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Arm and finger measurements in the third trimester: Implications for blood pressure measurement

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ABSTRACT

Objectives: To obtain arm and finger measurements of women ≥32 weeks gestation to determine: the requirement for different arm cuff sizes; the suitability of available finger cuffs in this population; the best predictor of arm conicity; the frequency of cuff placement on the forearm or leg.
Study design: Prospective observational pilot study.
Main outcome measures: Right and left mid-arm circumference (MAC) and to compare these to the recommended cuff sizes; right and left finger circumference; right and left arm conicity; the responses of women to a three-point Likert scale regarding cuff placement.
Results: Measurements were obtained for 450 women at an Australian tertiary hospital with a median (IQR) gestation of 35.7 (34.0–37.0); 299 (66.4%) were Caucasian and 35 (7.8%) had gestational hypertension. The median (IQR) body mass index (BMI) was 29.6 kg/m^2 (26.2–33.4), range 18.0–62.2. Median (IQR) right MAC was 29.9 cm (27.4–33), range 19.6–53.2. Based on right MAC, 58 (12.9%) required a large cuff and 6 (1.3%) a thigh cuff. Maximum right finger circumference was 7.0 cm. BMI, weight and right MAC were positively correlated with right arm conicity: r = 0.51, 0.42 and 0.45, p < 0.001 for all. R^2 for each were 0.26, 0.17 and 0.20. Fourteen (3.1%) reported cuff placement on the forearm or leg.
Conclusions: A small percentage of women are likely to be unsuited to traditional arm cuffs. Available finger-cuffs would suit this population. BMI could potentially be used to select women with cone-shaped arms for future studies of alternative devices.

1. Introduction

Detecting abnormal blood pressure in pregnancy is an essential part of antenatal, intrapartum and postnatal care. Traditional rectangular arm cuffs and mercury or hybrid sphygmomanometers are considered the gold standard in pregnancy [1]. However poorly fitting arm cuffs are known to be inaccurate in pregnant [2,3] and non-pregnant patients [4,5]. Both Kho [3] and Schoenfeld [2] found that women were misdiagnosed with hypertension when a small cuff was inappropriately used. Conversely, if real hypotension exists, the recognition of that hypotension may be delayed if an incorrectly sized cuff provides inaccurate but normal blood pressure readings.

In obese women it is not just the size, but the shape of the arm that may influence the accuracy of traditional arm cuffs. Bonso et al described the arm mathematically as a "truncated cone" [6] and Palatini et al subsequently demonstrated that rectangular cuffs overestimated blood pressure in non-pregnant patients with cone-shaped arms [5]. The arm becomes cone-shaped when the circumference of the upper arm is greater than that of the lower arm [5,7,8]. This results in a gap between the rectangular blood pressure cuff and the surface of the distal part of the arm, with the cuff expanding irregularly during inflation [5,9]. Trono-conical cuffs, which avoid the "gap" problem, have not been validated in pregnant women.

Devices that use finger cuffs include ClearSight™ (Edwards Lifesciences, Irvine, California 92614, USA) and CNAP™ (continuous non-invasive arterial pressure, CNSystems Medizintechnik AG, Graz,

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Austria). Both these devices apply the volume-clamp method of Penaz [10] to provide a continuous non-invasive blood pressure reading and avoid the problems of poorly-fitting arm cuffs. These may offer an alternative in women with large or conical arms, however it is not known if the available finger cuff sizes are suitable for obese women who may experience peripheral edema and vasodilatation in pregnancy [11]. ClearSight™ and CNAP™ apply a different technology to available oscillotonometric finger cuffs [10], which are not recommended due to inaccuracy [12,13].

The American Heart Association (AHA) makes recommendations for cuff bladder sizes in adults based on mid-arm circumference (MAC) [12]. The available sizes are small, adult, large and thigh, covering a range of MAC from 22 cm to 52 cm. This pilot study aimed to obtain arm and finger measurements of pregnant women in their third trimester to determine the: proportion of women requiring each AHA cuff size according to their right MAC, suitability of ClearSight™ and CNAP™ finger cuffs sizes in this population and best clinical predictor of arm conicity. The women also responded to a three-point rating scale questionnaire concerning their experience of cuff placement. These results will be used to determine inclusion criteria for future studies.

2. Methods

Ethical approval was provided by the Human Research Ethics Committee of the Royal Brisbane and Women's Hospital (HREC/17/QRBW/108). Women were recruited from the waiting room of the general and specialty antenatal clinics if they were ≥32 weeks gestation, aged > 16 years and able to complete the questionnaire in English. Written informed consent was obtained and participant incentives utilised in the form of supermarket or parking vouchers. Women provided demographic information and pregnancy information, including any history of chronic hypertension and previous or current diagnosis of gestational diabetes or gestational hypertension/preeclampsia. Body mass index (BMI) was calculated from the woman's height and weight measured on the day of recruitment. Participants responded on a three-point rating scale to a statement regarding their experience during the current pregnancy: "When midwives or doctors take my blood pressure they need to put it on my lower arm or leg". They were asked to indicate "never", "sometimes" or "always". The "lower arm" referred to the forearm and the "leg" to any site on the lower limb. Participants were assisted with this question if required.

Measurements were taken from both upper limbs, using standard clinical measuring tapes and according to standard anthropometry protocols when available [14]. The arm length (a standard measurement [14]) was measured on the posterior aspect of the arm, from the tip of the acromion process to the tip of the olecranon process, with the elbow in the flexed position. The MAC (standard measurement [14]) was measured at the mid-point of the arm length, with the arm hanging by the side. The proximal arm circumference was measured at the axilla and the distal arm circumference at the elbow above the elbow crease, with the arm hanging by the side (both non-standard measurements required to calculate conicity [6]). The diameter of the middle phalanx of the middle finger was measured with the hands relaxed (non-standard measurement). This measurement site was chosen as it is the recommended site for the ClearSight™ finger cuff and is also used with the CNAP™ double finger cuff.

The conicity index of the arms was calculated according to Bonso et al. [6] The conicity index was calculated as 100 (proximal arm diameter-distal arm diameter)/arm length. The difference between our calculated conicity index and that of Bonso et al. [6] was in the measurement of arm length; we used bony landmarks for accuracy and reproducibility. The proximal and distal arm diameters were calculated from the circumference measurements (diameter = circumference/π).

As a pilot study, there was no a priori sample size determination. We aimed to collect measurements on as many women as possible to provide a representative sample of the underlying pregnant population.

Table 1
Demographic and pregnancy information for 450 women who provided upper limb measurements at ≥ 32 weeks gestation.

Variable	Result
Age [years] mean (SD)	31.0 (4.8)
Nulliparous n (%)	194 (43.1)
Gestation [weeks] median (IQR)	35.7 (34.0–37.0)
BMI kg/m^2 median (IQR)	29.6 (26.2–33.4)
Range	18.0–62.2
Ethnicity n (%)	
Caucasian	299 (66.4)
Asian[a]	55 (12.2)
Indian	33 (7.3)
Aboriginal/Torres Strait Islander	11 (2.4)
Other	52 (11.6)
Chronic hypertension n (%)	6 (1.3)
Preeclampsia/gestational hypertension[b] n (%)	35 (7.8)
Gestational diabetes mellitus n (%)	124 (27.6)

[a] Includes Northeast Asian, Southeast Asian, those self-identifying as Asian.
[b] In the current or a previous pregnancy.

Categorical data was presented using number (percent). Mean (standard deviation (SD)) was presented for symmetrically distributed continuous variables and median (interquartile range (IQR) for skewed continuous variables. Range (minimum–maximum) was reported for selected continuous variables. Differences between left and right MAC and arm conicity within individuals were examined using paired t-tests. The linear association between right arm conicity and BMI, weight and right MAC was explored using Pearson correlation coefficients. Right arm conicity was modelled using linear regression. BMI, weight and right MAC were input into separate models due to their exhibiting collinearity. A statistical significance threshold was set at $\alpha < 0.05$. Data were analysed in STATA 15 (StataCorp, 2017, College Station, TX: StataCorp LLC).

3. Results

Data were collected for 450 women between June 2017 and March 2018. Demographic and pregnancy information are shown in Table 1. The median (IQR, range) right MAC was 29.9 cm (27.4–33.0, 19.6–53.2) and left MAC was 29.8 cm (27.0–33.0, 20.9–56.3). The mean difference between the right MAC and left MAC (within individuals) was 0.18 cm (95% CI 0.07–0.30), p = 0.002. Fig. 1 shows the frequency distribution of recommended cuff sizes according to right MAC and AHA recommendations [12]. One woman (0.2%) had a MAC below the small cuff range and one woman (0.2%) had a MAC above the thigh cuff range. Table 2 shows the median (IQR) right MAC

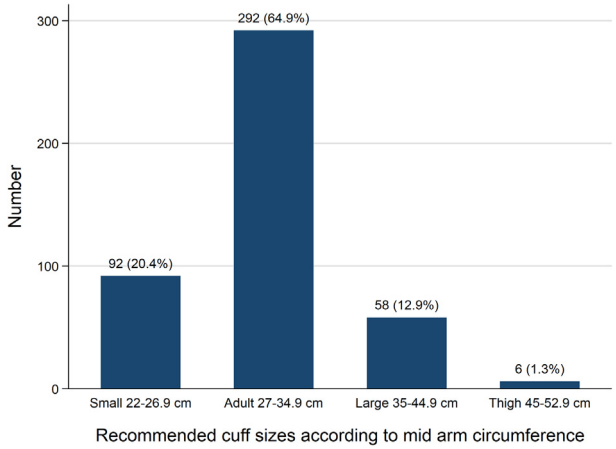

Fig. 1. Frequency distribution of recommended cuff sizes [12] according to right mid-arm circumference; 450 women in the third trimester.