Innovation in measuring obese patients' blood pressure: measurement with conical wrapping technique

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Introduction **Accurate measurement of blood pressure (BP) is difficult in obese patients due to their upper arm shape and width. Errors made during BP measurement cause misdiagnosis or lead to wrong treatment.**

Method **The data of this methodological study were collected from 40 patients who were 18 years old or above, with a BMI above 25 kg/m^2, and who were followed up with radial catheter arterial pressure in adult intensive care and postoperative care units between March and December 2020.**

Results **In total 55% of the participants were male with a mean age of 63.9 years, mean height of 165.7 cm, mean weight of 85.2 kg and mean BMI of 31.0 ± 2.1 kg/m^2. Intra-arterial BP (IABP) measurement values were found to be correlated with conical wrapping technique and cylindrical wrapping technique ($P<0.001$). As a result, a statistically significance was found between conical SBP and intra-arterial SBP ($r=0.921$; $P<0.05$) and conical DBP and intra-arterial DBP ($r=0.902$; $P<0.05$)**

Conclusion **It was determined that the SBP and DBP results of the conical wrapping technique were closer to the results obtained by IABP measurements. For this reason, it is more appropriate to measure BP with conical wrapping technique in clinically obese patients.** ***Blood Press Monit*** **XXX: 000–000** **Copyright © 2021 Wolters Kluwer Health, Inc. All rights reserved.**

Blood Pressure Monitoring XXX, **XXX**:000–000

Keywords: blood pressure, clinical skills, evidence-based practice, noninvasive monitoring, obesity.

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Received 3 May 2021 **Accepted** 15 July 2021

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Introduction

Measuring blood pressure (BP), which is the most frequently used procedure by nurses in the clinic and which is an important indicator of the health status of people, is a skill that must be performed accurately to get correct results. Errors made during measurement can lead to misdiagnosis and wrong treatments [1–3]. The most accurate result in BP is obtained by intra-arterial measurements performed by placing a catheter into the artery, which is considered to be the gold standard [4]. However, it is an expensive and invasive procedure and carries an increased risk of complications [5,6]. Therefore, the insertion of an intra-arterial cannula is not desirable in all patients. Instead, noninvasive methods are preferred to measure BP [4,5].

Factors that affect the accuracy of BP measurement can be cited as choosing the appropriate arm, choosing the appropriate cuff, the resting period and the inflation level of the cuff [7–9]. An issue that is often overlooked in BP measurement is the shape of the arm in obese patients. Accurate measurement of BP depends not only on the arm circumference but also on the shape of the arm [10]. Obese individuals often have a conical arm (where the upper limit measurement of the cuff wrapped around the patient's arm is greater than the lower limit measurement). This makes it difficult to attach the standard cylindrical cuff to the arm of obese individuals [11]. When a cylindrical standard cuff is used, due to the conical arm shape of obese individuals, the cuff does not adhere homogeneously to the upper arm surface. Hence, BP measurement of obese individuals may be inaccurate [12–15]. The shape of the cuff is important to obtain the correct BP measurement and it has been reported that the cuff should be conical for obese patients [13–16]. Study results have shown that arm size and cuff width are not taken into account by patients who measure BP at home and by some healthcare personnel [2,3].

Purpose and significance of the study

Conical cuffs with different angles are produced for the studies conducted abroad on BP measurement in obese patients and their effectiveness is investigated. However, because patients need to measure BP at home and ready-made conical cuffs are not available in clinics, it is necessary to use a different cuff wrapping method that can be easily used with obese patients. This study utilized the conical wrapping technique, which is suitable for the arm shape of obese patients and which minimizes the gap between the skin and the cuff. This study aims at evaluating the performance of the two cuffings using the intra-arterial method as the gold standard.

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Method

Type of study

The study was designed as a methodological study to determine the effect of cylindrical and conical wrapping techniques on the measurement results of obese patients' arterial BP measurements.

The venue, universe and sample of the study

The research was conducted in Çiğli Regional Training Hospital General ICU. The universe of the study consisted of patients who were followed up with radial catheter arterial pressure monitoring in adult intensive care and postoperative care units between December 2020 and March 2021. The sample of the study was composed of 40 patients. The participants were over 18 years old with a BMI over 25 kg/m^2 and they agreed to participate in the study. According to the postpower analysis, the study was completed with 90% power.

A sample group was created to determine the difference between the two cuff methods. The sample of the study consisted of patients who were inpatients in ICUs at the time of the study, who had intra-arterial BP (IABP) monitoring, who met the research criteria and accepted to participate in the study. Arterial catheters were not placed in patients for the purpose of this research. The sample of the study was composed of patients who already had arterial catheters.

Data collection tools

Patient information form

The form has a total of eight questions regarding the age, gender, height, weight and BMI of the patient as well as the patient's current chronic diseases.

Data record form

The data record form includes the values for the upper arm BP obtained by cylindrical wrapping technique and conical wrapping technique and IABP values.

Aneroid sphygmomanometer

Erka brand aneroid sphygmomanometer was used in this study. Cuffs measuring 16 × 36 cm were used in the study. Cuff characteristics: double hose pressure gauge connection and 16 × 36 cm green color hook cuff. The cuff consists of a cover and a removable inflation bladder. This construction is optimal in BP measurement because of even pressure distribution and the resulting highly precise values. The Erka green cuff fulfills all requirements of the latest The Association for the Advancement of Medical Instrumentation and American Heart Association guidelines for proper BP cuff size.

Intra-arterial monitor

It is a device used for direct measurement of arterial SBP and DBP by placing the catheter in the peripheral artery and providing the connection of this catheter with an electronic monitor. In this way, the measurement results of patients who have been provided with IABP monitoring will be recorded. Catheter insertion into the artery was performed by a specialist in the field of anesthesia and reanimation. GE Dash brand intra-arterial monitor was used in this study. The GE Dash 4000 is a clinically validated and 1-star automatic BP monitor. Both upper arm and intra-arterial measurements can be taken and it is intended for bedside patient monitoring. The GE DASH 4000 is a portable patient monitor that has capabilities to measure ECG, noninvasive blood pressure (NIBP), SpO_2 along with many other perimeters. The GE Dash 4000 patient monitor comes with a large 10.4-inch color screen. The GE Dash monitor also offers 12-lead 12sl, EK-Pro arrhythmia, ST-Segment analysis and A-fib Detection.

Data collection process steps

(1) BMI of the patients was calculated by taking the weight (kg) and height (cm) measurements of the patients.
(2) The cuff was wrapped around the patient's arm, and the arm circumferences at the upper border of the cuff, the midline of the cuff and the arm circumference at the lower border of the cuff were measured. The arms of the patients whose upper line measurement of the cuff was larger than the lower line measurement were determined as conical shape.

Fig. 1



Conical wrapping technique.

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(3) Arterial BP was measured by wrapping the cuff conically across the upper arm of the patient (Fig. 1).
(4) The IABP value was recorded 10 s after the first measurement.
(5) Two minutes after IABP measurement, BP was measured using the standard wrapping method.
(6) The IABP value was recorded 10 s after the standard measurement.
(7) IABP value, which is closer to the cuff measurement, was used.
(8) All BP measurements were taken from the arm with radial artery catheterization, and the arm was rested for 2 min between each measurement.
(9) Patient position was seated position with the arm at the heart level in every measurement technique.

Statistical analysis

SPSS package program 21.0 was used to analyze the data in this study. Individual characteristics of the patients were provided as mean ± SD. Correlation values and paired *t*-test were used to compare the BP results according to cuff wrapping techniques.

Ethics of the study

Permission was obtained from Çiğli Regional Training Hospital for the research. In addition, ethics committee approval was obtained from the Clinical Research Ethics Committee of a university (ethics committee number = 29533901-204.01.07-2050). Permission was obtained from the patient for Fig. 1.

Results

The distribution of the participants based on gender shows that 45% of the participants were females and 55% were males. The mean age of the participants was 63.9 years, the mean height of the participants was 165.7 cm, the mean weight of the participants was 85.2 kg and the mean BMI of the participants was 31.0 ± 2.1 kg/m^2 (Table 1).

Table 1 Participant characteristics

Age (M ± SD)	63.9 ± 12.1	
Body weight (kg) (M ± SD)	85.2 ± 9.1	
Height (m) (M ± SD)	165.7 ± 7.6	
BMI (kg/m^2) (M ± SD)	31.0 ± 2.1	
Upper arm upper circumferences (M ± SD)	42.72 ± 2.4	
Upper arm middle circumferences (M ± SD)	40.3 ± 2.5	
Upper arm lower circumferences (M ± SD)	36.42 ± 2.7	
Intra-arterial SBP and conical wrapping SBP difference SD	0.6	
Intra-arterial DBP and conical wrapping DBP difference SD	0.1	
Intra-arterial SBP and cylindrical wrapping SBP difference SD	2.3	
Intra-arterial DBP and cylindrical wrapping DBP difference SD	1.2	
Gender	*N*	%
Female	18	45.0
Male	22	55.0
Existence of chronic diseases	*N*	%
Yes	28	70.0
No	12	30.0
Total	40	100.0

When BP measurement results obtained with the cylindrical wrapping technique were compared with IABP measurement results, it was found that SBP was measured 3.4 mmHg ($t = -2.063$; df = 39; $P = 0.049$) higher and DBP was measured 2.8 mmHg higher ($t = -2.701$; df = 39 $P = 0.009$) with the cylindrical wrapping technique (Table 2)

Pearson's correlation was used to test the relationship between the cylindrical cuff and IABP measurements. Based on the results, a statistically significant and positive correlation was found between cylindrical SBP and intra-arterial SBP (IASBP) ($r = 0.798$; $P < 0.05$). A statistically significant and positive correlation was identified between cylindrical DBP and intra-arterial DBP (IADBP) as well ($r = 0.792$; $P < 0.05$) (Table 3, Figs. 2 and 3).

When BP measurement results obtained with the conical wrapping technique were compared with IABP measurement results, it was found that SBP was measured 1.4 mmHg ($t = -1.182$; df = 39; $P = 0.038$) higher and DBP was measured 1.3 mmHg higher ($t = -1.103$; df = 39; $P = 0.004$) with the conical wrapping technique (Table 2).

Pearson's correlation was used to test the relationship between the measurements obtained via conical wrapping technique and IABP measurement. As a result, a statistically significant and positive correlation was found between conical SBP and IASBP ($r = 0.921$; $P < 0.05$). There was a statistically significant and positive correlation between conical DBP and IADBP ($r = 0.902$; $P < 0.05$) (Table 3, Figs. 4 and 5).

IABP measurement values were found to be correlated with the conical wrapping technique and the cylindrical wrapping technique ($P < 0.05$). BP measurement results with the conical wrapping technique were identified to be more compatible with IABP measurement (Table 2).

Pearson correlation was used to test the relationship between the BP measurements obtained via cylindrical cuff and cross cuff wrapping techniques. As a result, a statistically significant and positive correlation was identified between cylindrical SBP and conical SBP ($r = 0.975$; $P < 0.05$). There was a statistically significant and positive correlation between cylindrical DBP and conical DBP ($r = 0.943$; $P < 0.05$) (Table 3).

Table 2 Comparison of mean noninvasive blood pressure vs. intra-arterial blood pressure parameters

Measurement	NIBP	IABP	NİBP–IABP Difference	*P* value	*t*
Conical wrapping and intra-arterial BP					
SBP	138.4	137.0	1.4	0.38	−1.182
DBP	71.6	70.3	1.3	0.04	−1.503
Cylindrical wrapping and intra-arterial BP					
SBP	140.5	137.1	3.4	0.04	−2.063
DBP	73.1	69.8	2.8	0.00	−2.701

NİBP, noninvasive blood pressure; IABP, intra-arterial blood pressure.

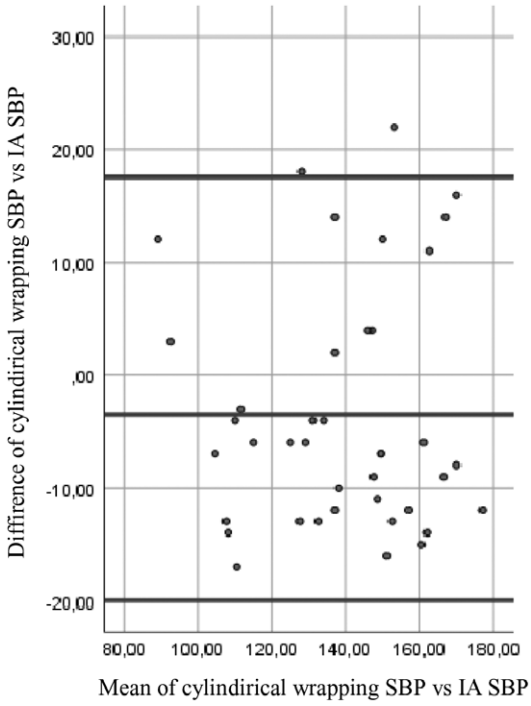
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Table 3 Comparison of correlation/noninvasive blood pressure vs. intra-arterial blood pressure parameters

Measurement	Pearson correlation	*P* value
IABP vs. conical wrapping SBP	0.921	0.0
IABP vs. conical wrapping DBP	0.902	0.0
IABP vs. cylindrical wrapping SBP	0.798	0.0
IABP vs. cylindrical wrapping DBP	0.792	0.0
Conical wrapping vs. cylindrical wrapping SBP	0.975	0.0
Conical wrapping vs. cylindrical wrapping DBP	0.943	0.0

NIBP, noninvasive blood pressure; IABP, intra-arterial blood pressure.

Fig. 2



Comparison of cylindirical wrapping SBP vs. intra-arterial SBP parameters

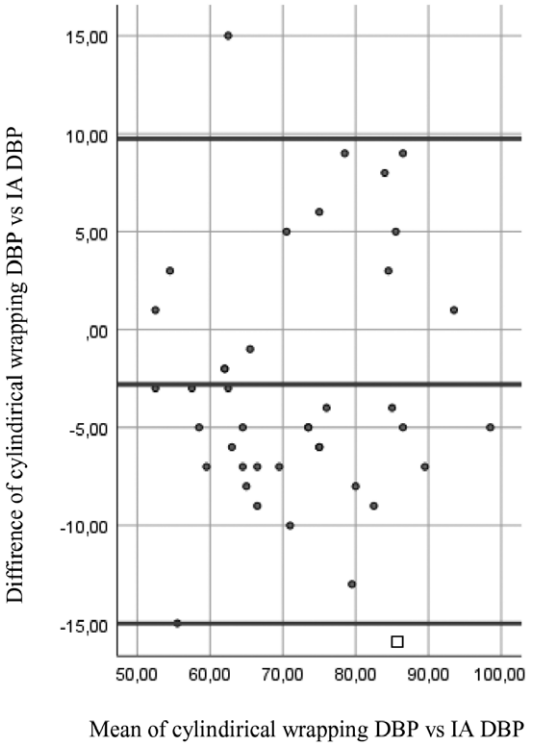
Spearman correlation was used to test the comparison of correlation NIBP, IABP parameters and mid-arm circumference. As a result, a statistically significant and positive correlation was found between IADBP and mid-arm circumference, conical wrapping SBP and mid-arm circumference ($r = 0.313$; $r = 0.389$; $P < 0.05$) (Table 4).

Spearman correlation was used to test the comparison of correlation NIBP, IABP parameters and conical shape of arm. As a result, a statistically significant and positive correlation was found between conical wrapping SBP and conical shape of arm, conical wrapping DBP and conical shape of arm, cylindrical wrapping SBP and conical shape of arm ($r = 0.958$ $r = 0.943$, $r = 0.896$; $P < 0.05$) (Table 5).

Discussion

Accurate measurement of arterial BP is very important, especially in obese patients who require intensive care

Fig. 3



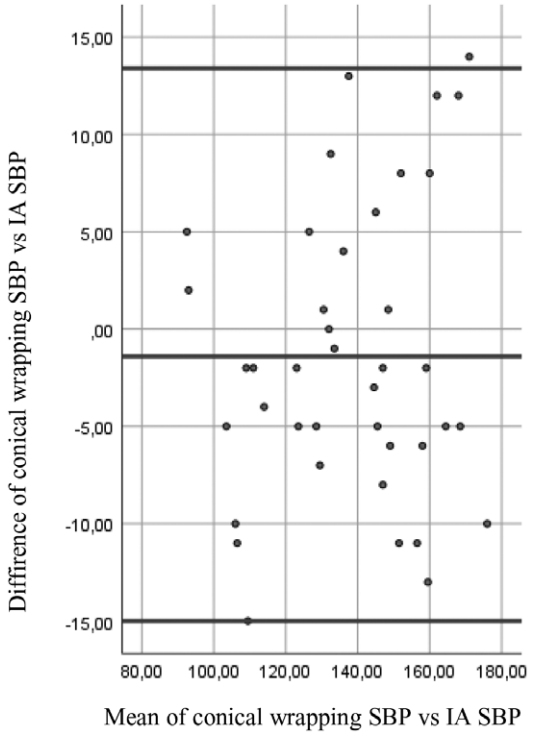
Comparison of cylindirical wrapping DBP vs. intra-arterial DBP parameters

treatment [17,18]. Many factors have been identified in the literature in regards to inaccurate measurement of arterial BP in obese patients [19]. One of the most important factors that cause errors in the measurement of arterial BP is the failure to use a suitable cuff size for the upper arm width of obese patients [20]. From time to time, erroneous high BP measurements are obtained due to cuff and arm incompatibility because either the BP cuff is too small for the patient or the cuff does not entirely fit around the conical upper arm of the patient [21]. In this study, SBP and DBP results obtained with cylindrical and conical wrapping techniques were compared with reference to IABP measurement in arterial BP measurement.

Literature specifies that studies have been carried out to eliminate errors in BP measurement of obese patients. Although these studies recommend using proper sized cuffs for obese patients as a solution, they also report that even if the cuff size is changed, erroneous measurement and technical difficulties still continue [22,23]. In addition to the cuff change, forearm cuff application is recommended but it is a temporary solution for obese patients as well [24,25]. In addition to these recommendations, it is reported that the conical cuffs can be used as a safe measurement tool, but it is difficult to access and use because it brings an economic burden for patients

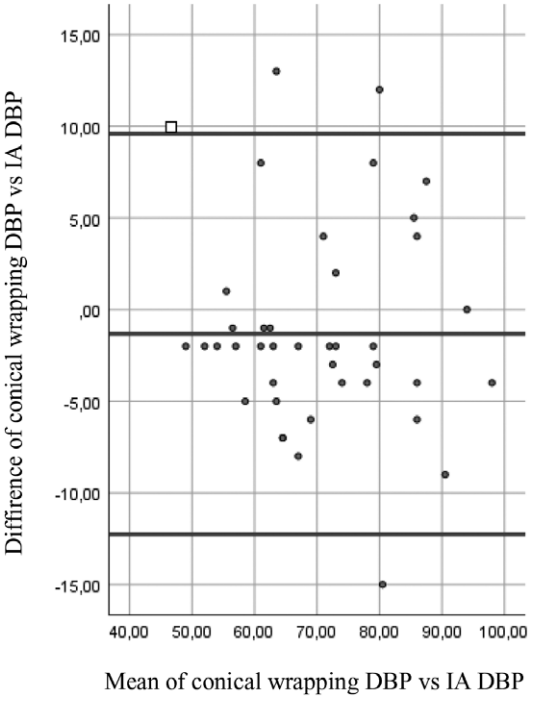
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Fig. 4



Comparison of conical wrapping SBP vs. intra-arterial SBP parameters

Fig. 5



Comparison of conical wrapping DBP vs intra-arterial DBP parameters

Table 4 Comparison of correlation noninvasive blood pressure, intra-arterial blood pressure parameters and mid-arm circumference

Measurement circumference	Spearman correlation	*P* value
IASBP – arm circumference	0.510	0.7
IADBP – arm circumference	0.313	0.4
Conical wrapping SBP – arm circumference	0.289	0.4
Conical wrapping DBP – arm circumference	0.896	0.8
Cylindrical wrapping SBP – arm circumference	1.107	0.9
Cylindrical wrapping DBP – arm circumference	1.793	0.6

IADBP, intra-arterial-DBP; IASBP, intra-arterial SBP.

[23,26]. In their study, Maxwell *et al.*, [11] reported that the BP measurement obtained with the cylindrical cuff was higher in obese patients compared to the obtained with the conical cuff. IABP measurements of 34 obese patients with a mean BMI of 33 kg/m^2 obtained with a conical cuff were compared. As a result of the study, the systolic mean error (–0.8 mmHg) and SD (6.0 mmHg), the diastolic mean error (1.5 mmHg) and SD (3.8 mmHg) and the mean arterial BP mean error (2.5 mmHg) and SD (4.2 mmHg). It was stated that SBP and DBP values measured by both methods were close [27]. In their study on 51 obese patients (BMI 40 ≥35 kg), Leblanc *et al.*, [17] evaluated the degree of consistency between cylindrical BP measurements in the forearm and upper arm and the BP measurements obtained with the intra-arterial method. The general trend in all patients was that the SBP was measured to be higher than it was and DBP was measured to be lower than it was when the forearm method was compared with intra-arterial values.

In their study on 79 obese patients (arm circumference >40 cm), Palatini *et al.*, [26] reported that SBP and diastolic DBP was measured to be higher in BP measurement when a cylindrical cuff was used. The current study found that the SBP was measured 3.48 mmHg higher and DBP was 2.8 mmHg higher when the results of IABP measurement were compared with the cylindrical cuff wrapping technique in 40 obese patients. This suggests that the cuff may not have completely covered the patient's arm because obese patients may have a conical arm shape. At the same time, due to its conical arm shape, when a cylindrical standard cuff is used, arm of obese individuals is not homogeneous adherence to the upper arm surface. This indicates that the measurement results with the cylindrical cuff could be higher in this case.

In a study in which they compared the BP measurement results in 34 obese patients (BMI = 33.0 ± 7.9) by using a conically formed cuff with IABP measurement as a reference, Hersh *et al.*, [27] obtained SBP and DBP values close to the reference value. In the present study, it was found that the conical wrapping technique, the cylindrical wrapping technique and IABP measurement values were correlated ($P < 0.001$). However, according to the

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Table 5 Comparison of correlation noninvasive blood pressure, intra-arterial blood pressure parameters and conical shape of the arm

Measurement-conical shape of arm	Spearman correlation	*P* value
IASBP – conical shape of arm	0.275	0.8
IADBP – conical shape of arm	0.141	0.8
Conical wrapping SBP – conical shape of arm	1.028	0.4
Conical wrapping DBP – conical shape of arm	0.943	0.3
Cylindrical wrapping SBP – conical shape of arm	0.896	0.1
Cylindrical wrapping DBP – conical shape of arm	0.184	0.6

IADBP, intra-arterial-DBP; IASBP, intra-arterial SBP.

results of our study, BP measurement results with the conical wrapping technique were more compatible with IABP measurement than the results obtained with the cylindrical wrapping technique.

In other studies comparing the results of a conical wrapping, cylindrical wrapping and IABP measurement, it was stated that the most suitable cuff for obese patients was conical cuffs [27,28]. Based on the results of this study, it can be argued that the difference in BP measurement results with a standard cylindrical cuff in obese patients occurs due to the conical arm shape of obese patients. Although there are conical cuffs developed for obese patients, it is possible to measure the BP of obese patients more accurately with the conical wrapping technique without additional cost or equipment.

Studies have reported that socio-demographic characteristics of obese patients such as age, gender and existence of chronic diseases do not affect the results of different BP measurement techniques [26,28,29]. Similarly, in the current study, it was found that the socio-demographic characteristics of the patients did not affect the BP results measured with the conical wrapping technique. This indicates that the conical wrapping technique can be utilized in slightly overweight and obese patients, regardless of the demographic characteristics of the patients.

Conclusion

The study concluded that all cuff wrapping techniques in obese patients have a significant relationship with BP values and intra-arterial measurement values. However, it was determined that the SBP and DBP results of the conical wrapping technique were closer to the results obtained by IABP measurements. For this reason, it is more appropriate to measure BP with conical wrapping technique in clinically obese patients, both to facilitate BP measurements and to obtain accurate results. However, it should be noted that the comparison between cuff and invasive measurements was made for BP measured at two different sites. This in itself may explain an invasive BP difference to the headline.

Limitations and suggestions

Obtaining a single measurement for each of the wrapping techniques and not measuring the patients at the same time can be listed among the limitations of the study. It may be more appropriate to take BP measurements more than once a day with different techniques and take their average. Because IABP measurement values can change instantaneously, the average values can be calculated by measuring IABP in every position before and after oscillometric measurements. Including relatively mildly obese patients may alter the results. Therefore, researchers should pay attention to this in future studies.

In addition, although obese patients have a conical arm shape, the measurements of the arm circumference may also have an effect on BP results. Therefore, to find the appropriate cuff size for each patient, it may be recommended to measure the arm circumference and compare measurements obtained by conical wrapping and IABP measurement.

Acknowledgements

This research do not have source of funding.

Conflicts of interest

There are no conflicts of interest.

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