Clinical evaluation and comparison of the Infrasonde, Arteriosonde, and mercury sphygmomanometer in measurement of blood pressure in children

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SUMMARY Both systolic and diastolic pressures can be measured in children with the mercury sphygmomanometer, the Arteriosonde and the Infrasonde. Estimates made blindly with these instruments were compared with directly measured intra-arterial blood pressures in 50 children aged between 4 days and 14 years. Systolic and diastolic estimates with the three techniques showed highly significant correlations with simultaneous intra-arterial measurements (P < 0.001). The Infrasonde diastolic estimates were least satisfactory and the slope of the regression line against the intra-arterial pressure differed significantly from unity (y = 0.54x + 29.53). In 11 small children a satisfactory diastolic estimate could not be obtained with the mercury sphygmomanometer. While the mercury sphygmomanometer should remain the standard hospital equipment, an Arteriosonde would be valuable if it is difficult to hear Korotkoff’s sounds on auscultation and if a diastolic pressure is required. For research investigations into childhood blood pressure an Arteriosonde or mercury sphygmomanometer, coupled with a device to exclude observer bias, is probably most suitable. Although the Infrasonde is not sufficiently accurate for research purposes, it is acceptable for routine ward use.

The importance of blood pressure (BP) measurement in children has been emphasised (Loggie, 1971; Londe et al., 1971; Lauer et al., 1978), but in practice it may present difficulties (Elseed et al., 1973). The use of the mercury sphygmomanometer in routine paediatric practice is established. The many sources of error, such as cuff size, are recognised and most can be avoided (Moss, 1978). It is now generally accepted that the 4th Korotkoff sound, corresponding to the point of muffling as the cuff is deflated, is the best estimate of diastolic pressure in children (American Task Force on Blood Pressure Control in Children, 1977). However, in some individuals no sounds are audible, while in others sounds are detectable continuously down to zero with no recognisable muffle on auscultation. Several new instruments have been developed in an effort to overcome this type of difficulty.

Instruments based on the Doppler principle, e.g. the Roche Arteriosonde 1011*, are already widely used in intensive care despite doubts expressed about the accuracy of the diastolic estimate (Whyte et al., 1975). The Infrasonde 3000* is a newer device, based on the theory that a collapsed artery flutters when a pulse passes into it from the vessel segment under a deflating cuff. This flutter gives rise to low frequency vibrations (infrasound) in the arm tissues which cease when the cuff pressure falls below the diastolic pressure. By detecting these vibrations and reproducing them as an audiosignal, a BP estimate is obtained (Edwards et al., 1976). This instrument is more compact and cheaper than the Arteriosonde but has yet to be evaluated in children.

We wished to assess which of the three instruments was most suitable for use for (a) BP research purposes, and (b) routine clinical practice. In this study systolic and diastolic estimates obtained using the Arteriosonde, Infrasonde, and mercury sphygmomanometer were compared with directly measured intra-arterial pressures.

*Distributed in the UK by Kontron Instruments Ltd., Watford.
Patients and methods

The 50 patients were undergoing cardiac catheterisation to elucidate their congenital heart lesions. Aortic pressure was measured directly as a routine part of these investigations. Indirect BP measurements were performed simultaneously on the right arm unless unequal pressures existed on both sides, e.g. due to the presence of Blalock-Taussig shunt. Patients were between 4 days and 14 years old, with a mean age of 4·76 years. The diagnoses established at catheterisation are shown in Table 1.

Descending aortic pressure was measured in each child via the cardiac catheter (Goodale-Lubin FG 5–7). This was connected to a Bell and Howell pressure transducer (4–422–0001) via a polyethylene connection tube (Lectrocath 115–10 length 100 mm, diameter 2 mm) filled with an 0·18% saline 4·0% dextrose solution and perfused at 6 ml/hour using an inflaflow device (Sorenson Research Co., Utah). This apparatus was calibrated daily against a mercury manometer. The patients’ pressures were recorded on a Mingograph 81 (Elema-Schonander, Siemens, Stockholm) by the cardiac technician.

Arterial pressure was measured in the descending thoracic aorta in all patients, except in one with coarctation in whom the pressure in the ascending aorta was used. Patients in whom direct arterial pressure was obtained from a needle puncture into the right femoral artery were excluded. Such measurements may give a slightly higher reading than aortic pressures obtained via a catheter (Wiggers, 1952; Taylor, 1976).

Simultaneous indirect pressure measurements were recorded independently by a second observer. Cuff size was chosen to cover at least two-thirds of the upper arm as recommended by the American Task Force on Blood Pressure Control in Children (1977). The inflatable portion was chosen to surround the entire arm circumference. With each device the cuff was inflated rapidly to 150 mmHg and then deflated slowly at a rate of 5 mmHg/second.

The Arteriosonde and the Infrasonde were linked to a 2-channel Elcromatic recorder (EM 720) to produce a continuous write-out of cuff pressure and audio signal (Figs 1 and 2). The operator was not aware of the BP estimates by the two instruments nor did he know the result of the direct measurement. Finally the BP was measured carefully with a mercury sphygmomanometer and stethoscope using the standard technique.

The paper records were subsequently examined in the laboratory where the interpretation of systolic pressure was taken as the pressure at the first audio-signal deflection, and the diastolic pressure as that at the change in complex size (Figs 1 and 2). This change in the recorded complex corresponds to the change in the sound produced by the instruments and is recommended by the manufacturers as indicating the diastolic end point.

As the paper recorder would be unsuitable for use with the Infrasonde and the Arteriosonde in routine clinical practice, the study was extended to compare estimates with and without this method of eliminating observer bias. Nurses experienced in the use of these instruments measured BP in 15 children without the recorder. The recording device was immediately connected to each instrument and a second BP estimate obtained from the paper write-out by one of us.

Results

There was good correlation between the estimates of systolic pressure by all three indirect methods when compared with simultaneous intra-arterial measurement: \( r = 0·90 \) (P<0·001) mercury sphygmanometer, \( r = 0·89 \) (P<0·001) Arteriosonde, and \( r = 0·83 \) (P<0·001) Infrasonde (Table 2). Using Fisher’s Z transformation there was no significant difference between these correlation coefficients. The

![Fig. 1 Typical Arteriosonde record: cuff pressure (above) and audiosignal deflections (below).](attachment:image.png)
systolic estimate with each instrument plotted against the simultaneously measured intra-arterial pressure (Figs 3–5) showed that the points were close to each regression line. Student's t test applied to the paired observations indicated a small significant difference between the direct measurement and each of the three noninvasive methods ($P<0.05$). The three instruments slightly underestimated the true systolic pressure, as shown by the mean differences and SDs for each device (Table 2).

Table 2  Results of comparisons of indirect estimates with directly measured blood pressure

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Regression equation</th>
<th>Correlation coefficient</th>
<th>Mean difference $\pm$ SD from direct measurement</th>
<th>Mean $\pm$ SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic BP</td>
<td>$y = 0.87x + 0.90$</td>
<td>$r = 0.90$</td>
<td>$-2.92 \pm 8.68$</td>
<td>$15.56 \pm 0.90$</td>
</tr>
<tr>
<td>Arteriosonde</td>
<td>$y = 0.94x + 0.89$</td>
<td>$r = 0.89$</td>
<td>$-3.49 \pm 8.68$</td>
<td>$9.09 \pm 0.72$</td>
</tr>
<tr>
<td>Infrasonde</td>
<td>$y = 0.94x + 0.83$</td>
<td>$r = 0.83$</td>
<td>$-3.96 \pm 11.86$</td>
<td>$7.73 \pm 0.54$</td>
</tr>
<tr>
<td>Diastolic BP</td>
<td>$y = 0.73x + 0.84$</td>
<td>$r = 0.84$</td>
<td>$1.84 \pm 6.27$</td>
<td>$16.4 \pm 0.74$</td>
</tr>
<tr>
<td>Arteriosonde</td>
<td>$y = 0.9x + 0.72$</td>
<td>$r = 0.72$</td>
<td>$-2.14 \pm 6.23$</td>
<td>$6.44 \pm 0.54$</td>
</tr>
<tr>
<td>Infrasonde</td>
<td>$y = 0.54x + 0.73$</td>
<td>$r = 0.73$</td>
<td>$-3.9 \pm 10.65$</td>
<td>$29.53 \pm 0.73$</td>
</tr>
</tbody>
</table>

Fig. 2  Typical Infrasonde record (above) and Mingograph intra-arterial record (below).

The diastolic estimates with the three indirect methods also showed good correlation (Figs 6–8) with direct measurement: $r = 0.84$ ($P<0.001$) mercury sphygmomanometer, $r = 0.72$ ($P<0.001$) Arteriosonde, and 0.73 ($P<0.001$) Infrasonde. As can be seen, the diastolic correlations were less satisfactory than the systolic (Table 2). Using Fisher's Z transformation, there was no significant difference between the diastolic correlations with
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each instrument. Student's t test applied to the

paired diastolic results indicated a small significant
difference between intra-arterial diastolic pressure

and estimates from the three instruments. Although

both Infrasonde and Arteriosonde underestimated

the diastolic pressure we found the mercury sphygmomanometer gave a slight overestimate in terms of

mean difference from direct arterial measurement

(Table 2). Only with the Infrasonde diastolic

regression line (Fig. 8) is there a significant difference

in the slope from unity ($y = 0.54x + 29.53$).

There were 11 patients aged between 4 days and

4.5 years in whom the diastolic end point could not

Fig. 4 Relationship and regression line of Infrasonde

estimate and intra-arterial systolic pressure.

Fig. 5 Relationship and regression line of Arteriosonde

estimate and intra-arterial systolic pressure.

Fig. 6 Relationship and regression line of mercury

sphygmomanometer estimate and intra-arterial diastolic

pressure.

Fig. 7 Relationship and regression line of Infrasonde

estimate and intra-arterial diastolic pressure.
be clearly established on auscultation. In this instance, therefore, statistical analysis is based on the remaining 39 (Fig. 6).

The difference between the Arteriosonde and the Infrasonde estimates obtained by experienced nursing staff using standard instruments compared with results obtained by the blind technique using a paper recorder were not significant: Arteriosonde both systolic and diastolic $r = 0.71$ (P < 0.01), Infrasonde systolic $r = 0.81$ (P < 0.001), diastolic $r = 0.76$ (P < 0.01).

### Discussion

Direct intra-arterial measurement of systolic and diastolic pressures had previously been compared with indirect estimates in the case of the mercury sphygmomanometer (Holland and Humerfelt, 1964; Elseed et al., 1973) and the Arteriosonde (Hernandez et al., 1971; Elseed et al., 1973). However, the Infrasonde 3000 had not been assessed in this way in adults or children.

We found that systolic pressure estimates with all three instruments showed highly significant correlations with intra-arterial pressure and there were no significant differences between estimates with any. The three techniques slightly underestimated the true systolic pressure but the slopes of the regression lines (Figs 3–5) did not suffer significantly from zero. These findings suggest that the systolic estimate using the Arteriosonde, Infrasonde, and the mercury sphygmomanometer are sufficiently accurate for research purposes. The incorporation of the Elcomatic recorder in our apparatus has excluded observer bias from the Arteriosonde and Infrasonde readings. This can also be achieved with the mercury sphygmomanometer using the London School of Hygiene’s random zero instrument (Holland, 1963).

It is interesting to see that systolic and diastolic pressure results obtained by experienced nurses using the instruments alone did not differ statistically from those obtained using the unbiased technique.

The diastolic pressure estimates with the three instruments also showed highly significant correlations with intra-arterial pressure and there was no statistical difference between correlations obtained by each (Table 2). However, examination of the diastolic regression lines (Figs 6–8) showed that the slope of the Infrasonde line differed significantly from unity on Student’s $t$ test. The diastolic estimates obtained with the Arteriosonde with observer bias excluded, were more reliable than suggested by Whyte et al. (1975) who did not use such a technique. We feel that although the Arteriosonde and mercury sphygmomanometer used as described would be reliable enough for research investigations, the Infrasonde diastolic estimate would not.

Diastolic estimates were generally not as accurate as systolic estimates and, in some cases, could not be obtained at all with the mercury sphygmomanometer. However, as systolic pressures in adults have the best correlations with morbidity and mortality (Kannel and Dawber, 1974) it is possible that the importance of the diastolic BP has been exaggerated.

We found by using a blind technique that the Arteriosonde gave highly accurate estimates of both systolic and diastolic pressure. However, these results were no better than those obtained by the mercury sphygmomanometer used conventionally by an experienced observer. The Infrasonde recorded only systolic pressure with a similar degree of accuracy. We suggest, therefore, that for research the Arteriosonde or mercury sphygmomanometer be employed, with a device to eliminate observer bias. The Arteriosonde has the advantage of providing a diastolic estimate in all cases. These three instruments were all suitable for routine clinical monitoring of children’s BP. Although we found that the Infrasonde diastolic estimate was the least accurate, it is acceptable for routine clinical use and is considerably cheaper than the Arteriosonde. This study supports the continued use of the mercury sphygmomanometer for daily use, but in circumstances where an accurate diastolic estimate is required, the Arteriosonde would be preferred.
We thank the medical, nursing, and technical staff of the cardiac catheterisation room and the nursing staff of the renal unit, The Hospital for Sick Children, for their patience and help during the study, and especially Drs K. Daley and P. G. Rees.

J.M.S. holds a Medical Research Council Training Fellowship.

References

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Received 18 July 1978