important. The method
described by Bland and Altman permits quan-
tification of the degree of agreement between
two measurements of the same variable. The
limits of agreement for independent, paired
observations of AT:RVET(c) were between
-26.3 and +25.4%, suggesting that the esti-
mate of true value would most probably lie
between plus and minus approximately 25% of
any calculated value of AT:RVET(c). For a cal-
culated value of 0.4, the true value would lie
between 0.3 and 0.5. Therefore, we suggest
that repeated measurements be made to help
confirm an isolated abnormal value. Further-
more, expression of AT:RVET(c) and other
time intervals to three decimal places, as is
generally quoted, is inconsistent with the
degree of intraobserver variation found.

There are several potential sources of error
that may have been responsible for the degree
of variation seen in this study. Errors in mea-
surement of time intervals probably ac-
counted for a major part of the total variation.
In particular, there was uncertainty in deciding
precisely when the velocity waveform left the
baseline, reached its peak velocity, and
returned to the baseline. These inaccuracies
were most important when measuring short
time intervals, such as AT, which lasted only
between 25 and 60 ms. As the overall intraob-
server variation associated with measurement
of AT was comparable with other indices, how-
ever, this error was probably balanced by the
need to make only one measurement, whereas
calculation of AT:RVET and AT:RVET(c)
involved two or three separate measurements,
respectively.

The shape of the pulmonary artery wave-
form is influenced by both the position of the
sample volume and the alignment of the ultra-
sound beam within the main pulmonary
artery.11 Two dimensional imaging only allows
for consistent positioning of the sample volume
and beam in one plane, and therefore small
differences in position or direction may have
affected the shape of the waveforms, and hence
the measurements obtained.

The effect of beat to beat variations in stroke
volume, which reflect changes with respiration,
may be minimised by using the mean from a
greater number of waveforms than was used in
this study. Our own observations (unpub-
lished) have shown that the coefficient of varia-
tion for AT:RVET(c) decreases with increasing
waveforms used (from 14.7% with three wave-

Table 1 Analysis of differences between paired measurements of time intervals (%)

<table>
<thead>
<tr>
<th>Time interval</th>
<th>Overall mean difference</th>
<th>Range of observed differences</th>
<th>SD</th>
<th>Limits of agreement</th>
<th>Coefficient of repeatability</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT</td>
<td>-1.2</td>
<td>-26.1 to 29.3</td>
<td>12.8</td>
<td>-26.8 to 24.4</td>
<td>25.6</td>
</tr>
<tr>
<td>AT(c)</td>
<td>-0.7</td>
<td>-28.1 to 30.0</td>
<td>12.5</td>
<td>-25.7 to 24.3</td>
<td>25.0</td>
</tr>
<tr>
<td>AT:RVET</td>
<td>-2.1</td>
<td>-24.8 to 21.6</td>
<td>12.5</td>
<td>-27.1 to 22.9</td>
<td>25.0</td>
</tr>
<tr>
<td>AT:RVET(c)</td>
<td>-0.9</td>
<td>-27.5 to 22.9</td>
<td>12.7</td>
<td>-26.3 to 24.5</td>
<td>25.4</td>
</tr>
</tbody>
</table>
forms to 12.3% with 20 waveforms). Although the limitations of our system prevented us from doing so, calculating the mean ratio from five to 10 waveforms would seem to be a reasonable compromise between improved accuracy and practical acceptability.

Despite the two independent measurements being made within a few minutes of each other, there might have been a change in PAP, although all infants were haemodynamically stable during the study period. Short term variation is common in other cardiovascular parameters,\textsuperscript{12} and similar changes in PAP would have decreased the reproducibility of any method. But as there was no overall systematic difference between observations (the mean observed percentage difference between paired measurements being -0.9\% for AT:RVET(c)), there does not seem to have been any consistent effect from the procedure itself.

The reproducibility of other Doppler measurements has been studied, although there are no published studies of the intraobserver variation associated with other non-invasive methods of estimating PAP. Although a previous study seemed to show good agreement between pairs of measurements of AT:RVET (with a correlation coefficient of 0.92),\textsuperscript{13} only a single examination was performed on each infant with two observers measuring the AT:RVET independently from one hard copy. Our study is fundamentally different and represents the overall variation present when two independent examinations are made by one observer. We have presented our data expressing the difference between pairs of measurements as a percentage of their mean value in order to describe the degree of agreement uniformly across a range of measurements. This allows comparisons to be made of the variation of different methods, rather than merely expressing variation in absolute figures. Direct comparison with other Doppler studies\textsuperscript{8 7} is difficult because different methods have been used to quantify the variation present. Nevertheless, our results are in keeping with the variation observed in these studies.

Recent studies using pulmonary artery Doppler ultrasound have described longitudinal changes in groups of infants with RDS or chronic lung disease of prematurity and have shown trends in non-invasively assessed PAP with time.\textsuperscript{13 14} Despite the inherent intraobserver variation, these authors were still able to demonstrate significant temporal changes. The wide range of values obtained, however, may reflect the degree of variation present. It may be necessary to study a large number of infants to detect small (but perhaps clinically important) differences in Doppler derived time intervals and their ratios.

In conclusion, we have shown that there is considerable intraobserver variation when using Doppler derived systolic time intervals to estimate PAP non-invasively in the neonatal period. As interobserver variation would inevitably be greater still, we suggest that a single observer should make serial measurements in any individual infant. Two consecutive measurements would need to differ by at least 25\% to ensure that a true change in PAP had occurred. Repeated measurements would be helpful to confirm any calculated value, to maximise the reliability of this technique. Although pulmonary artery Doppler measurements offer distinct advantages over other methods of assessing PAP, awareness of these limitations is important.

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