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An Automated Oscillometric Technique for Estimating Mean Arterial Pressure in Critically Ill Newborns

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A variety of noninvasive techniques are currently available for the measurement of blood pressure in the neonate, but each method has significant shortcomings. Flush and palpation methods are critically dependent upon technique and skill, and are not sufficiently accurate to justify continued use.[1–3] Auscultatory methods are usually not feasible in the critically ill neonate, particularly in the noisy environment of the newborn intensive care unit.[1–3] A number of electronic devices are capable of accurate noninvasive measurement of systolic arterial pressure, but measurement of diastolic pressure is either much less accurate or impossible with each of them.[4–8]

Many centers continue to rely upon invasive techniques of blood pressure monitoring in the sickest neonates. As improved methods for direct measurement of arterial pressure have become available, there has been an increased practice of recording mean arterial pressure (MAP), perhaps because simultaneous continuous fluid administration and continuous monitoring of nondamped systolic pressures cannot be easily accomplished in newborns. While the superiority of MAP to systolic or systolic/diastolic pressures as a basis for clinical decision making remains debatable, a noninvasive technique for direct, rather than calculated, measurement of MAP would be of value. Oscillometric techniques first described by Marey,[9] and most recently applied by Yelderman and Ream[10] in adult patients undergoing cardiac surgery, can provide accurate noninvasive measurements of MAP. A commercial instrument which automatically determines MAP using this technique is also available.** A detailed description of its mode of operation has been previously reported.††

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** Dinamap®, Applied Medical Research Corporation, 5041 West Cypress Street, Tampa, Florida 33607.

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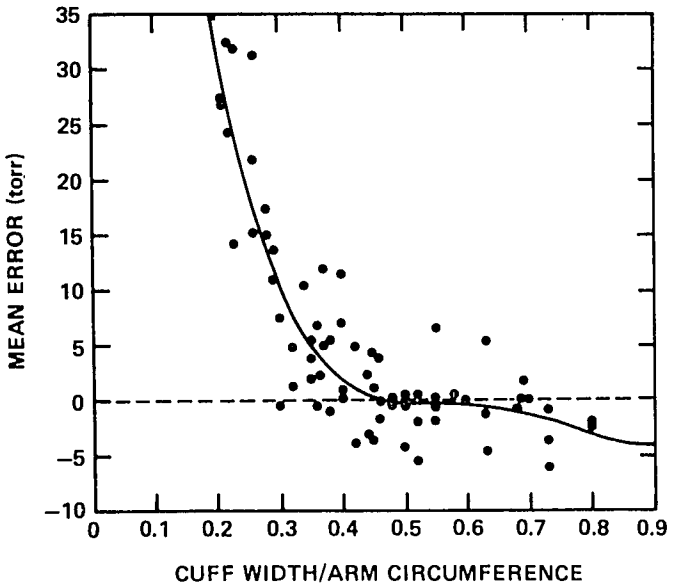

FIG. 1. A non-linear regression analysis comparing error (Dinamap®–intra-arterial) with cuff width to arm circumference ratio. Each point represents the average of 10 determinations with the same cuff in a given patient.

We designed this study to determine whether or not the oscillometric technique can be used to provide accurate measurements of MAP in critically ill neonates, and to assess the performance of a commercially available instrument in such patients. The study was also designed to determine the appropriate cuff size to use with this instrument.

METHODS

Seventeen newborn infants requiring an indwelling umbilical arterial catheter for their care were chosen for the study. They ranged from 28 to 40 weeks gestation (mean 34.8 ± 3.6) and weighed from 740 to 3600 g (mean 2185 ± 939).

A 5-F umbilical catheter had been previously placed in each infant, and the tip adjusted to the level of L3-L4 on a standard AP portable roentgenogram. The catheter was liquid coupled via 0.6–1.2 m of noncompliant tubing to a pressure transducer (Statham®, model P23Db) located at heart level, and coupled to a clinical monitor (Hewlett-Packard®). Blood pressure waveforms were continuously displayed during the study, and data collection was discontinued if any damping occurred. The outputs from the intra-arterial transducer and the Dinamap® were simultaneously digitalized by an analog to digital converter (Hewlett-Packard®, model 47310A) and a calculator (Hewlett-Packard®, model HP9825A) and stored on magnetic tape for subsequent evaluation. Measurements were made with each of four different sized cuffs, 2.2 × 5.9 cm, 3.0 × 6.8 cm, 3.8 × 10.2 cm, and 4.4 × 11.2 cm. Using noncompliant tubing, the cuff was coupled to the Dinamap®. Both the transducer connected to the arterial catheter and the Dinamap® were calibrated using a mercury manometer.

The cuff order was randomized and 10 determinations for each cuff were made on each infant. The cuff was rapidly inflated to suprasystolic pressure and deflated in decrements of 3–6 torr over 30 s to infradiastolic pressure. Each cuff was left in place during the ten measurements, and there was no delay between measurements. Occasionally, an infant would become restless between measurements, and in such cases was allowed to become quiet before the next determination.

For each patient, the mean error and standard deviation of the error were calculated for each cuff. The error was defined as the Dinamap® value minus the intra-arterial value. Nonlinear regression analysis was then performed comparing mean error with the ratio of cuff width to arm circumference. The latter was measured at the mid-upper arm with a 1-cm wide tape. An arbitrary range of cuff width to arm circumference ratios over which the error was small was then selected, and all data from cuff-infant combinations within this range were pooled. Mean error and standard deviation were then calculated, and linear regression analysis performed.

RESULTS

Analysis of individual patient data revealed mean errors ranging from 0.0 ± 2.1 to 32.2 ± 5.9 torr. Fourth order nonlinear regression analysis plotting mean error against cuff width to arm circumference ratio revealed a sharp increase in the mean error when this ratio fell below 0.45, and a less dramatic increase when it exceeded 0.70 (fig. 1). We therefore evaluated all determinations where the ratio fell between these limits. Two hundred fifty determinations on 13 different infants were thus grouped and analyzed. The mean error for these grouped data was −0.2 torr with a standard deviation of 3.8 torr. Linear regression analysis for the grouped data revealed an r value of 0.853, a standard deviation about the line of 3.68 torr, and a regression line of $Y = 0.822\ X + 7.480$ (fig. 2).

DISCUSSION

The Dinamap® compares favorably with other noninvasive methods of blood pressure determination. Limited statistical analysis in other studies, and the inability of other techniques to measure MAP, somewhat limit comparison. Black *et al.*[5] evaluated the Doppler technique in 28 infants weighing between 4.5

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and 11 lbs., comparing systolic and diastolic pressures to simultaneously obtained measurements from arterial catheters. They reported mean errors and standard deviations of −2.48 ± 1.99 torr for systolic, and +3.32 ± 2.37 torr for diastolic pressures.

Dweck *et al.*,[6] again using a Doppler device, compared their measurements with readings obtained via catheters. In 40 newborns, they obtained r values of 0.79 and 0.56 for arm systolic and diastolic pressures, and 0.75 and 0.80 for leg systolic and diastolic pressures respectively.

Bucci *et al.*[11] used a xylol pulse indicator to measure systolic pressure in 10 low-birthweight newborns. A mean error of −0.50 torr with a standard deviation of 1.4 torr compared with direct arterial pressures was found. Diastolic pressures could not be measured with this device.

Reder *et al.*[8] compared three modern electronic systems which use either a transducer to detect ultrasonic or filtered low-frequency sounds, or a Doppler ultrasonic flow detector, to measure blood pressure in 45 infants and children, and compared their results to direct arterial pressures. Although all three systems gave acceptable results for systolic arterial pressure, measurements of diastolic pressure were either not possible, or were much less accurate. These authors concluded that "an accurate, indirect marker for end diastole is not currently available." Even granting that appropriate assumptions regarding pressure wave contour and heart rate can be made to allow calculation of MAP from noninvasively measured systolic and diastolic pressures, a MAP so derived will be at least as unreliable as the diastolic pressure upon which it is based. The Dinamap® thus constitutes the only currently available technique for the accurate, noninvasive measurement of mean arterial pressure in the newborn infant.

Our results demonstrate the importance of cuff size if reliable results are to be obtained in newborns. For practical purposes, selecting a cuff of a width which encircles one-half to two-thirds of the infant's mid-upper arm will assure maximal accuracy.

The only problem encountered with this technique was that, as with any technique employing an occlusive cuff, the subject must remain reasonably still during the pressure measurement (usually 20–30 s).

In comparison with other noninvasive methods, the Dinamap® has the advantages of ease of operation, direct measurement (rather than calculation), and digital read-out of mean arterial pressure, completely automatic cycling at intervals as frequent as every 60 s, and superior accuracy in the determination of MAP when the aforementioned constraints regarding cuff size are observed.

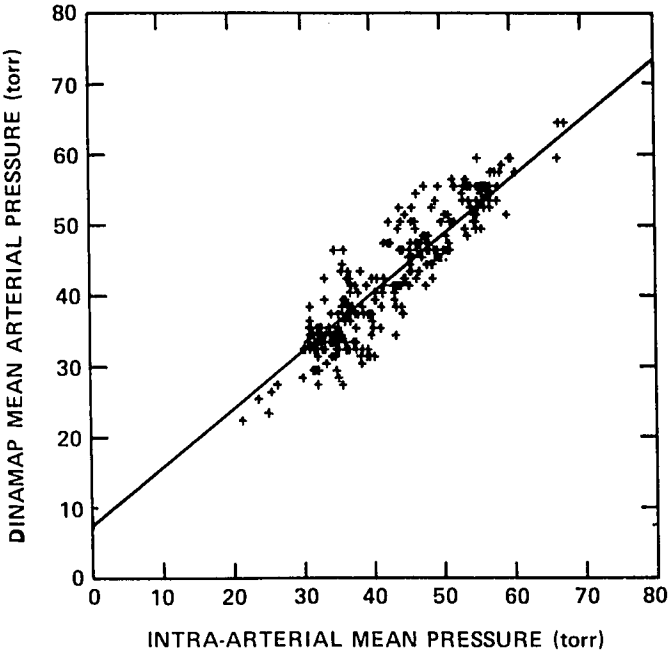

FIG. 2. A comparison of intra-arterial and Dinamap mean blood pressure determinations where cuff width to arm circumference ratio is between 0.45 and 0.70 (linear regression analysis). Each data point represents a single measurement in a given patient.

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