Equipment

Systolic arterial pressure determination by a new pulse monitor technique

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The Doppler ultrasound (DUS) technique is a widely accepted non-invasive technique to estimate systolic blood pressure (SBP) accurately in paediatric patients. The DUS has a number of limitations. A new pulse monitor, Mr Pulse (MP), operating on the principle of a finger plethysmograph, was developed to offer an alternative technique to estimate SBP. From 104 paired SBP measurements taken in 16 paediatric patients undergoing general anaesthesia, SBP determined by the MP technique correlated closely with that by the standard DUS technique ($r^2 = 0.98$). Analysis of degree of agreement performed indicated that there was good agreement between SBP obtained by the MP and the DUS techniques. The mean $\pm$ standard deviation of differences in paired SBP values between the two measurement techniques was 0.55 ± 3.59 mmHg. Mr Pulse is as accurate as the DUS technique in estimating SBP and has the advantage of less critical sensor positioning as it is not subject to electrical interference. It has no electrical hazard.

Les appareils à ultrasons avec effet Doppler (UED) sont couramment utilisés pour évaluer de façon non-invasive la pression systolique chez les enfants. La technique des UED a plusieurs limites. Un nouveau moniteur de pouls appelé « Mr. Pulse » a récemment été développé afin de permettre une autre

façon d'évaluer la pression systolique. Cette nouvelle technique utilise la pléthysmographie digitale. Chez 16 patients pédiatriques, 104 mesures appariées de pression systolique ont permis d'établir qu'il existe une excellente corrélation entre les valeurs obtenues avec « Mr. Pulse » et celles obtenues avec un appareil à UED ($r^2 = 0,98$). La concordance entre les mesures obtenues avec les deux méthodes est aussi très bonne puisque la moyenne des différences ($\pm$ écart-type) entre les valeurs mesurées par les deux techniques n'est que de $0,55 \pm 3,59$ mmHg. Mr. Pulse est donc aussi précis que les appareils à UED dans l'évaluation de la pression systolique. Mr. Pulse a l'avantage d'avoir un capteur moins sensible au positionnement et aux interférences électriques, et il ne présente aucun risque de fuite de courant électrique.

Key words

MEASUREMENT TECHNIQUES: blood pressure, Doppler ultrasound;
MONITORING: blood pressure;
EQUIPMENT: Doppler, Mr Pulse.

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The Doppler ultrasound technique has been widely used in paediatrics to estimate systolic arterial blood pressure (SBP) accurately. However, the Doppler technique can be affected by electrical interference, e.g., electrocautery, sensor probe displacement and movement artifacts. In order to minimize the problems associated with the Doppler ultrasound, a new pulse monitor (Mr Pulse) was recently developed (Figure 1). This new pulse monitor is based on the principle of a finger plethysmograph which transforms a change in volume into a change in pressure.¹ The sensor (Figure 2) consists of a small air-filled chamber that is taped to the pulp of a distal phalanx. An increase in the pulp volume with each arterial pulsation decreases the volume of the sensor. This change in volume is transmitted as a pressure wave along a narrow plastic tubing to the pressure transducer in the monitor. There, the pressure wave is transformed into an audible signal. The purpose of this study was to establish the degree of agreement between SBP measurements obtained with Mr Pulse and a standard Doppler technique.

Methods

After institutional approval, consecutive ASA physical status I or II paediatric patients undergoing general anaesthesia were studied. Surgical procedures performed

FIGURE 1 Mr Pulse monitoring unit. The light-emitting diode indicating arterial pulsation is located in the lower left corner of the unit.

included cardiac, neurological, spinal and general surgery. Standard aneroid sphygmomanometers with appropriately sized cuffs and Parks Electronics Model 811 Ultrasound Doppler units were used. The Mr Pulse sensor was applied to the distal phalanx with tape and the Doppler sensor was applied over the ipsilateral radial artery. To obtain a SBP measurement, the blood pressure cuff was inflated until the pulse and Doppler signals were eliminated. The cuff was then deflated at a rate of $2 \text{ mmHg} \cdot \text{sec}^{-1}$. The pressures at which the Mr Pulse and Doppler signals reappeared were recorded.

The correlation of SBP values obtained with both techniques was compared using least squares linear regression analysis and the coefficient of determination (r^2). As suggested by Bland and Altman,² in order to replace an established measurement technique (DUS) by a new one (MP), the degree of agreement between measurements obtained by the two techniques needs to be established. First, we decided, *a priori*, that the clinically acceptable range of deviation from the "true" SBP values would be $\pm 10 \text{ mmHg}$, i.e., a SBP measurement in the range of 90 to 110 mmHg would be acceptable for a "true" SBP value of 100 mmHg. Subsequently, from prospectively collected SBP values, the 95% confidence interval in differences between paired SBP measurements was calculated by the mean $\pm$ two standard deviations (SD). Assuming a normal distribution, 95% of the differences between paired SBP would fall within the range of mean $+2\text{SD}$ and mean -2SD . If this calculated 95% confidence interval falls within the previously set clinically acceptable range of deviation, then the degree of agreement between the two methods is considered to be good.

Results

One hundred and four paired systolic blood pressure (SBP)

FIGURE 2 The silastic pulse sensor is shown over a finger and subsequently taped onto it.

measurements were obtained in 16 patients. The patients' ages ranged from 18 days to 16 yr with a median age of four years. There were eight boys and eight girls. Systolic blood pressures obtained by MP were plotted against that obtained by the DUS technique (Figure 3). The coefficient of determination (r^2) was 0.97. The differences in paired SBP values were plotted against SBP by the DUS technique (Figure 4). The mean $\pm$ SD of differences in paired SBP values between MP and DUS techniques was $0.55 \pm 3.59 \text{ mmHg}$. The 95% confidence interval (mean $\pm 2\text{SD}$) = 7.75 to -6.65 mmHg is shown in Figure 4. This 95% confidence interval falls within the acceptable range of deviation of $\pm 10 \text{ mmHg}$.

Discussion

In the present study, the calculated 95% confidence interval for differences in paired SBP values between the MP and DUS techniques was found to fall within the previously decided clinically acceptable range of deviation. We concluded that there was good agreement between SBP measurements obtained by the new MP technique and the established DUS technique.

FIGURE 3 Systolic blood pressure (SBP) measurements by the Mr Pulse technique are plotted against the paired SBP measurements by the Doppler ultrasound technique.

We did not attempt to compare SBP obtained by MP with that by invasive arterial cannulation technique due to the limitations and potential inaccuracies associated with the latter. Firstly, the invasive nature and associated complications limit its use.³ Secondly, invasive SBP measurements are subject to errors generated during zeroing and calibration. Thirdly, the physical characteristics of the external transducer system have to be accounted for.^{4,5}

Doppler ultrasound is considered to be an accurate and widely accepted non-invasive technique to estimate SBP in children. Reder *et al.*⁶ compared SBP determined by three indirect non-invasive blood pressure measuring systems (Arteriosonde, Infrasonde and Pedisphyg) with that obtained by subclavian intra-arterial monitoring in 45 paediatric patients. The SBP values obtained by the Pedisphyg system utilizing a blood pressure cuff and a DUS detector correlated very well with the values obtained invasively ($r = 0.99$). Steinfeld *et al.*⁷ found the DUS a more accurate method in measuring SBP than by auscultation.

Two recent reports assessed the correlation of SBP measurements by pulse oximeter and Doppler techniques. Wallace *et al.*⁸ compared 729 paired SBP readings obtained by oximetric or DUS technique and showed a high degree of correlation ($r = 0.93$). Korban *et al.*,⁹ in a similar study, compared SBP determined by pulse oximetry or Doppler during cuff inflation (ascending) and cuff deflation (descending). They found a very close correlation of SBP by the ascending technique with the DUS technique ($r = 0.99$). The descending technique consistently underestimated the SBP as there was a time

FIGURE 4 The differences in paired systolic blood pressure (SBP) measurements are plotted against SBP measurements by the Doppler technique. The mean, mean + 2SD and mean - 2SD values are shown in the graph.

lag for arterial pulse detection during the cuff deflation phase.

Non-invasive SBP determination in children is more difficult than in adults because of the small limb size, requirement for varying cuff sizes, difficulty in auscultation and lack of cooperation. The DUS technique, although widely used and accepted as a standard in SBP measurement, has its limitations. The DUS sensor position is highly critical and the DUS is subject to electrical interference by electrocautery application. Mr Pulse was developed in an attempt to overcome these difficulties.

We found a high degree of correlation ($r^2 = 0.97$) in SBP obtained by the MP and the DUS techniques. However, this high correlation does not necessarily mean that values obtained with the two techniques agree. The coefficient of determination measures the strength of relationship between the two variables, not the agreement between them. There is perfect correlation if the points in Figure 3 lie along any straight line but there will be perfect agreement only if the points lie along the line of equality. In our study, we wanted to determine if a new measurement technique (MP) could replace an established DUS technique. This is possible only if there is good agreement in values obtained by the two techniques. Our data indicated good agreement between SBP values obtained by MP and DUS techniques and that MP could be used as an alternative technique to accurately measure SBP.

After experience with MP, we found several limitations in SBP determinations by the MP techniques. Mr Pulse was unable to detect arterial pulsation in several patients with severe peripheral vasoconstriction, low cardiac output

states or SBP less than 40 mmHg. However, there were also difficulties in detecting flow with DUS in the same patients. We also noted that the differences in SBP by the two measurement techniques increased when SBP values were less than 60 mmHg. The accuracy of SBP determinations by MP needs to be further assessed in this subset of patients.

Mr Pulse is as accurate as the Doppler ultrasound technique in estimating SBP. In comparison with the Doppler ultrasound, Mr Pulse has the following advantages: the sensor is quick and easy to apply; the sensor position is not critical; it is not subject to electrical interference, e.g., electrocautery; there is no electrical hazard and it is relatively inexpensive.

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