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Protocol for Measurement of Mean Arterial Pressure at 11–13 Weeks' Gestation

L.C.Y. Poon[a] N.A. Zymeri[a] A. Zamprakou[a] A. Syngelaki[a] K.H. Nicolaides[a, b]

[a]Harris Birthright Research Centre of Fetal Medicine, King's College Hospital, and [b]Department of Fetal Medicine, University College Hospital, London, UK

Key Words
First-trimester screening · Blood pressure · Preeclampsia · Methodology

Abstract
Objectives: To identify the best protocol for measurement of mean arterial pressure (MAP) in early pregnancy for the prediction of preeclampsia (PE). ***Methods:*** This was a prospective study in singleton pregnancies attending for a routine hospital visit at 11–13 weeks' gestation when a minimum of four recordings of MAP were taken from each arm. The performance of screening for PE by different combinations of MAP was compared to the protocol of the National Heart Foundation of Australia (NHFA). ***Results:*** The MAP was measured in 587 (2.4%) cases that developed PE and in 22,900 that were unaffected by hypertensive disorders in pregnancy. The area under the receiver operating characteristic curve (AUROC) for prediction of PE by MAP as recommended by the NHFA protocol was 0.773 (95% CI 0.768–0.778). This AUROC was not significantly different from the AUROC obtained by the average MAP of the first three measurements from one arm (0.765, 95% CI 0.760–0.771) or the average of the first (0.766, 95% CI 0.760–0.771), the first two (0.771, 95% CI 0.766–0.777), or the first three measurements from the two arms (0.773, 95% CI 0.768–0.778). ***Conclusion:*** Performance of screening for PE by taking the average of a minimum of two measurements from both arms is comparable to the NHFA protocol.

Introduction

Effective prediction of preeclampsia (PE) can be achieved at 11–13 weeks' gestation by a combination of maternal characteristics, mean arterial pressure (MAP), uterine artery pulsatility index, maternal serum placental growth factor and pregnancy-associated plasma protein-A [1]. There is extensive evidence that there is considerable individual variability in blood pressure and that the first recording is often higher than subsequent ones [2–6]. It is therefore recommended by professional bodies that a series of blood pressure measurements should be made until a prespecified level of stability is achieved [7, 8]. It is also recommended that the blood pressure should be recorded in both arms because of large inter-arm variations which are not confined to pathological conditions, such as dissection or coarctation of the aorta, peripheral vascular disease and unilateral neurological and muscu-

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Prof. K.H. Nicolaides
Harris Birthright Research Centre for Fetal Medicine
King's College Hospital
Denmark Hill, London SE5 9RS (UK)
Tel. +44 203 299 8256, E-Mail kypros@fetalmedicine.com

loskeletal abnormalities, but it is also found in normal healthy individuals [9, 10].

The National Heart Foundation of Australia (NHFA) has recommended that blood pressure should be measured in both arms and a minimum of two recordings should be made at 1-min intervals until variations between consecutive readings fall to within 10 mm Hg in systolic blood pressure and 6 mm Hg in diastolic blood pressure in both arms [7]. When this point of stability is reached, the average of the last two stable measurements of the left and right arms is calculated and it is recommended that the highest of these two measurements from the two arms should be used [7].

The objective of this study is to identify the simplest protocol for measurement of MAP at 11–13 weeks' gestation that could achieve a comparable performance in the prediction of PE to that obtained using the NHFA protocol.

Methods

This was a prospective screening study for hypertensive disorders in women attending for their routine first hospital visit in pregnancy at King's College Hospital, University College London Hospital and Medway Maritime Hospital. In this visit, which is held at 11^{+0}–13^{+6} weeks' gestation, all women have an ultrasound scan to confirm gestational age from the measurement of the fetal crown-rump length, to diagnose any major fetal abnormalities and measure fetal nuchal translucency thickness as part of screening for aneuploidies [11, 12]. We recorded maternal characteristics and medical history and measured blood pressure by automated devices [13]. Written informed consent was obtained from the women agreeing to participate in the study, which was approved by the Ethics Committee of each participating hospital.

We prospectively examined 25,505 singleton pregnancies between February 2007 and February 2011. We excluded 1,363 (5.3%) because they had missing outcome data (n = 873), there was a major fetal defect (n = 51) or aneuploidy (n = 96), the pregnancies resulted in fetal death or miscarriage before 24 weeks of gestation (n = 238) or the women underwent termination of pregnancy (n = 105). In the remaining 24,142 cases, there were 587 (2.4%) that developed PE, 655 with gestational hypertension (GH) and 22,900 (94.9%) cases that were unaffected by PE or GH.

Blood pressure was taken by automated devices (3BTO-A2; Microlife, Taipei, Taiwan), which were calibrated before and at regular intervals during the study [13]. The recordings were made by doctors who had received appropriate training on the use of these machines. The women were in the seating position, their arms were supported at the level of their heart and either a small (<22 cm), normal (22–32 cm) or large (33–42 cm) adult cuff was used depending on the mid-arm circumference [7]. After rest for 5 min, blood pressure was measured in both arms simultaneously and a series of four recordings were made at 1-min intervals. When the last two blood pressure measurements in either arm differed by more than 10 mm Hg in systolic and 6 mm Hg in diastolic blood pressure, more recordings were made in both arms until variations between consecutive readings fell to within 10 mm Hg in systolic and 6 mm Hg in diastolic blood pressure.

Outcome Measures

The definitions of PE and GH were those of the International Society for the Study of Hypertension in Pregnancy [14]. In GH the diastolic blood pressure should be 90 mm Hg or more on at least two occasions 4 h apart developing after 20 weeks of gestation in previously normotensive women in the absence of significant proteinuria and in PE there should be GH with proteinuria of 300 mg or more in 24 h or two readings of at least ++ on dipstick analysis of midstream or catheter urine specimens if no 24-hour collection is available. In PE superimposed on chronic hypertension, significant proteinuria (as defined above) should develop after 20 weeks of gestation in women with known chronic hypertension (history of hypertension before conception or the presence of hypertension at the booking visit before 20 weeks of gestation in the absence of trophoblastic disease).

Data on pregnancy outcome were collected from the hospital maternity records or their general medical practitioners. The obstetric records of all women with preexisting or pregnancy-associated hypertension were examined to determine if the condition was PE or GH.

Statistical Analysis

Descriptive data were presented in median and interquartile range (IQR) for continuous variables and in numbers and percentages for categorical variables. Comparison between the outcome groups was by χ^2 or Fisher's exact test for categorical variables and Mann-Whitney U test for continuous variables.

Based on the NHFA protocol [7], we calculated the MAP of each arm as the average of the last two stable measurements and as recommended we took the arm with the highest final MAP for the subsequent analysis of results. Based on the first four recordings from both arms, 50 possible combinations of MAP were generated. The performance of screening for each of these 50 combinations was determined by the area under the receiver operating characteristic curve (AUROC) and this was compared to the AUROC of the NHFA protocol [15].

The statistical software package SPSS 18.0 (SPSS Inc., Chicago, Ill., USA) and MedCalc (MedCalc Software, Mariakerke, Belgium) were used for all data analyses.

Results

The maternal characteristics of the outcome groups are presented in table 1. In the 24,142 cases included in the study, according to the NHFA protocol the point of stability in blood pressure (difference between two measurements of <10 mm Hg for systolic and <6 mm Hg in diastolic blood pressure) was reached after two recordings in 11,618 cases (48.1%), three in 5,784 (24.0%), four in 6,305 (26.1%) and five or more in 435 (1.8%).

The median and IQR of MAP by different methods of measurements in the 587 cases that developed PE and the

Table 1. Maternal characteristics in the outcome groups

Maternal characteristic	Control (n = 22,900)	PE (n = 587)	p
Maternal age, years	26.6 (26.6–34.9)	31.8 (26.4–36.3)	0.003*
Weight, kg	65.3 (58.6–75.4)	72.2 (63.9–85.0)	<0.0001*
Height, m	1.64 (1.60–1.69)	1.64 (1.60–1.68)	0.042*
Racial origin			
Caucasian	16,449 (71.8)	304 (51.8)	0.0001*
Afro-Caribbean	4,074 (17.8)	226 (38.3)	0.0001*
South Asian	1,143 (5.0)	38 (6.5)	0.127
East Asian	650 (2.8)	8 (1.4)	0.044*
Mixed	584 (2.6)	12 (2.0)	0.524
Parity			
Nulliparous	11,446 (50.0)	348 (59.3)	<0.0001*
Parous – no previous PE	10,851 (47.4)	146 (24.9)	<0.0001*
Parous – previous PE	603 (2.6)	93 (15.8)	<0.0001*
Cigarette smoker	2,145 (9.4)	37 (6.3)	0.014*
Family history of PE – mother	1,035 (4.5)	60 (10.2)	<0.0001*
Conception			
Spontaneous	22,185 (96.9)	552 (94.0)	0.0002*
Ovulation drugs	220 (1.0)	8 (1.4)	0.442
In vitro fertilization	495 (2.2)	27 (4.6)	0.0001*
Chronic hypertension	266 (1.2)	68 (11.6)	<0.0001*
Diabetes mellitus	154 (0.7)	14 (2.4)	<0.0001*

Values are median (range) or n (%). Comparison between the outcome groups was by χ^2 or Fisher's exact test for categorical variables and Mann-Whitney U test for continuous variables. * $p < 0.05$.

22,900 cases that were unaffected by hypertensive disorders in pregnancy are presented in table 2. The median MAP by all 50 possible protocols was significantly higher in the PE than in the unaffected group ($p < 0.0001$).

The AUROC and the detection rates of PE for false positive rates of 5 and 10% in screening by MAP measured as per the NHFA protocol and by the 50 combinations of MAP based on the first four recordings are given in table 3. The AUROC for prediction of PE by MAP as recommended by the NHFA protocol was 0.773 (95% CI 0.768–0.778). This AUROC was significantly higher than the AUROC obtained from the first, second, third or fourth measurement of MAP from either the left or the right arm and from most combinations of two of these four measurements from either arm. The AUROC from the NHFA protocol was not significantly different from the AUROC obtained by the average MAP of the first measurement from the two arms (0.766, 95% CI 0.760–0.771), the average of the first two measurements from the two arms (0.771, 95% CI 0.766–0.777), the average of the first three measurements from the two arms (0.773, 95% CI 0.768–0.778) or the first three measurements from one arm (0.765, 95% CI 0.760–0.771) or all four measurements from one arm (0.766, 95% CI 0.761–0.771).

The patient-specific risks for development of PE from MAP at 11–13 weeks' gestation, recorded as the average of the first one, two and three measurements from the two arms are illustrated in figure 1. The patient-specific risks for PE were calculated from the formula: odds/(1 + odds), where odds = e^Y and Y was derived from logistic regression analysis of each MAP measurement in the prediction of PE (table 4).

Discussion

The findings of this study demonstrate that in first-trimester screening for PE by MAP, the best performance is provided by following the NHFA protocol [7]. However, in order to achieve the necessary point of stability in blood pressure according to this protocol it was necessary to perform a minimum of two measurements from both arms in about 50% of cases, three measurements in 25%

Table 2. Median and IQR of MAP (in mm Hg) by different protocols for measurements of MAP in the outcome groups

Blood pressure protocol	Unaffected (n = 22,900)		PE (n = 587)		p
	median	IQR	median	IQR	
NHFA	86.0	80.7–91.5	95.2	89.2–102.2	<0.0001
Left arm					
MAP-1	86.0	80.3–92.7	95.3	88.3–103.3	<0.0001
MAP-2	84.3	78.7–90.3	93.7	87.0–101.7	<0.0001
MAP-3	83.3	77.7–89.0	92.0	85.7–100.0	<0.0001
MAP-4	82.7	77.3–88.7	92.0	85.0–99.0	<0.0001
MAP-1+2	85.3	79.8–91.2	94.7	88.5–102.2	<0.0001
MAP-2+3	83.8	78.5–89.5	93.0	86.7–100.7	<0.0001
MAP-3+4	83.0	77.7–88.7	92.2	85.5–99.5	<0.0001
MAP-1+2+3	84.7	79.2–90.3	93.9	87.4–101.3	<0.0001
MAP-2+3+4	83.6	78.2–89.0	92.9	86.1–99.9	<0.0001
MAP-1+2+3+4	84.3	78.9–89.8	93.8	86.9–100.4	<0.0001
Right arm					
MAP-1	86.7	80.7–92.7	95.7	89.3–103.0	<0.0001
MAP-2	84.7	79.0–90.7	94.0	86.7–101.7	<0.0001
MAP-3	83.3	78.0–89.3	93.0	85.3–99.7	<0.0001
MAP-4	83.0	77.3–88.7	91.7	86.0–99.0	<0.0001
MAP-1+2	85.5	80.0–91.5	95.0	88.3–102.2	<0.0001
MAP-2+3	84.0	78.7–89.8	93.3	86.3–100.5	<0.0001
MAP-3+4	83.2	77.8–88.8	92.5	85.8–99.3	<0.0001
MAP-1+2+3	84.8	79.4–90.7	94.3	87.7–101.1	<0.0001
MAP-2+3+4	83.7	78.4–89.3	92.9	86.3–99.9	<0.0001
MAP-1+2+3+4	84.3	79.1–90.1	93.5	87.3–100.7	<0.0001
Highest					
MAP-1	88.3	82.7–94.7	98.0	91.7–106.0	<0.0001
MAP-2	86.7	81.0–92.7	96.3	89.3–103.7	<0.0001
MAP-3	85.3	80.0–91.0	95.0	88.0–102.0	<0.0001
MAP-4	85.0	79.3–90.7	94.0	87.7–101.0	<0.0001
MAP-1+2	87.3	81.8–93.2	96.8	90.3–104.0	<0.0001
MAP-2+3	85.7	80.3–91.3	95.2	88.5–102.3	<0.0001
MAP-3+4	84.4	79.7–90.5	94.2	87.5–101.2	<0.0001
MAP-1+2+3	86.4	81.1–92.1	95.8	89.3–102.8	<0.0001
MAP-2+3+4	85.2	80.1–90.8	94.6	88.3–101.4	<0.0001
MAP-1+2+3+4	85.9	80.8–91.4	95.3	88.8–102.3	<0.0001
Lowest					
MAP-1	84.0	78.3–90.0	93.3	86.7–100.7	<0.0001
MAP-2	82.3	77.0–88.0	91.7	84.7–99.0	<0.0001
MAP-3	81.3	76.0–87.0	90.3	83.7–97.7	<0.0001
MAP-4	80.7	75.7–86.3	89.7	83.3–96.3	<0.0001
MAP-1+2	83.5	78.2–89.2	93.3	86.2–100.0	<0.0001
MAP-2+3	82.0	76.8–87.7	91.7	84.5–98.5	<0.0001
MAP-3+4	81.3	76.3–86.8	90.5	83.8–97.3	<0.0001
MAP-1+2+3	83.0	77.8–88.6	92.7	85.4–99.2	<0.0001
MAP-2+3+4	81.9	76.8–87.3	91.2	84.3–98.2	<0.0001
MAP-1+2+3+4	82.7	77.5–88.1	92.0	85.1–98.8	<0.0001
Average of left and right					
MAP-1	86.3	80.7–92.3	95.8	89.0–103	<0.0001
MAP-2	84.3	79.0–90.2	94.0	87.2–101.5	<0.0001
MAP-3	83.3	78.2–88.8	92.8	85.7–100.0	<0.0001
MAP-4	82.8	77.7–88.3	91.8	85.7–98.3	<0.0001
MAP-1+2	85.4	80.1–91.0	95.0	88.3–101.7	<0.0001
MAP-2+3	83.8	78.8–89.3	93.3	86.7–100.3	<0.0001
MAP-3+4	83.0	78.0–88.5	92.2	85.8–99.0	<0.0001
MAP-1+2+3	84.7	79.6–90.2	94.0	87.6–101.1	<0.0001
MAP-2+3+4	83.5	78.5–88.9	92.7	86.4–99.9	<0.0001
MAP-1+2+3+4	84.3	79.2–89.7	93.5	87.3–100.4	<0.0001

Comparison between the outcome groups by Mann-Whitney U test.

Table 3. Performance of screening for PE by different protocols for measurements of MAP, in comparison to the method recommended by NHFA

Blood pressure method	AUROC (95% CI)	p	DR (95% CI) for 10% FPR	DR (95% CI) for 5% FPR
NHFA	0.773 (0.768–0.778)		42.3 (38.2–46.4)	29.6 (26.0–33.5)
Left arm				
MAP-1	0.755 (0.749–0.760)	0.010*	38.2 (34.2–42.2)	26.4 (22.9–30.2)
MAP-2	0.760 (0.755–0.766)	0.041*	40.7 (36.7–44.8)	28.3 (24.7–32.1)
MAP-3	0.752 (0.747–0.758)	0.001*	39.4 (35.9–44.0)	28.1 (24.5–31.9)
MAP-4	0.755 (0.749–0.760)	0.006*	38.0 (34.0–42.1)	27.1 (23.5–30.9)
MAP-1+2	0.764 (0.758–0.769)	0.119	41.2 (37.2–45.3)	28.8 (25.2–32.6)
MAP-2+3	0.763 (0.758–0.769)	0.074	40.4 (36.4–44.5)	30.7 (27.0–34.6)
MAP-3+4	0.759 (0.754–0.765)	0.016*	40.4 (36.4–44.5)	29.1 (25.5–33.0)
MAP-1+2+3	0.766 (0.761–0.771)	0.190	42.4 (38.4–46.5)	29.5 (25.8–33.3)
MAP-2+3+4	0.765 (0.760–0.771)	0.132	42.1 (38.0–46.2)	29.6 (26.0–33.5)
MAP-1+2+3+4	0.767 (0.762–0.773)	0.266	43.1 (39.1–47.2)	29.5 (26.1–33.7)
Right arm				
MAP-1	0.755 (0.749–0.761)	0.010*	39.0 (35.0–43.1)	24.7 (23.1–28.4)
MAP-2	0.753 (0.747–0.758)	0.001*	40.2 (36.2–44.3)	28.6 (25.0–32.5)
MAP-3	0.756 (0.751–0.762)	0.004*	41.9 (37.9–46.0)	26.1 (22.6–29.8)
MAP-4	0.754 (0.749–0.760)	0.003*	38.5 (34.5–42.6)	26.6 (23.0–30.3)
MAP-1+2	0.762 (0.756–0.767)	0.053	41.1 (37.0–45.2)	27.8 (24.2–31.6)
MAP-2+3	0.760 (0.755–0.766)	0.014*	42.9 (38.9–47.0)	29.0 (25.3–32.8)
MAP-3+4	0.760 (0.755–0.766)	0.015*	42.1 (38.0–46.2)	28.5 (24.8–32.3)
MAP-1+2+3	0.765 (0.760–0.771)	0.125	42.3 (38.2–46.4)	28.3 (24.7–32.1)
MAP-2+3+4	0.763 (0.757–0.768)	0.033*	43.3 (39.2–47.4)	29.3 (25.6–33.2)
MAP-1+2+3+4	0.766 (0.761–0.771)	0.150	42.8 (38.7–46.9)	28.8 (25.2–32.6)
Highest				
MAP-1	0.760 (0.754–0.765)	0.031*	39.5 (35.5–43.6)	27.3 (23.7–31.1)
MAP-2	0.764 (0.759–0.770)	0.072	41.9 (37.9–46.0)	28.1 (24.5–31.9)
MAP-3	0.764 (0.758–0.769)	0.036*	41.6 (37.5–45.7)	27.8 (24.2–31.6)
MAP-4	0.763 (0.758–0.768)	0.053	38.8 (34.9–42.9)	27.3 (23.7–31.1)
MAP-1+2	0.769 (0.764–0.774)	0.387	43.6 (39.6–47.7)	29.0 (25.3–32.8)
MAP-2+3	0.770 (0.764–0.775)	0.363	43.6 (39.6–47.7)	29.6 (26.0–33.5)
MAP-3+4	0.767 (0.761–0.772)	0.120	40.7 (36.7–44.8)	29.1 (25.5–33.0)
MAP-1+2+3	0.772 (0.767–0.778)	0.866	44.6 (40.6–48.8)	29.1 (25.5–33.0)
MAP-2+3+4	0.771 (0.765–0.776)	0.488	42.9 (38.9–47.0)	29.1 (25.5–33.0)
MAP-1+2+3+4	0.773 (0.767–0.778)	0.978	42.8 (38.7–46.9)	28.6 (25.0–32.5)
Lowest				
MAP-1	0.762 (0.757–0.767)	0.107	40.9 (36.9–45.0)	26.6 (23.0–30.3)
MAP-2	0.759 (0.754–0.765)	0.024*	42.1 (38.0–46.2)	29.1 (25.5–33.0)
MAP-3	0.757 (0.751–0.762)	0.006*	39.0 (35.0–43.1)	28.3 (24.7–32.1)
MAP-4	0.757 (0.752–0.763)	0.013*	38.7 (34.7–42.7)	27.1 (24.0–31.4)
MAP-1+2	0.766 (0.760–0.771)	0.200	42.9 (38.9–47.0)	29.1 (25.5–33.0)
MAP-2+3	0.763 (0.758–0.769)	0.069	42.9 (38.9–47.0)	30.2 (26.5–34.0)
MAP-3+4	0.762 (0.757–0.768)	0.049*	41.9 (37.9–46.0)	28.5 (24.8–32.3)
MAP-1+2+3	0.767 (0.762–0.772)	0.262	42.9 (38.9–47.0)	30.7 (27.0–34.6)
MAP-2+3+4	0.765 (0.760–0.771)	0.131	43.3 (39.2–47.4)	31.0 (27.3–34.9)
MAP-1+2+3+4	0.768 (0.762–0.773)	0.320	43.3 (39.2–47.4)	30.8 (27.1–34.7)
Average of left and right				
MAP-1	0.766 (0.760–0.771)	0.233	41.1 (37.0–45.2)	27.6 (24.0–31.4)
MAP-2	0.766 (0.761–0.771)	0.172	43.6 (39.6–47.7)	29.5 (25.8–33.3)
MAP-3	0.765 (0.760–0.770)	0.076	41.2 (37.2–45.3)	30.0 (26.3–33.9)
MAP-4	0.765 (0.760–0.770)	0.112	40.2 (36.2–45.0)	27.9 (24.3–31.8)
MAP-1+2	0.771 (0.766–0.777)	0.701	42.8 (38.7–46.9)	28.6 (25.0–32.5)
MAP-2+3	0.770 (0.765–0.776)	0.470	43.1 (39.1–47.2)	30.5 (26.8–34.4)
MAP-3+4	0.768 (0.763–0.774)	0.259	42.8 (38.7–46.9)	29.5 (25.8–33.3)
MAP-1+2+3	0.773 (0.768–0.778)	1.000	43.4 (39.4–47.6)	29.3 (25.6–33.2)
MAP-2+3+4	0.771 (0.766–0.777)	0.641	44.1 (40.1–48.2)	29.3 (25.6–33.2)
MAP-1+2+3+4	0.773 (0.768–0.779)	0.898	44.3 (40.2–48.4)	30.0 (26.3–33.9)

AUROC = Area under receiver operating characteristic curve; MAP = mean arterial pressure; DR = detection rate; FPR = false-positive rate. * $p < 0.05$.

Table 4. Logistic regression analysis for the prediction of PE

Independent variable	Average of first MAP in both arms		Average of first two MAP in both arms		Average of first three MAP in both arms	
	coefficient (SE)	p	coefficient (SE)	p	coefficient (SE)	p
Total PE						
Constant	–49.311 (1.912)	<0.0001	–51.965 (24.713)	<0.0001	–52.797 (1.973)	<0.0001
log MAP	23.299 (0.966)	<0.0001	24.713 (0.991)	<0.0001	25.185 (1.001)	<0.0001
R^2	0.124		0.132		0.134	

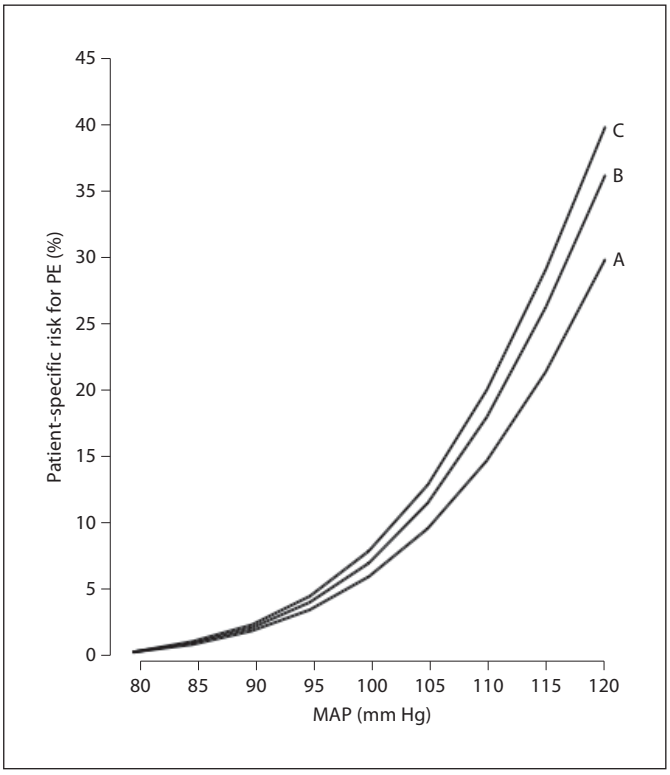

Fig. 1. Patient-specific risks of PE based on MAP. The average of the first measurement in both arms (A), the first two measurements in both arms (B), and the first three measurements in both arms (C).

of cases and four measurements in 25%. Our results suggest that similarly good results to those achieved with the NHFA protocol can be obtained by a simpler protocol using the average of three, two or even one measurement from each arm.

The first recording of MAP from each arm in both the PE and unaffected groups was consistently higher than the subsequent three. This finding, which has been referred to as white coat hypertension, is thought to be the consequence of patient anxiety at first contact with healthcare professionals. It is therefore recommended to obtain a series of recordings until stability is achieved [2–6]. However, as shown by our results on individual measurements from either arm, the performance of screening for PE was similar when the first, second, third or fourth measurement was used. Similarly, when the average of two or three recordings was used for the calculation of MAP there was a tendency for improved performance of screening with firstly, an increasing number of recordings and secondly, if the first recording was included, rather than excluded from the calculation of the average MAP.

In general, the performance of screening for PE by MAP was similar for recordings taken from the left and right arms, was better when the highest recording was used and best when the average of the readings from the two arms was considered. Although a large difference in blood pressure between the two arms is a common finding in certain pathological conditions, such as dissection or coarctation of the aorta, peripheral vascular disease and unilateral neurological and musculoskeletal abnormalities, it is also found in normal healthy individuals [9, 10]. The inter-arm difference in blood pressure has no clear pattern and it does not appear to be determined by whether the patient is right- or left-handed [9]. In the non-pregnant population it is recommended that blood pressure should be measured in both arms at the first examination and if there is a consistent inter-arm difference in blood pressure, the arm with the highest recording should be used for subsequent assessments [7, 8]. Although current recommendations suggest that this practice is not needed in pregnancy [16, 17], our results highlight the importance of measuring MAP in both arms.

Measurement of MAP at 11–13 weeks' gestation is an important component of effective first-trimester screening for PE by a combination of maternal history and measurement of MAP, uterine artery pulsatility index and serum placental growth factor [1, 18]. Recent evidence suggests that the prophylactic use of low-dose aspirin starting from early pregnancy, unlike the use after 16 weeks, could halve the prevalence of the disease [19]. In our study, appropriately trained doctors have used a validated automated device to measure blood pressure in a large population of pregnant women at 11–13 weeks' gestation. The study has established that the high performance of screening for PE by MAP using the complex NHFA protocol can be achieved by the simpler approach of using the average of two recordings from each arm.

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