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Could the arm blood pressure measured with simultaneous bilateral arm method be used for hypertension diagnosis?

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ABSTRACT

Objective Simultaneous bilateral arm blood pressure (BP) measurement (bilateral arm method) is suggested for the first BP measurement in clinical practice, but whether the arm BP measured with bilateral arm method (RA-2) is similar to that with unilateral arm method (RA-1) is unclear.

Design Quantitative research, paired sample T-test, Bland-Altman and multivariate linear regression analyses were used.

Setting This study included 295 subjects (18–90 years, 60.0±14.6 years old, 126 males) in the clinic of cardiovascular medicine of the Second Affiliated Hospital of Nanchang University. They were randomly instructed to one of two BP measurement proposals: (1) right-arm–bilateral arm–right-arm–bilateral arm, or (2) bilateral arm–right-arm–bilateral arm–right-arm to attenuate bias induced by BP measurement order.

Participants From June to October of 2019, 295 outpatients (18–90 years, 60.0±14.6 years old, 126 males and 169 females) with sinus rhythm (SR) were enrolled. The exclusion criteria were acute myocardial infarction, congenital heart disease, acute heart failure, syncope, hemiplegia, arrhythmia and pulseless (by palpation).

Outcome measures We compared the BP differences between bilateral arm method and unilateral arm method. The difference between RA-2 and RA-1 was calculated as Dif-RA. Data are expressed as means±SD for continuous variables. The percentage increase (PI) was calculated on the formula: (RA-2–RA-1)/RA-1.

Results The RA-2 on systolic blood pressure (SBP)/diastolic blood pressure (DBP) was slightly, but statistically higher by 1.2/0.4 mm Hg against the RA-1. Multivariate regression analyses showed that hypertension therapy type was positive impact factor, but RA-1 was negative factor for PI of Dif-RA on SBP, DBP and pulse pressure.

Conclusion The SBP and DBP of right arm measured with bilateral arm method are slightly, but statistically higher (1.2 and 0.4 mm Hg) than those with the unilateral arm BP method.

Strengths and limitations of this study

- This study specially designs two different proposals of blood pressure (BP) measurements to attenuate the impact of measurement order on arm BP readings.
- The systolic blood pressure (SBP) and diastolic blood pressure of right arm measured with bilateral method are slightly, but statistically higher (1.2 and 0.4 mm Hg) than those with the unilateral method.
- Multivariate regression analyses showed that hypertension therapy type was positive impact factor for Dif-RA on SBP and pulse pressure.
- The sample of this observational study was not large.
- Only the difference of the right arm, but not of the reference arm between the bilateral and unilateral method was compared.

INTRODUCTION

Blood pressure (BP) measurement is the fundamental means and method of evaluating BP level, diagnosing hypertension and observing antihypertensive efficacy. Many hypertension guidelines emphasise bilateral arm BP measurement for the subjects with initial BP measurement.[1–5] If there is interarm BP difference (IAD),[6] unilateral arm BP measurement may possibly lead to misdiagnosis of hypertension.[7–9] The best way for bilateral arm BP measurement is the simultaneous method as which could avoid time-order effects. Therefore, simultaneous bilateral arm BP measurement (bilateral arm method) is suggested in clinical practice and epidemiological studies.[10 11]

However, there is a question for physicians and even patients, that is, whether the arm BP measured with bilateral arm method is similar to that measured with traditional unilateral arm (unilateral arm) method. We suspect that the BP readings may be different as the inflation of two cuffs may block more artery bed and induce more obvious discomfort.[12–14] However, a little study on this topic is available at present. Only van der Hoeven *et al* found a mean difference of 1.3/0.4 mm Hg between the bilateral and unilateral arm BP measurement in 240 subjects in their study focusing on the influence of sequential simultaneous measurements on IAD in 2013.[15]

Therefore, we specially designed a study to test our hypothesis. If the BP of arm measured

with simultaneous bilateral arm method is not equal to that with unilateral arm method, we could not use the BP value to diagnose hypertension and evaluate antihypertensive efficacy. In this situation, we should detect at first the reference arm (the arm with higher BP reading) with the bilateral arm method, and then use the BP reading form the reference arm measured with unilateral arm method.[1–3] This information may guide our clinical practice.

SUBJECTS AND METHODS

According to a published paper that indicates the difference between the arm SBP levels from single arm BP measurement and four-limb BP measurement was 1.9 mm Hg[16], we calculated the sample size. Assuming an SD difference of 11 mm Hg, we calculated that 263 persons would be needed to demonstrate a 1.9 mm Hg difference with 80% power and a=0.05. From June to October 2019, 295 outpatients (18–90 years, 60.0±14.6 years old, 126 males and 169 females) with sinus rhythm (SR) were enrolled. Among them, 125 had and 170 had not hypertension history.

The exclusion criteria were acute myocardial infarction, congenital heart disease, acute heart failure, syncope, hemiplegia, arrhythmia and pulseless (by palpation).

Among these participants, 31 were treated with calcium channel blockers, 22 with diuretics, 28 with beta-blockers, 21 with ACE inhibitor and 18 with angiotensin receptor blocker. Meanwhile, 26 were treated with combination therapy.

Patient and public involvement

Patients or public were not involved in the study.

BP measurements and parameters

BP measurement

Before BP measurement, the participants were asked to empty bladder, and then to bare upper arms for properly placing appropriately sized cuffs of two validated oscillometric automatic BP measurement devices (Omron, HBP-1300). After 10 min rest, the seated BP was measured by a physician when the cuffs positioned at heart level. During all measurements both cuffs remained attached to both arms.

To attenuate bias induced by BP measurement order, this study designed two BP measurement proposals: the first was: right-arm–bilateral arm–right-arm–bilateral arm; the second was: bilateral arm–right-arm–bilateral arm–right-arm. The participants were randomly instructed to follow the first or the second proposal. The interval between the BP measurements was 2 min. Furthermore, the BP devices on each arm were randomly changed (figure 1).

Therefore, each participant had systolic and diastolic BP (SBP and DBP) values for right arm: two from unilateral arm method (RA-1), and the others from bilateral arm method (RA-2). Their average was calculated as the final values of RA-1 or RA-2, respectively. Pulse pressure (PP) was the difference between SBP and DBP.

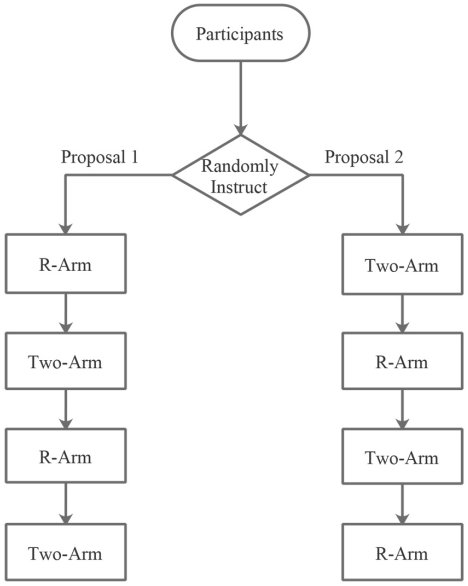

Figure 1 The two proposals for blood pressure measurement.

In this study, the BP of RA-1 was termed as baseline BP. The difference between RA-2 and RA-1 was calculated as Dif-RA. Furthermore, percentage increase (PI) of Dif-RA was calculated on the formula: Dif-RA/RA-1 for each participant.

The agreement of SBP, DBP and PP between RA-1 and RA-2 was evaluated by the method described by Bland and Altman.[17] With this method, intermeasurement differences were plotted against their means and the 95% limits of agreement (LoA) were determined (95% LoA=mean intermeasurement difference±1.96 SD).

The HR measured with unilateral arm or bilateral arm method was recorded as HR-1 or HR-2.

Statistical analysis

Data are expressed as means±SD for continuous variables. The paired sample t-test was used. Linear and multivariate correlation analysis was used to determine the relationship of variable with Dif-RA. For multivariate regression analysis, the dependent factors were Dif-RA (SBP or DBP or PP) and the independent factors included age, sex (0=woman; 1=man), hypertension therapy type (0=no therapy, 1=single drug, 2=combination therapy) and the RA-1 (SBP or DBP or PP) level. A two-sided p value <0.05 was considered to be statistically significant.

RESULTS

BP parameters between RA-2 and RA-1

Against the RA-1, the mean SBP on RA-2 were slightly, but statistically higher by 1.2 mm Hg (p<0.001) and the mean DBP by 0.4 mm Hg (p=0.03); the PI of Dif-RA for SBP was 1.1%±7.1 % and that for DBP was 0.6%±5.2%,

Table 1 BP of right arm measured with right arm or bilateral arm methods

Method	SBP (mm Hg)	DBP (mm Hg)	PP (mm Hg)	HR (bpm)
RA-1	127.7±20.2	75.4±11.3	52.3±15.0	73.8±11.8
RA-2	128.9±20.3**	75.8±11.5*	53.1±15.4*	74.1±11.7
Dif-RA	1.2±5.0	0.4±2.7	0.8±5.3	0.28±3.5
PI (%)	1.0±4.4	0.4±3.7	2.3±13.9	0.6±3.5

*P<0.05; **p<0.01 (compared with the RA-1).
†RA-1: measured with single right arm method; RA-2: measured with bilateral arm method; Dif-RA=RA-2−RA-1; PI=Dif-RA/RA-1.

respectively. Meanwhile, the PP on RA-2 was higher by 0.8 mm Hg (p=0.006) than the PP on RA-1 (table 1).

The levels of HR-1 (73.8±11.8 bpm) and HR-2 (74.1±11.7 bpm) were similar, and the Dif-HR was only 0.28±3.5 and its PI was 0.6±3.5 bpm (table 1).

The SBP/DBP/PP differences between RA-2 and RA-1 were 1.17/0.35/0.82 mm Hg. For SBP, the 95% limits of agreement were from −8.7 to 11.0 mm Hg; for DBP the limits y were from −5.0 to 5.7 mm Hg and for PP the limits were from −9.6 to 11.3 mm Hg (figure 2).

Meanwhile, the percentage of the patients with absolute difference of ≤10 mm Hg for SBP (sIAD) was 96.5%, and that for DBP (dIAD) was 99.8%. That is, 3.5% patients had sIAD >0 mm Hg.

The influencing factors for the Dif-RA and PI on BP

Multivariate regression analyses showed that hypertension therapy type was positive impact factor for Dif-RA and PI of Dif-RA on SBP and PP. However, RA-1 was negative factor for Dif-RA on SBP, DBP and PP, and for PI of Dif-RA on SBP, DBP and PP (table 2).

DISCUSSION

Although the mean differences of SBP/DBP between RA-2 and RA-1 were small (about 1.2/0.4 mm Hg), the differences had statistical significance. In 2013, van der Hoeven *et al* found that the mean difference of 1.3/0.4 mm Hg between the bilateral and unilateral arm BP measurement in 240 subjects.[15] These values were very close to each other. These findings demonstrated that the arm BP value from simultaneous bilateral arm BP measurement could overestimate the true BP level.

The reasons for the higher BP of RA-2 may be following: the first is that the inflation of two cuffs may induce a stronger stress to lead to more obvious BP rise against one cuff. The second is that two cuff inflation may block more artery bed to increase arterial resistance, and then to rise BP.[18–20] As the HR-2 was higher than the HR-1 by 0.28 bpm, activation of sympathetic nervous system respond to the SBP rise during bilateral arm BP measurement.[19]

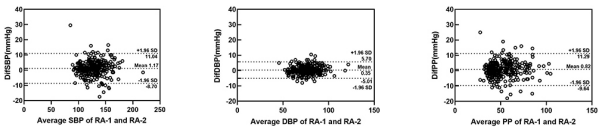

Figure 2 The agreement between RA-1 and RA-2 on systolic blood pressure (SBP), diastolic blood pressure (DBP) and pulse pressure (PP). RA-1: measured with unilateral right arm method; RA-2: measured with bilateral arm method.

Second, multivariate regression analyses showed that in the patients with combination antihypertensive therapy had higher BP rise in bilateral arm BP measurement than those with single therapy. Furthermore, combination antihypertensive therapy is positively associated with PI of Dif-RA on SBP, DBP and PP, even these parameters are correlated with their baseline levels. Indeed, the patients who need combination therapy usually have more serious hypertension. Therefore, we could consider that the serious hypertension may be a positive factor for the rise of arm SBP induced by bilateral arm BP measurement. It is easy to understand this finding as the hypertension is associated with higher BP reflect with various stresses.

Multivariate regression analysis demonstrated age as a positive factor for Dif-RA on PP, but not for its PI, which means that the age is not a main factor for the arm BP rise in bilateral arm BP measurement. Meanwhile, RA-1 was a negative factor for both Dif-RA and PI of Dif-RA on SBP, DBP and PP, these findings indicated that in the subjects with higher baseline BP at test, the rise of arm BP in bilateral arm BP measurement was relatively lower.

Bilateral arm BP method is recommended for identify IAD, which is a useful index for diagnosis of disease and predicting the outcome.[7 21] In the study the detection rate of sIAD was 3.5%, which was lower than the values reported by other schoolers. The underlying reason for this difference is mainly due to the different studied population. Another reason may be that the IAD was evaluated on repeated bilateral BP measurements, and this approach may attenuate the bias of BP measurement, and then decreases the detection rate of IAD. A study showed that two of three patients with an initial large sIAD ≥10 mm Hg on initial sequential measurement would have a normal inter-arm BP difference (<10 mm Hg) on a single simultaneous measurement. Adding a second simultaneous measurement further reduced this number.[15]

Clinical implication

This study found that the arm SBP/DBP levels measured with bilateral arm BP method were higher by 1.2 and 0.4 mm Hg against the unilateral arm method. In fact, the impact of various factors in routine clinical BP measurement, such as white coat effect, rest time, posture,

Table 2 Multivariate regression analyses for the Dif-RA and PI

	SBP		DBP		PP	
Variable	B (95% CI)	P value	B (95% CI)	P value	B (95% CI)	P value
Dif-RA						
Constant	9.946	<0.001	2.566	0.067	3.231	0.039
Age	0.042 (–0.003 to 0.254)	0.056	–0.007 (–0.096 to 0.164)	0.585	0.059 (–0.028 to 0.232)	0.002
Male	–0.598 (–0.183 to 0.024)	0.296	0.075 (–0.115 to 0.102)	0.821	–1.018 (–0.181 to 0.045)	0.098
RA-1	–0.097 (–0.223 to 0.058)	<0.001	–0.031 (–0.167 to 0.073)	0.07	–0.117 (–0.244 to 0.019)	<0.001
therapy	2.639 (0.007 to 0.246)	<0.001	0.772 (0.009 to 0.22)	0.015	1.53 (–0.065 to 0.172)	0.015
PI of Dif-RA						
Constant	0.1	<0.001	0.043	0.025	0.135	0.001
Age	0.001 (–0.06 to 0.224)	0.152	0.001 (–0.108 to 0.175)	0.581	0.001 (–0.119 to 0.176)	0.228
Male	–0.006 (–0.184 to 0.007)	0.198	0.001 (–0.122 to 0.105)	0.795	–0.29 (–0.162 to 0.029)	0.073
RA-1	–0.001 (–0.283 to 0.015)	<0.001	–0.001 (–0.182 to 0.045)	0.025	–0.003 (–0.294 to –0.026)	<0.00
Therapy	0.021 (–0.045 to 0.197)	<0.001	0.01 (–0.022 to 0.197)	0.02	0.036 (–0.101 to 0.12)	0.029

DBP, diastolic blood pressure; PI, percentage increase; PP, pulse pressure; SBP, systolic blood pressure.

observer, on SBP may be >1.2 mm Hg, meanwhile, this variation is within the permitted error range for certification of new BP device, even the error of BP measurement with oscillometric method may be about 5 mm Hg; thus, such a small difference may be negligible. However, this difference was systemic and statistically significant, we could consider that the BP readings with bilateral arm method overestimate the real BP.

Based on our data from an adult population study in rural China based on three BP readings at each of three visits in 1 week, a 2/1 mm Hg overestimation for SBP/DBP may induce a rise of hypertension prevalence increased from 33.4% to 37.3%, and the control rate decreased from 9.7% to 7.5% in 1540 community adults.[22 23] Based on a strict approach, BP should be measured at first with simultaneous bilateral arm method to detect the reference arm, then, the BP reading measured on the reference arm with unilateral arm BP method is used as the final value in clinical practice.

CONCLUSION

The SBP and DBP of right arm measured with bilateral arm method are slightly, but statistically higher (1.2 and 0.4 mm Hg) than those with the unilateral arm BP method.

Contributors TW: data collecting and analysis. Y-hW: revision of article format. HS: provision of the idea and article writing. Z-qH: statistics and article improvement.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not required.

Ethics approval The proposal and consent procedures of this study were approved by the Ethic Committee of the Second Affiliated Hospital of Nanchang University. All patients provided their verbal informed consent. This study was performed in the Second Affiliated Hospital of the Nanchang University.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data sharing not applicable as no datasets generated and/or analysed for this study. No data are available.

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