Original Paper

Comparison of Blood Pressure Measurement Results from Two Different Regions (Upper Arm and Ankle)

ASUMAN ÇOBANOĞLU[1]

[1]*Giresun University Faculty of Health Sciences, Department of Fundamental Nursing, Giresun, Türkiye*

ABSTRACT: Background: This study was conducted to determine the clinical concordance of non-invasive blood pressure (NIBP) measurements from the upper arm and ankle and to determine whether there is a difference between them. Methods: A prospective and cross-sectional research design was used in this study. The study population included 106 patients hospitalized in the surgical clinics of a training and research hospital. Non-invasive blood pressure measurements were performed from both upper arms and ankles in the supine position. In the data analysis, ANOVA and the Bland-Altman plot were employed. Results: Based on the results of NIBP measurements from the arm and ankle, the differences between diastolic blood pressure (DBP) and mean blood pressure (MBP) were acceptable and within the limits of concordance. The difference between the mean systolic blood pressure (SBP) was found to be significantly different and outside the limits of concordance. The difference between the mean SBP measured from the ankle and the upper arm was determined to be 18 mmHg. Conclusion: It was determined that the results of SBP measured from the ankle were significantly higher and outside the limits of concordance compared to the upper arm, while the results of DBP and MBP measurements were within acceptable limits.

KEYWORDS: *Ankle blood pressure, blood pressure, blood pressure measurement, upper arm blood pressure.*

Introduction

Blood pressure (BP) measurement is a fundamental vital sign used frequently in patient care and treatment [1].

In addition to detecting arterial hypertension, blood pressure measurement is a significant monitoring value in providing information about the stability of the cardiovascular system and determining the clinical events that may occur during the patient's hospitalization [2].

The clinic's BP monitoring and assessment of non-critical patients is often performed non-invasively around the upper arm [3].

The European Society of Cardiology and the American College of Cardiology/American Heart Association (ESC, ACA / AHA) also recommend that non-invasive blood pressure (NIBP) should initially be measured in both upper arms using a cuff around the arm [4,5].

The upper arm circumference is known to be a commonly used region in NIBP measurements; however, in some cases, measurements cannot be taken from the upper arm (injury and catheter in the arm, arteriovenous fistula, fracture, sprain, burn, wound, etc.). The ankle is one of the preferred areas in such cases due to the ease of access and the similar circumference to the upper arm [3].

In non-invasive blood pressure measurement, one of the most significant factors affecting the measurement results is the region where NIBP measurement is taken [6,7].

It is known that NIBP measurements taken at the ankle may yield higher results compared to NIBP measurements taken from the upper arm due to the distal arteries in the ankle being more resistant and the cuff having ineffective compression on the posterior tibial artery [8,9].

Since there are inter-regional measurement differences in non-invasive blood pressure measurement, in the interpretation of the results, the region from which the measurement is performed, the concordance and difference between the measurement regions, and the assessment of the evaluation accordingly provide success in patient follow-up and treatment. In addition to misdiagnosis, inaccurate high readings in blood pressure cause unnecessary use of medication and changes in diet and lifestyle, while inaccurate low readings cause delayed diagnosis and treatment [10].

Therefore, to avoid inaccurate measurements of NIBP, the measuring region must be known, and accurate measurements and readings must be taken.

Some studies conducted on the subject have indicated that the results of NIBP measurements from the ankle are higher than those from the upper arm, hence it is appropriate to use it only in cases where the upper arm cannot be used [3,9,11-14].

However, Goldstein et al. (2014) report that the ankle measurement result should not be used as an alternative to the upper arm measurement result [8].

Furthermore, the significance of the difference in measurements between the two regions in hemodynamically and cardiovascularly stable patients and the results regarding the difference

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between them are not yet clear. It may not always be possible to take measurements from both the ankle and the arm in clinical patient follow-up.

Also, in some cases, both arms of the patient may not be suitable for NIBP measurement. Thus, in such cases, one should be aware of how to evaluate the results of ankle NIBP measurements and assess the patient accordingly. Although there are many studies in the literature on the results of NIBP measurements around the upper arm, there are very limited research outcomes of measurements around the ankle, which is one of the preferred regions when the upper arm cannot be used.

Therefore, this research was conducted to reveal the concordance and difference between upper arm and ankle measurements in NIBP measurement and to provide evidence to the literature on this subject.

Materials and Methods

Design, study setting and sample

This is a prospective and cross-sectional study. The research was conducted between September 2022 and March 2023 in the surgical clinics of a teaching and research hospital in Northern Turkey. The sample size was calculated using the G Power 3.1.9.2 program with a theoretical power of 99% and an alpha value of 0.01. For statistical power, the effect size was calculated using similar studies [15].

Based on the power analysis, the minimum sample size was calculated as 67 patients. A total of 106 patients were included in the study to ensure that parametric tests were utilized in statistical analysis and that the data met the normality condition. The study sample consisted of patients between the ages of 18-65, without communication problems, diagnosis of hypertension, cardiovascular disease, a body mass index (BMI) greater than 45, pregnancy, amputation, a condition that prevents measurement of the arm and ankle (mastectomy, arterio-venous fistula, open wound, burn, etc.), and pain and who agreed to participate in the study.

Study intervention

Within the research process, the patients in surgical clinics who met the sampling criteria were first informed about the study and then asked whether they were willing to participate. Age, gender, BMI, heart rate, and oxygen saturation values of the patients participating in the study were measured and recorded before NIBP measurement. Blood pressure measurements were taken per the 2018 Management of Hypertension guidelines of the American Heart Association and the European Society of Cardiology [5,16].

To prevent measurement discrepancies in blood pressure measurements, measurements were performed by the investigator at the same period and using the same device. For all BP measurements, measurement results were validated and calibrated, and a non-invasive measuring device was used. The measurement device was calibrated before the data collection and was not used in any other clinical situation during the data collection period. To determine the size of the cuff for BP measurement, the arm circumference was measured before the measurement, and the appropriate cuff (small <24cm, medium 24-34cm, 12-13cm wide, and large >34cm) was used for BP measurement.

Patients were rested for at least 5 minutes before all measurements. There was no conversation between the investigator and the patient during the measurements. The room where the measurements were taken was quiet and the room temperature averaged 21-22°C.

Patients were asked to wait at least 30 minutes if they had consumed food or caffeinated beverages before blood pressure measurement. Patients were wearing loose clothing and their arms and legs were extended straight during blood pressure measurements. BP measurements were taken from both the upper arms (brachial artery) and ankles (posterior tibial artery) in the supine position. When there was a difference of more than 15mmHg in BP measurements between arms and ankles, the measurements were repeated. The physicians were notified to assess the patients if the difference in measurement results between both upper arms and both ankles exceeded 15mmHg, and such patients were not included in the research sample. If the difference in measurement was less than 15mmHg, however, the higher measurement value on either side was recorded as the BP measurement result. If measurement could not be taken from the patient, the patient was rested for 5 minutes and then measured again and the measured BP value was recorded.

NIPB Measurement from the Upper Arm: The patient was placed in the supine position with palms facing upwards and the arms were held at the level of the heart and supported from below.

The clothing on the arm where the measurement was to be performed was removed. After palpation of the brachial artery with an appropriately sized cuff and placement of the

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midpoint of the cuff of the measuring device in the artery, SBP, DBP and mean blood pressure (MBP) were measured first in the left upper arm and then in the right upper arm. Blood pressure readings of SBP, DBP, and MBP were recorded. The patient was placed in a suitable position and made comfortable after the measurement. The procedure was concluded by properly storing the materials.

NIBP Measurement from the Ankle: The patient was placed in a supine position with legs extended straight. The posterior tibial artery was palpated from both ankles (3 cm above the medial malleolus), and a sphygmomanometer cuff of appropriate size was placed on the artery. After the posterior tibial artery was palpated and the midpoint of the cuff of the measuring device was positioned on the artery, SBP, DBP, and MBP were measured first in the left ankle and then in the right ankle, and the readings were recorded. The patient was placed in a suitable position and made comfortable after the measurement. The procedure was concluded by properly storing the materials.

A Structured Patient Information Form containing the socio-demographic characteristics (age, sex) and physical evaluation parameters (weight, height, BMI, heart rate, respiratory rate, oxygen saturation, SBP, DBP, and MBP) of the patients was used for data collection.

Ethics

The principles of the Declaration of Helsinki were considered at all stages of the study. It was explained to the participants that their personal information would not be shared with anyone, their identities would be kept confidential, and they could withdraw from the research whenever they wanted.

For the implementation of the study, permission was obtained from the University Ethics Committee (05.12.2019, decision number: 17), and institutional permission has been obtained from the relevant institution.

Data analysis

In the analysis of the research data, IBM SPSS Statistics 25.0 (IBM, USA) was utilized. To analyze the descriptive data, descriptive statistics such as count, percentage, arithmetic mean, standard deviation, and minimum and maximum values were used. To assess the conformity of blood pressure measurements to the normal distribution, the Shapiro-Wilk W test was used ($p>0.05$). Since data showed normal distribution, Pearson correlation analysis was used for the relationship between measurements. To determine the difference between BP measurements by measuring sites, the ANOVA with repeated measures was used. Bonferroni correction was used for pairwise comparisons.

For the comparison of the concordance between the two measurement sites, a standard method, the Bland-Altman statistic, was used [17].

For the differences in NIBP measurements of the upper arm and ankle, standard deviation (SD) and limits of agreement (LOA) values were calculated by the Bland-Altman method for each measurement of SBP, DBP, and MBP, respectively. In Bland-Altman graphs, the 95% agreement limit was accepted as±1.96 standard deviation. The p values <0.05 were considered statistically significant.

Results

The mean age of the patients was 46.69±13.24 years and, 62.3% were male. The mean BMI of the patients was 27.12±5.09, the mean respiratory rate was 19.87±2.83, the mean heart rate was 78.81±11.86, and the mean oxygen saturation was 96.25±1.86 (Table 1).

The mean SBP value measured in the upper arm was 122.30±12.46, the mean DBP value was 76.56±9.29, and the mean MBP value was 91.79±9.47. The mean SBP value measured at the ankle was 141.10±17.24, the mean DBP value was 83.21±12.41, and the mean MBP value was 102.66±13.69 (Table 1).

Table 1. Biophysiological Findings and Blood Pressure Measurements (n=106).

	n	%	
Gender			
Male	66	62.30	
Female	40	37.70	
	Min	Max	Mean±SD
Age	18	65	46.69±13.24
BMI	18.17	44.54	27.12±5.09
Respiration rate	14	26	19.87±2.83
Pulse	52	107	78.81±11.86
Oxygen saturation	90	99	96.25±1.86

Upper Arm SBP	90.00	147.00	122.30±12.46
Upper Arm DBP	46.00	92.00	76.56±9.29
Upper Arm MBP	64.00	107.00	91.79±9.47
Ankle SBP	105.00	192.00	141.10±17.24
Ankle DBP	56.00	114.00	83.21±12.41
Ankle MBP	73.00	151.00	102.66±13.69

BMI, Body mass index; BP, Blood pressure; SBP, Systolic blood pressure; DBP, Diastolic blood pressure; MBP, Mean blood pressure.

Based on the results of one-way ANOVA in repeated measures, it was determined that there was a statistically significant difference between the mean SBP (F=266.44, p<0.01), mean DBP (F=51.726, p<0.01), and MBP (F=116.475, p<0.01) measurement results compared to the results of NIBP measurements performed from the upper arm and ankle (Table 2).

Table 2. Comparison of Blood Pressure Measurements According to Measurement Sites.

	Mean SBP Mean±SD	Mean DBP Mean±SD	Mean MBP Mean±SD
Upper Arm	122.30±12.46	76.56±9.29	91.79±9.47
Ankle	141.10±17.24	83.21±12.41	102.66±13.69
F	266.44	51.726	116.475
p	0.00*	0.00*	0.00*

*p <0.05, BP, Blood pressure; SBP, Systolic blood pressure; DBP, Diastolic blood pressure; MBP, Mean blood pressure.

Table 3 presents the correlation findings between BP measurements. There was a meaningful and positive correlation between SBP, DBP, and MBP measurements taken from the upper arm and ankle.

Table 3. Table 3. Pearson Correlation Coefficient between Blood Pressure Measurements.

	1	2	3	4	5	6
Upper Arm SBP (1)	1					
Upper Arm DBP (2)		1				
r	0.59					
p	0.00*					
Upper Arm MBP (3)			1			
r	0.83	0.92				
p	0.00*	0.00*				
Ankle SBP (4)				1		
r	0.72	0.48	0.63			
p	0.00*	0.00*	0.00*			
Ankle DBP (5)					1	
r	0.47	0.65	0.61	0.62		
p	0.00*	0.00*	0.00*	0.00*		
Ankle MBP (6)						1
r	0.60	0.59	0.65	0.78	0.89	
p	0.00*	0.00*	0.00*	0.00*	0.00*	

*p <0.05, BP, Blood pressure; SBP, Systolic blood pressure; DBP, Diastolic blood pressure; MBP, Mean blood pressure.

The concordance between blood pressure measurements was evaluated using the Bland-Altman approach. Differences were calculated against the means of NIBP measurements obtained from the upper arm and ankle. The limits of agreement were calculated by evaluating the difference between each pair of scores. The systolic blood pressure measurements had the widest limits of concordance compared to DBP and MBP (4.442 to -42.0455) (Table 4).

Table 4. Limits of Agreement for Systolic, Diastolic and Mean Blood Pressure (mmHg).

	Mean Difference	95% limits of agreement
SBP Upper Arm-Ankle	-18.8019	4.442 to-42.0455
DBP Upper Arm-Ankle	-6.6509	12.0101 to-25.3119
MBP Upper Arm-Ankle	-10.2784	9.4566 to-28.2013

BP, Blood pressure; SBP, Systolic blood pressure; DBP, Diastolic blood pressure; MPB, Mean blood pressure.

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The difference between the mean upper arm and ankle SBP measurements was-18.8019 in the Bland-Altman analysis ($p < 0.05$; 95% confidence interval, 4.442 to-42.0455) (Figure 1).

The difference between the mean upper arm and ankle DBP was -6.6509 ($p<0.05$; 95% confidence interval, 12.0101 to-25.3119) (Figure 2). The difference between the mean measurements of upper arm and ankle MBP was -10.2784 ($p<0.05$; 95% confidence interval, 9.4566 to-28.2013) (Figure 3).

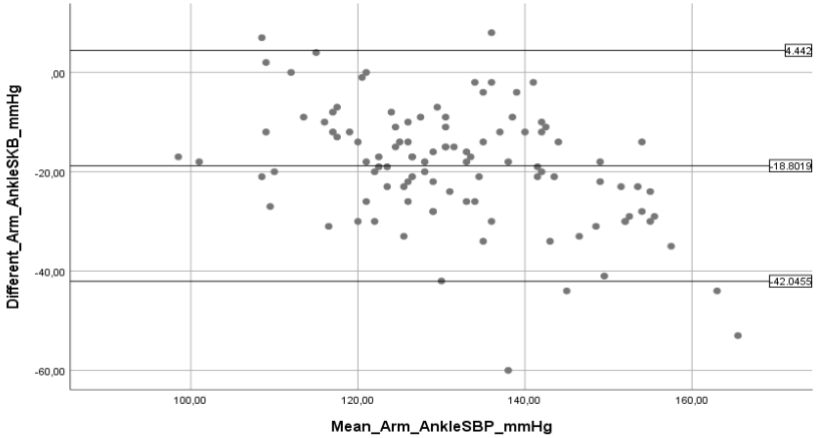

Figure 1. Bland-Altman Graph comparing SBP measurements taken from the upper arm and ankle. The middle line shows the difference in the mean SBP measurements from both sites. The top and bottom lines show the upper and lower limits of the 95% concordance limit.

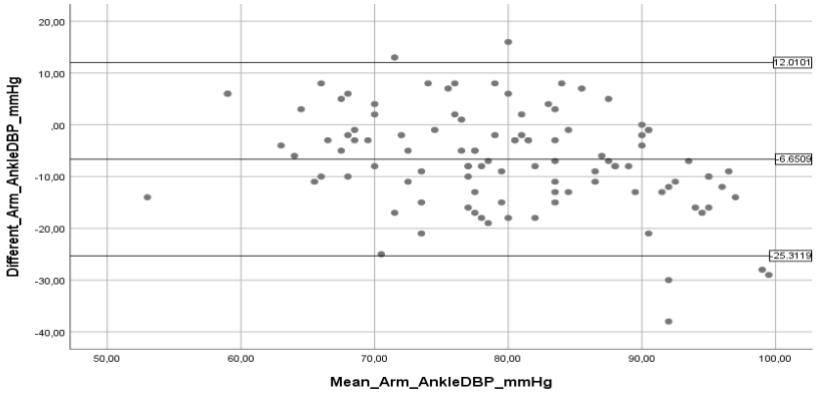

Figure 2. Bland-Altman Graph comparing DBP measurements taken from the upper arm and ankle. The middle line shows the difference in the mean DBP measurements from both sites. The top and bottom lines show the upper and lower limits of the 95% concordance limit.

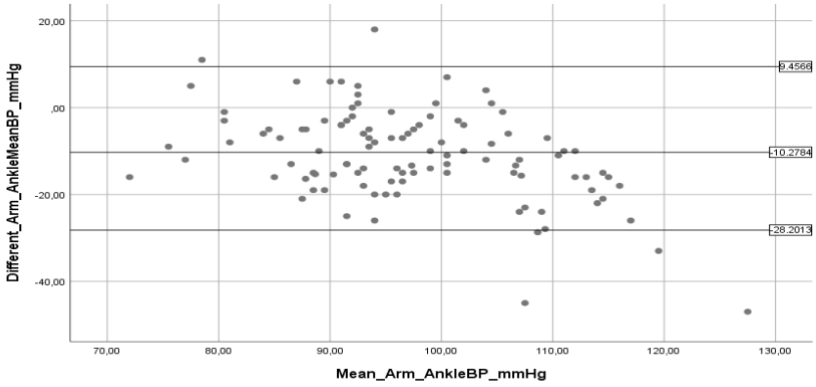

Figure 3. Bland-Altman Graph comparing MBP measurements taken from the upper arm and ankle. The middle line shows the difference in the mean MBP measurements from both sites. The top and bottom lines show the upper and lower limits of the 95% concordance limit.

Discussion

In this study, the results of NIBP measurements taken from the upper arm and ankle were compared. Based on the NIBP values measured from the upper arm and ankle, the difference between DBP and MBP measurements was found to be within acceptable limits (>10mmHg) [8], while the difference between SBP measurements was found to be outside acceptable limits. The mean SBP measured from the ankle was found to be 19mmHg higher than the mean SBP measured from the upper arm. Not only was this difference outside the clinically acceptable range (>10mmHg) [8], but it was also noteworthy that there was a wide range of differences in SBP measurements between the patients (4.442 to-42.0455). Based on this result, we can conclude that the SBP averages measured from the ankle are not compatible with the averages measured from the upper arm and should not be used interchangeably. In the literature, the reasons for higher NIBP values at the ankle include greater resistance of the distal vessels, ineffective compression of the cuff on the posterior tibial artery, and poor detection of oscillations [9,13].

The blood pressure waveform becomes stronger as it progresses away from the heart, leading to a progressive increase in SBP and a decrease in DBP [18].

Therefore, the difference between the mean SBPs taken from the ankle may have been higher than the mean SBPs taken from the upper arm in this study. Although mean BP is regarded as a better indicator of perfusion of vital organs, high SBP measurement values affect patient care and treatment decisions [13].

Therefore, SBP measurement values taken from the patient are important. Similar to this study, Moore et al. (2008) found that the difference in SBP measurement between the upper arm and ankle was 18mmHg in the study they conducted [3].

In the study by Moore et al. (2008), it was suggested to perform blood pressure measurements from the arm first to assess the difference between the two regions before measuring blood pressure from the ankle [3].

This process was termed ankle blood pressure calibration. Goldstein et al. (2014) found that the results of SBP measured from the upper arm and ankle were significantly different, and the results of MBP were within acceptable limits. In the same study, they reported that ankle NIBP measurement and upper arm measurement results cannot be used interchangeably [8].

In their study, Çiftçi et al. (2021) found that the difference between SBPs measured from the ankle and upper arm was 14mmHg and the difference between DBPs was 4mmHg [11].

In this study, NIBP measurements taken at the calf were found to be more consistent with upper arm measurements than at the ankle.

Lee et al. (2020) reported in their study that the difference between SBP measurements in NIBP measurements taken from the upper arm and ankle was 15mmHg, and that blood pressure taken from the ankle may be an alternative in cases where measurements from the upper arm cannot be taken [13].

In the study, the difference between DBP and MBP measured from the ankle and the upper arm was within clinically acceptable limits (>10mmHg). According to this result, we can conclude that the DBP and MBP measurements obtained from the ankle are compatible with the upper arm. Clinically, DBP has less clinical significance in the assessment of BP than SBP or MBP [3].

Moore et al. (2008) found the difference between MBP measured at the ankle and upper arm to be 8mmHg [3].

According to this result, it was determined that in the comparison of the results of upper arm and ankle measurements, the mean DBP was compatible with the mean SBP [3].

Wilkes and DiPalma (2004) reported that in patients who underwent colonoscopy, the results of BP and MBP measurements made from the ankle were higher than the results of BP and MBP measurements made from the upper arm and that the ankle can be used as an alternative in patients who could not have BP measurements made only from the upper arm [14].

Sanghera et al. (2006) reported in their study that there was no concordance between NIBP measured from the ankle and arm in patients undergoing cesarean section under spinal anesthesia and that the ankle is not an alternative NIBP measurement site to the arm [9].

All NIBP measurements were taken from the upper arm and ankle in the supine position. The results should not be extrapolated to NIBP measurement results obtained in different positions and regions.

Conclusion

In conclusion, NIBP values measured from the ankle were determined to be higher than the results measured from the upper arm.

It was determined that the results of DBP and MBP measured from the ankle were within acceptable limits compared to the results measured from the upper arm, but the results of SBP measurement were outside acceptable limits.

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According to the results of this research, in the interpretation of the SBP measurement value taken from the ankle, a comparison cannot be made with the results of the SBP measurement taken from the upper arm.

If the ankle is the only site for measurement, the difference in measurement between the upper arm and ankle should be considered in the assessment.

Further studies are required to confirm the research results in different clinical populations.

In addition, the development and validation of NIBP algorithms for the ankle is important for the assessment and interpretation of BP for patients in whom upper arm measurements cannot be performed.

Future studies with larger populations, multicenter and different positions are recommended.

Conflict of interests

None to declare

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Corresponding Author: Asuman Çobanoğlu, Giresun University Faculty of Health Sciences, Department of Fundamental Nursing, Giresun, Türkiye, e-mail: asuman.cobanoglu@giresun.edu.tr