Twenty-four-hour ambulatory blood pressure measurement in a primigravid population

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Objective: To establish the profiles of 24-h non-invasive ambulatory blood pressure measurement (ABPM) during the trimesters of pregnancy and the puerperium in normotensive healthy primigravidae.

Design: A prospective study in which 24-h ABPM was performed on five occasions in each subject: in the first trimester between 9 and 16 weeks' gestation; in the second trimester between 18 and 24 weeks; in the third trimester between 26 and 32 weeks and between 33 and 40 weeks; and finally at 6 weeks *post partum*.

Method: One hundred and six Caucasian primigravid women who were normotensive at their first booking visit were recruited consecutively from the antenatal clinic and had 24-h ABPM performed with the SpaceLabs 90207 ambulatory system.

Results: Of the 106 women recruited, 98 completed 24-h ABPM on four of the five measurement occasions. Four women delivered prematurely before 33 weeks' gestation, thereby missing one ABPM measurement. Changes during pregnancy and the puerperium were assessed against the ABPM performed in the first trimester. There was no difference for daytime or night-time systolic blood pressure between 9 and 33 weeks, but it rose significantly from 33 to 40 weeks. At 6 weeks *post partum*, systolic blood pressure was not significantly different from the daytime pressure in the first-trimester ABPM but was raised significantly at night. Diastolic blood pressure decreased significantly between 18 and 24 weeks for both daytime and night-time. From 33 to 40 weeks it increased in parallel with systolic blood pressure, and at 6 weeks *post partum* it was raised significantly compared with first-trimester values for daytime and night-time. The nocturnal fall in blood pressure was preserved throughout pregnancy with a significant difference between daytime and night-time measurements present on all measurement occasions for systolic, diastolic and mean blood pressures and heart rate. There were significant differences between daytime ABPM and clinic blood pressure for both systolic and diastolic blood pressure up to 33 weeks. From 33 weeks until 6 weeks *post partum* there was no significant difference between daytime ambulatory and clinic blood pressures.

Conclusion: This study provides reference values for ABPM in healthy primigravidae with generally uncomplicated pregnancies.

Journal of Hypertension 1993, **11**:869–873

Keywords: 24-Hour ambulatory blood pressure, pregnancy, primagravidae.

Introduction

In developed countries more mothers die in the perinatal period from pregnancy-induced hypertension than other causes, and the incidence of toxaemia is greatest among primigravidae [1]. Consequently, blood pressure measurement is one of the most frequently used screening tests in pregnancy [2]. Conventional blood pressure measurement has several shortcomings in pregnancy: it provides a measurement that represents only a fraction of the 24-h blood pressure profile, usually under circumstances that may have a

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Sponsorship: This study was supported by the Friends of the Rotunda, The Charitable Infirmary Charitable Trust and The Health Research Board.

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Date of receipt: 12 November 1992; revised: 8 May 1993; accepted: 21 May 1993.

pressor effect, and the technique is fraught with potential errors [3,4]. The development of devices capable of accurately measuring 24-h blood pressure non-invasively is proving valuable in predicting the cardiovascular complications of hypertension in the non-pregnant population, and it is likely that the technique will also prove useful in pregnancy [5,6]. Although reference values are now available for 24-h ambulatory blood pressure measurement (ABPM) in non-pregnant subjects [7–9], the use of the technique in pregnancy [10] has grown in the absence of such reference values. The present study was therefore undertaken to determine the profiles of ABPM in the trimesters of pregnancy and the puerperium in healthy primigravid women who were normotensive at the onset of pregnancy.

Subjects and methods

Subjects

One hundred and six primigravid women attending for their booking visit to the Rotunda antenatal clinic, who did not have a history of hypertension, renal or cardiovascular disease, or diabetes mellitus, were asked consecutively to enter the study. An explanation of the potential values of ABPM ensured that none of the women approached refused to participate. The study was approved by the hospital ethics committee.

Twenty-four-hour ambulatory measurement

ABPM was performed with the SpaceLabs 90207 (SpaceLabs Inc., Redmond, Washington, USA) [11] on five occasions in each subject: first trimester, at the booking visit between 9 and 16 weeks' gestation; second trimester, between 18 and 24 weeks; third trimester, between 26 and 32 weeks and between 33 and 40 weeks; and in the puerperium at 6 weeks *post partum*. The SpaceLabs 90207, which was programmed to deflate in 8-mmHg bleed steps every 30 min throughout the 24-h period, was fitted between 0900 and 1000 h. Subjects were instructed to keep their arm still during recording. A cuff containing a bladder appropriate for the arm circumference was selected according to criteria of the British Hypertension Society (BHS) [12]. The 24-h period was divided into daytime (1000–2259 h) and night-time (0100–0659 h) periods. A 24-h record was acceptable only if there were more than 15 daytime and nine night-time readings.

Clinic blood pressure

One clinic blood pressure was measured carefully at each attendance for ABPM, using a standard mercury column sphygmomanometer according to the BHS recommendations [12], with particular care being taken to ensure that a cuff containing a bladder with dimensions appropriate for the arm circumference was chosen, and that subjects were seated and relaxed with the arm supported at heart level. In keeping with the BHS recommendations [12], diastolic blood pressure was taken as Korotkoff phase IV.

Statistical analysis

The 24-h ABPM data were analysed with the SAS Software Package (SAS Institute Inc., Cary, North Carolina, USA). Quartiles were calculated using the weighted average method in SAS PROC UNIVARIATE [13]. The first ABPM was compared with those in the second and third trimesters using one-way analysis of variance for repeated measurements in SAS PROC GLM [14]. $P < 0.05$ was considered statistically significant.

Pregnancy outcome

The internationally agreed definitions of gestational hypertension and pre-eclampsia were used to determine the outcome of pregnancy [15].

Results

Subjects

A total of 106 primigravid Caucasian women considered from a socioeconomic viewpoint to be representative of an urban Irish population, who were normotensive upon recruitment (blood pressure < 150/90 mmHg at the first visit), not taking any medication other than iron and folic acid supplements, gave written informed consent. Six women dropped out during the study (four moved out of the Dublin area, two could not attend for ABPM because of domestic difficulties and the records of two patients were excluded from analysis because they lacked the requisite number of measurements), leaving 98 mothers who completed the study. Of these, four delivered prematurely after 33 weeks' gestation, thus missing the fourth measurement between 33 and 40 weeks. No patient defaulted from the study because the procedure was found to be unacceptable.

Subject characteristics were: mean age 24.5 years (range 18–32), mean height 160 cm (range 150–170) and mean weight gain during pregnancy 9.9 kg (range 2.8–18). Of the mothers 48% were unmarried, the instrumental delivery rate was 30% and 12% were delivered by Caesarian section.

Twenty-four-hour ambulatory measurement

Four hundred and ninety-six 24-h ABPM were performed, yielding 11 572 daytime and 5413 night-time blood pressure measurements for analysis. An average of 23 daytime recordings and 11 night-time recordings were obtained. Table 1 shows the means, medians, SD and 95th centiles for daytime and night-time systolic and diastolic blood pressures for the five periods of measurement.

Table 1. Clinic and ambulatory blood pressure during the trimesters of pregnancy and the puerperium in 100 primigravid women.

	Gestation (weeks)				
	9–16	18–24	26–32	33–40	6 pp
n	98	98	98	94	98
Ambulatory blood pressure (daytime)					
Systolic blood pressure (mmHg)					
Mean ± SD	115 ± 8	115 ± 8	116 ± 9	119 ± 9***	118 ± 9
Median	115	113	115	119	116
95th centile	128	128	132	134	132
Diastolic blood pressure (mmHg)					
Mean ± SD	70 ± 7	69 ± 6***	70 ± 7	74 ± 7***	76 ± 7***
Median	70	68	70	72	75
95th centile	82	80	85	86	87
Ambulatory blood pressure (night-time)					
Systolic blood pressure (mmHg)					
Mean ± SD	100 ± 7	99 ± 8	101 ± 8	106 ± 8***	104 ± 10
Median	99	98	100	106	102
95th centile	114	113	115	119	118
Diastolic blood pressure (mmHg)					
Mean ± SD	55 ± 5	54 ± 6	55 ± 6	58 ± 7***	59 ± 8***
Median	54	53	55	58	58
95th centile	65	64	67	71	71
Clinic blood pressure					
Systolic blood pressure (mmHg)					
Mean ± SD	121 ± 10	124 ± 10	123 ± 10	119 ± 10	117 ± 8
Median	120	120	122	120	116
95th centile	140	140	138	135	130
Diastolic blood pressure (mmHg)					
Mean ± SD	77 ± 8	78 ± 8	78 ± 7	75 ± 8	74 ± 7
Median	80	80	78	74	75
95th centile	90	90	90	88	86

***$P < 0.001$, versus first trimester. pp, *post partum*.

Changes during pregnancy and the puerperium were assessed against the first ABPM performed in the first trimester. There was no difference for daytime or night-time systolic blood pressure between 9 and 33 weeks, but it rose significantly from 33 to 40 weeks ($P < 0.001$). At 6 weeks *post partum* systolic blood pressure was not significantly different from the daytime pressure in the first trimester ABPM ($P = 0.30$) but was raised at night (+4 mmHg, $P = 0.003$).

Diastolic blood pressure decreased between 18 and 24 weeks for both daytime ($P < 0.001$) and night-time ($P < 0.04$). From 33 to 40 weeks it increased in parallel with systolic blood pressure, and at 6 weeks *post partum* it was raised compared with first-trimester values for daytime (+6 mmHg, $P < 0.001$) and night-time (+4 mmHg, $P < 0.001$).

Mean daytime blood pressure decreased between 18 and 24 weeks ($P = 0.005$), but remained constant during the night until 33 weeks. From 33 to 40 weeks it increased for both daytime and night-time ($P < 0.001$). At 6 weeks *post partum* both daytime (+6 mmHg, $P < 0.001$) and night-time (+5 mmHg, $P < 0.001$) mean arterial pressure remained elevated.

Heart rate increased steadily from early pregnancy until 33 weeks. At 6 weeks *post partum* it had fallen below the first-trimester level for both daytime (−5 beats/min, $P < 0.001$) and night-time (−7 beats/min, $P < 0.001$).

The nocturnal fall in blood pressure was preserved throughout pregnancy, with a significant difference ($P < 0.001$) between daytime and night-time measurements present on all measurement occasions for systolic, diastolic and mean blood pressures and heart rate.

Table 2 gives confidence intervals for the mean differences between ABPM1 (9–16 weeks) to ABPM4 (33–40 weeks) and ABPM5 (6 weeks *post partum*), demonstrating a drop in blood pressure over the first three ABPM with a return to normal levels by ABPM4.

Office blood pressure

Table 1 shows the means, medians, SD and 95th centiles for clinic systolic and diastolic blood pressures for the five gestational periods. There were significant differences between daytime ABPM and clinic blood pressure for both systolic (−8 mmHg, $P < 0.001$) and diastolic (−9 mmHg, $P < 0.001$) blood pressure up to 33 weeks. From 33 weeks until 6 weeks *post partum* there was no significant difference between daytime ambulatory and clinic blood pressures.

Outcome

Seven of the 100 mothers developed pregnancy-induced hypertension. Four of these were classified as

Table 2. Confidence intervals for the mean differences between ABPM1 to ABPM4 and ABPM5, the reference ABPM at 6 weeks *post partum*.

	ABPM difference (mmHg)			
	1–5	2–5	3–5	4–5
Systolic blood pressure (mmHg)				
Daytime	−4.4 to 0.5	−5.4 to −1.3	−4.4 to 0.2	−2.0 to 2.7
Night-time	−6.4 to −1.7	−7.0 to −2.2	−5.1 to −0.6	−0.7 to 4.5
Diastolic blood pressure (mmHg)				
Daytime	−7.3 to −4.0	−8.8 to −5.8	−7.6 to −4.1	−4.2 to 0.4
Night-time	−6.2 to −2.6	−7.4 to −3.8	−6.4 to −2.8	−2.8 to 1.2

The individual confidence limits are 98.75%. ABPM, ambulatory blood pressure monitoring.

gestational proteinuric hypertension (i.e. pre-eclampsia) and three had gestational hypertension (diastolic blood pressure ≥90 mmHg on two or more consecutive occasions more than 4 h apart [15]). Two of the mothers with pre-eclampsia were delivered by Caesarian section; the remaining two and the three with gestational hypertension were induced and delivered vaginally. Three of the four women who subsequently developed pre-eclampsia had elevated nocturnal systolic blood pressure between 18 and 24 weeks. This finding was observed 13–21 weeks before its clinical detection.

Discussion

Hypertensive disease of pregnancy remains a major cause of morbidity and maternal death [16,17] and it contributes significantly to perinatal morbidity and mortality [18,19]. Any technique that can potentially give insight into hypertensive disease of pregnancy is therefore to be welcomed. The recent development of accurate devices for measuring 24-h ABPM is one such technique [11]. There are no published data yet on the accuracy of the SpaceLabs 90207 in pregnancy, but we have recently validated it according to the BHS protocol [11] in pregnant normotensive women and shown it to achieve an A grading for systolic blood pressure and a C grading for diastolic blood pressure (O'Brien E, unpublished data, 1993). The grading achieved for systolic blood pressure is one grade higher than in non-pregnant subjects, and the grading achieved for diastolic blood pressure is one grade lower. The better performance for systolic blood pressure can be explained by the fact that the SpaceLabs 90207 is more accurate in lower than in higher pressure ranges [21]. One of the interesting features to emerge from the validation study in 85 subjects was the lability of diastolic blood pressure measured by auscultation in pregnant women, which suggests that the apparent diastolic inaccuracy of the device in pregnancy may be due to this phenomenon rather than to the inherent inaccuracy of an automated device.

There have been relatively few studies of blood pressure change in normal pregnancy, and some of these studies have been biased by preconceived opinions concerning the definition of normal blood pressure and the blood pressure criteria for pre-eclampsia [22]. Nevertheless, the general consensus from the literature is that both systolic and diastolic blood pressures tend to fall in pregnancy, reaching a nadir in the middle of the second trimester and returning to prepregnancy levels at term [23–26]. In our primiparous women there was a statistically significant rise in both systolic and diastolic blood pressure from 33 weeks' gestation. There was no fall in systolic blood pressure between the first and second trimesters and, although diastolic blood pressure did decrease in the second trimester during the daytime and night-time, the decrease, although statistically significant, was not of the magnitude previously reported [22]. The observed decrease in daytime mean arterial blood pressure in the early part of the second trimester with a rise towards term is in accord with an earlier study [27], whereas nocturnal mean arterial pressures remained constant until 33 weeks. Nocturnal systolic and diastolic blood pressures and daytime diastolic and mean arterial blood pressures were all significantly higher at 6 weeks *post partum*. Although the time at which blood pressure returns to normal after pregnancy is debatable, if, as suggested by MacGillivray *et al.* [26], it can be assumed that the blood pressures observed at 6 weeks *post partum* are equivalent to prepregnancy blood pressure, it would appear from the present study that any fall in blood pressure in pregnancy must occur very early, rather than (as has been suggested) in the middle trimester [27]. The occurrence of higher clinic systolic and diastolic blood pressures than daytime ABPM up to 33 weeks, but not thereafter, is also of interest.

The diurnal pattern of blood pressure during pregnancy has been investigated in a non-ambulatory setting using direct [3] and indirect [5] measurement techniques. Such studies have shown a preservation of the normal circadian rhythm in pregnancy and its reversal in established pre-eclampsia. Four of the present primigravid women developed pre-eclampsia in late pregnancy. Interestingly, three of these women had lost their nocturnal dip in blood pressure between 18 and 24 weeks' gestation. This finding was confined to this group and occurred 13–21 weeks before the women were diagnosed as toxaemic. This observation, together with the recognized unreliability of clinic

blood pressure [28], suggests that ABPM may have an early predictive value in toxaemia and merits further study.

Acknowledgement

The assistance of A.M. Burke SRN is acknowledged with gratitude.

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