ORIGINAL ARTICLES

Postanesthesia Patients With Large Upper Arm Circumference: Is Use of an "Extra-long" Adult Cuff or Forearm Cuff Placement Accurate?

Sheri Watson, BSN, RN, CPAN, Marita Aguas, MS, BSN, RN, CNL, CCRN, Tracy Bienapfl, RN, Pat Colegrove, BSN, RN, Nancy Foisy, BSN, RN, Bonnie Jondahl, BS, RN, CCRN, Mary Beth Yosses, MN, BSN, RN, CCRN, Larissa Yu, BSN, RN, Zoe Anastas, MPH, BSN, RN-BC

The purpose of this study was to determine if blood pressure (BP) measured in the forearm or with an extra-long BP cuff in the upper arm accurately reflects BP measured in the upper arm with an appropriately sized BP cuff in patients with large upper arm circumference. A method-comparison design was used with a convenience sample of 49 PACU patients. Noninvasive blood pressures were obtained in two different locations (forearm; upper arm) and in the upper arm with an extra-long adult and recommended large adult cuff sizes. Data were analyzed by calculating bias and precision for the BP cuff size and location and Student's t-tests, with $P < .0125$ *considered significant. Significantly higher forearm systolic (*$P < .0001$*) and diastolic (*$P < .0002$*) BP measurements were found compared to BP obtained in the upper arm with the reference standard BP cuff. Significantly higher systolic (*$t_{48df} = 5.38$*,* $P < .0001$*), but not diastolic (*$t_{48df} = 4.11$*,* $P < .019$*), BP differences were found for BP measured with the extra-long cuff at the upper arm site compared to the upper arm, reference standard BP. Findings suggest that the clinical practice of using the forearm or an extra-long cuff in the upper arm for BP measurement in post anesthesia patients with large upper arm circumferences may result in inaccurate BP values.*

Keywords: *blood pressure measurement, arm circumference, research.*

ACCURATE BLOOD PRESSURE (BP) measurement is crucial for the assessment and treatment of all patients, particularly those at risk for cardiovascular or respiratory complications associated with surgery and/or general anesthesia.[1] In the PACU, BP is most frequently measured

Sheri Watson, BSN, RN, CPAN, is a PACU charge/staff nurse; Marita Aguas, MS, BSN, RN, CNL, CCRN, is a PACU staff nurse; Tracy Bienapfl, RN, is a PACU staff nurse; Pat Colegrove, BSN, RN, is a PACU charge/staff nurse; Nancy Foisy, BSN, RN, is a PACU charge/staff nurse; Bonnie Jondahl, BS, RN, CCRN, is a PACU staff nurse and PACU Educator; Mary Beth Yosses, MN, BSN, RN, CCRN, is a PACU staff nurse; Larissa Yu, BSN, RN, is a PACU charge/staff nurse; and Zoe Anastas, MPH, BSN, RN-BC, is a Clinical Education Coordinator, Providence Portland Medical Center, Post Anesthesia Care Unit, Portland, OR.

Conflicts of interest: None to report.

Address correspondence to Sheri Watson, Providence Portland Medical Center, Post Anesthesia Care Unit, 4805 NE Glisan Street, Portland, OR 97213; e-mail address: sheri.watson@providence.org.

1089-9472/$36.00
doi:10.1016/j.jopan.2011.02.001

noninvasively with an automated BP device. Although a variety of sites for BP cuff location are available (upper arm, lower arm, thigh), the American Heart Association (AHA) national guidelines for BP measurement recommend the use of the upper arm for noninvasive BP measurement, if possible.[2]

Accuracy of noninvasive BP measurement is dependent on a number of factors, including the relationship between the circumference of the extremity where the BP cuff will be located and the width and length of the BP cuff bladder.[2-5] Although national guidelines for BP measurement recommend use of the upper arm for BP cuff placement, because it most closely approximates systemic BP,[2] upper arm circumference in patients with large arms often exceeds the recommended relationship between arm circumference and BP cuff width/length for a regular adult BP cuff (Table 1). Instead of using the AHA-recommended large adult BP cuff, clinicians often use a regular adult BP cuff in the forearm location, assuming it will provide an accurate reflection of systemic BP.[4] Another clinical approach in patients with large arm circumference is to use an "extra-long" adult cuff to obtain the BP in the upper arm. This may also be problem-prone because the bladder size of that cuff is only slightly longer than the bladder of a regular adult BP cuff, and is therefore too small for large arm–circumference patients.

Limited studies have been published regarding the accuracy of using the forearm rather than the upper arm for BP measurement,[5-10,11] particularly in subjects with large arms.[10,12] Studies that compared blood pressures in individuals with average arm circumferences found forearm measurements to consistently overestimate upper arm BP, with most studies finding average differences between the two locations of 4 to 12 mm Hg (with standard deviations [SD] >9.0 mm Hg) for systolic BP.[5-9,11] Differences were even greater between forearm and upper arm BP in the two studies that included obese subjects with large arm circumferences.[10,12]

Several methodological issues limiting the generalizability of prior studies included poorly described methods (eg, location of forearm BP cuff placement, sizes of BP cuffs),[5-13] potential bias from inadequate randomization procedures,[5-10,12] and inappropriate statistical analysis.[5-7,9-11,13] Of particular concern in prior studies comparing forearm with upper arm BP is that only four of the nine studies adequately described the anatomic location of the forearm cuff.[5,11-13] Those 4 studies all described a "wrist" location (lower edge of the cuff at or slightly above the radial artery location at the wrist).

No studies to date have evaluated forearm vs upper arm location for the BP cuff in the PACU clinical setting, nor the use of the AHA-recommended large BP cuff vs a regular-sized BP cuff bladder with an extra-long arm wrap (extra-long BP cuff) in obese patients. Use of the forearm for BP determination, as well as the extra-long BP cuff in the upper arm position, is common practice when the appropriately sized BP cuff is not available for PACU patients with large arm circumferences.

Purpose

The primary purpose of this study was to determine the accuracy of the forearm location for noninvasive BP measurements in patients with large arm circumference. A secondary purpose was to determine the

Table 1. American Heart Association* and Manufacturer's Recommendations for Blood Pressure Cuff Size Based on Arm Circumference

	AHA Recommendations		Manufacturer's Recommendations	
BP Cuff Name	Bladder Size of BP Cuff	Arm Circumference	Bladder Size of BP Cuff	Arm Circumference
Regular adult	16 cm wide, 30 cm long	27-34 cm	13 cm wide, 28 cm long	27-35 cm
Large adult	16 cm wide, 36 cm long	35-44 cm	17 cm wide, 38 cm long	34-43 cm
"Extra-long" adult	None listed	None listed	13.5 cm wide, 30 cm long	27.5-36.5 cm
Adult "thigh"	16 cm wide, 42 cm long	45-52 cm	20 cm wide, 42 cm long	42-54 cm

AHA, American Heart Association; BP, blood pressure.
*Based on data from reference 2.

accuracy of using an extra-long BP cuff for measurement of BP in the upper arm.

Materials and Methods

This study was conducted in a 29-bed PACU of a 485-bed, not-for-profit hospital in the Pacific Northwest. The study was approved by the Institutional Review Board for the health system.

Study Design

A method-comparison design was used to prospectively compare two locations (forearm and upper arm) and two different upper arm cuff sizes (large adult or extra-long adult) for noninvasive BP measurement in a convenience sample of PACU patients. Each participant served as his or her own control with BP measured in both locations and with both sized cuffs. The primary dependent variables were the difference in systolic BP (SBP) and diastolic BP (DBP) measurements between the upper arm and forearm using the AHA-approved BP cuff sizes and the difference in SBP and DBP measurements between two different cuff sizes for the upper arm BP (AHA-approved large and extra-long BP cuff). The order of BP measurement was randomly assigned by a computer-generated randomization scheme.

Sample Selection

Participants for this study were PACU patients that met the following criteria: age ≥18 years, English speaking, no contraindications or physical impediments to obtaining a noninvasive BP in the upper arm and forearm of the same arm, upper arm circumference between 34 and 43 cm, upper arm length from the acromion to the olecranon ≥19 cm, forearm length from the olecranon to the wrist ≥16 cm, absence of intravenous vasoactive or topical nitroglycerin ointment drug administration while in the PACU, criteria for discharge from the PACU met, and regular heart rate of 50 to 100 beats per minute. The only exclusion criterion was designation as comfort or palliative care.

Sample size was determined by power analysis for a power of 0.80 at an alpha level of 0.0125 when the effect size was at least 0.51.[14,15] Effect size was calculated based on the clinical need to detect at least a 10 mm Hg systolic and 7 mm Hg diastolic difference in BP obtained from the two locations. Mean and SD values for sample size calculation were based on data from a prior BP study.[10]

Instruments

All BP measurements were obtained by following the AHA guidelines[2] (Table 1) using an automated BP device connected to a bedside monitor (MP50 Intellivue, Philips Medical, Andover, MA) according to the manufacturer's guidelines. Upper arm BP cuffs (large adult cuff, nondisposable model #M1575A, Philips Medical; appropriate for arm circumference 34-43 cm) were applied to the upper arm according to the manufacturer's directions and used as the reference standard BP for comparison purposes. An extra-long adult BP cuff (nondisposable model #M4556A, Philips Medical; appropriate for arm circumference 27.5-36.5 cm) was used to obtain a second upper arm BP and was applied to the upper arm according to the manufacturer's directions. Forearm BP cuffs were either large adult cuffs (nondisposable model #M1575A, Philips Medical; appropriate for arm circumference 34-43 cm) or regular adult cuffs (nondisposable model #M1574A, Philips Medical; appropriate for arm circumference 27-35 cm) as determined by forearm circumference, and were applied to the forearm according to AHA guidelines.[2]

Study Procedure

All investigators were trained in the study procedures before data collection and only study investigators obtained BP measurements. Automated BP devices were calibrated according to the manufacturer's specifications before study enrollment.

Before discharge from the PACU, each participant had his or her BP taken three times (upper arm with a large adult BP cuff based on AHA guidelines[2]; forearm with an AHA-appropriate cuff size based on forearm circumference[2]; upper arm with an extra-long, regular-size cuff) by one of the study investigators (Table 2) in the randomly assigned order. At least one minute elapsed between each BP measurement, with all three BP measurements obtained within a six-minute time period.

Data Analysis

Data were summarized using descriptive statistics. BP obtained with the large adult cuff in the

Table 2. Procedure for Obtaining Noninvasive Blood Pressure Measurements*

General Preparations

1. Position the patient supine, with head of bed at 30 degrees.
2. Measure upper and lower arm circumference and length. Upper arm circumference was measured at the midpoint between the acromion and olecranon, and forearm circumference was measured at the midpoint between the olecranon and wrist. Upper arm length was measured from the acromion to the olecranon, and the forearm length was measured from the olecranon to the wrist.
3. Forearm BP cuff size was based on the manufacturer's recommended cuff sizes:
   - 27-35 cm circumference and >14-cm arm length—regular adult cuff
   - 27.5-36.0 cm circumference and >14-cm arm length—extra-long adult cuff
   - 34-43 cm circumference and >17-cm arm length—large adult cuff
4. An automated BP device was set up and used according to the manufacturer's guidelines.
5. Time between each BP measurement was greater than 1 minute but less than 3 minutes.

Upper Arm BP Measurements

1. The brachial artery was palpated in the antecubital fossa.
2. The midline of the assigned BP cuff bladder was placed so that the indicator arrow was 2-3 cm above the arterial pulsation at the antecubital fossa.
3. The upper arm was positioned level to the right atrium (horizontal to the fourth intercostal space, mid-axillary line). Pillows were used to achieve this level of elevation and arm support, if necessary.
4. The automated BP device was activated and the systolic and diastolic BPs recorded.

Forearm Measurements

1. The radial artery was palpated in the wrist area.
2. The midline of the recommended BP cuff bladder was placed so that the indicator arrow was 2-3 cm above the arterial pulsation at the wrist area.
3. The forearm was positioned level to the right atrium (horizontal to the fourth intercostal space, mid-axillary line). Pillows were used to achieve this level of elevation and arm support, if necessary.
4. The automated BP device was activated in the manual mode and the systolic and diastolic BPs recorded.

BP, blood pressure.
*Based on data from reference 2.

upper arm (AHA-recommended size) was used as the reference standard BP (clinical "gold standard"). Differences and limits of agreement between the forearm and upper arm BP location and between the upper arm large adult and extra-long adult BP cuff sizes were calculated and graphed according to the Bland-Altman method (see Box 1).[16-21] Student t test was used to determine whether systolic and diastolic BP differed between BP cuff sites (forearm and upper arm) and BP cuff size (large adult or extra-long adult upper arm BP). A Bonferroni correction for the use of multiple t tests was used, with the significance level set at $P < .0125$. Multiple regression analysis was used to determine whether body mass index (BMI) or arm circumference explained differences in forearm or extra-long cuff systolic and diastolic BP and the upper arm reference standard BP, with a $P < .05$ considered significant.

Results

Forty-nine PACU patients were studied over a nine-month period. Demographics, comorbidities, and arm circumference measurements are summarized in Table 3. Upper arm and forearm circumferences ranged from 34 to 43 cm and 27 to 37 cm, respectively. Seven of the 41 participants had upper arm circumferences within the manufacturer's range of acceptable size for use of the extra-long BP cuff (Table 2). All but five of the participants had forearm circumferences in the regular adult BP cuff range (Table 2). BMI ranged from 28.2 to 57.4. Ranges of blood pressures measured in the different locations and cuff sizes are detailed in Table 3.

For BP measured at the forearm site, bias and precision were 7.8 ± 10. 2 mm Hg for SBP and 5.0 ± 8.5 mm Hg for DBP, with 39% of systolic and 27% of diastolic measurements showing a ≥10–mm Hg

Box 1. Description of Data Analysis Techniques When Comparing a Clinically Accepted Medical Device (Reference Standard) With Another Medical Device (Test Device) for Device Equivalence*

Data Analysis Term	Description
Bias	Bias is the mean difference between the values obtained with the test and reference standard medical devices. Bias indicates how similar one device measurement is to the other device and represents the amount of systematic error between the two methods. This value is calculated by subtracting the value of the reference standard device from the test device for each individual measurement and then averaging the values for all measurements. Bias values close to 0.0 indicate excellent agreement between the two medical devices. Positive bias values indicate that the test device consistently had higher values, on average, than the reference standard device. Negative bias values indicate that the test device had consistently lower values, on average, than the reference standard device.
Precision	Precision is the standard deviation of the differences between the test and reference standard medical devices. Precision represents the amount of variation between the individual difference scores. Precision values close to 0.0 indicate excellent repeatability between the two medical devices.
Bland-Altman graphing technique (refer to Figs 1 and 2)	Bland-Altman graphs are the recommended technique for plotting the values obtained when studying two medical devices for agreement. The Y-axis of the graph represents the difference between the two device scores for each subject and is a series of numbers from negative to positive. The X-axis represents the average of the two devices for each subject. Each subject's difference score between the two devices is then plotted against the average of the two device values for each subject on the graph. The calculated bias value is represented by a horizontal line drawn through the appropriate value on the Y-axis. Two additional horizontal lines are then drawn through the appropriate value on the Y-axis that represents two times the precision or standard deviation value above and below the bias value. These horizontal lines define the level of agreement between the two medical devices. The farther the lines representing ±2 standard deviations are from the bias line, the more imprecise or inaccurate the test device is compared with the reference device.

*Based on data from references 16-21.

difference from the upper arm BP, reference standard (Table 4; Fig 1). Differences of ≥20 mm Hg were found in 14% and 6% of systolic and diastolic measurements, respectively. Student *t* tests found significantly higher SBP ($t_{48df} = 5.37$, $P < .0001$) and DBP ($t_{48df} = 4.11$, $P < .0002$) measured at the forearm location compared with the upper arm, reference standard BP.

For BP measured with the extra-long cuff at the upper arm site, bias and precision were 6.3 ± 8.2 mm Hg for SBP and 2.7 ± 7.7 mm Hg for DBP, with 31% of systolic and 23% of diastolic measurements showing a ≥10–mm Hg difference from the upper arm BP, reference standard (Table 4; Fig 2). Differences of ≥20 mm Hg were found in 10% and 4% of systolic and diastolic measurements, respectively. Student *t* tests found significantly higher SBP measured with the extra-long cuff at the upper arm site compared with the upper arm, reference standard BP ($t_{48df} = 5.38$, $P < .0001$) but not for the DBP ($t_{48df} = 4.11$, $P < .019$).

Multiple regression analysis found no confounding factors (eg, age, arm circumference, gender) to significantly explain BP differences between the forearm or extra-long cuff BP and the reference standard BP ($P > .05$).

Discussion

This study found that in PACU patients with large arm circumference, both the forearm BP and the use of an extra-long BP cuff on the upper arm significantly overestimated BP measurements obtained with the AHA-recommended upper arm, large BP

Table 3. Demographic and Comorbidity Data for 49 Postanesthesia Patients

Age (y)*	50.1 ± 12.4
Gender	
Male	21
Female	28
BMI (kg/m^2)*	40.4 ± 6.3
Comorbidities	
PVD	1
Diabetes	13
Hypertension	21
COPD	3
Sleep apnea	13
Upper arm circumference (cm)*	41.1 ± 3.7
Forearm circumference (cm)*	30.4 ± 2.7

BMI, body mass index; PVD, peripheral vascular disease; COPD, chronic obstructive pulmonary disease.
*Mean (± SD).

cuff. The differences observed were large, with 23% to 39% of all BPs measured with the extra-long cuff or in the forearm location showing a >10–mm Hg difference from the AHA-recommended upper arm BP cuff, with 4% to 14% of all BPs showing a difference >20 mm Hg. These data confirm that in PACU patients with large arm circumference neither the forearm BP nor the upper arm, extra-long BP cuff should be used as a replacement for the AHA-recommended large adult BP cuff and upper arm location for BP measurements.

This is the first forearm vs upper arm BP study in PACU patients and one of only three studies that has evaluated BP cuff location in patients with large arm circumference.[10,12] Although both prior studies had methodologic issues that limit their generalizability, our findings of statistically higher systolic and diastolic pressures with the forearm location for the BP cuff were consistent with their findings. Prior studies of patients with normal arm circumference found similar increases in both systolic and diastolic pressures when measured in the forearm position compared with the recommended upper arm location.[5-9,11]

In addition, this is the first study to our knowledge to compare the often clinically used extra-long BP cuff with the large adult cuff size recommended by the AHA for patients with upper arm circumferences of 35 to 43 cm. With 31% of SBP values showing a >10–mm Hg difference from the use of the recommended large adult cuff SBP, use of the extra-long upper arm cuff should be avoided until more accurate studies can be conducted on this type of cuff. Despite the longer length of material on the extra-long cuff, the cuff bladder size is only marginally wider than a regular adult cuff (Table 2). It is not surprising that we found upper arm BP measured with these cuffs to be significantly higher than when obtained with the properly sized cuff. Although the extra-long cuff wraps around the large arm–circumference patients better than a regular adult BP cuff, the bladder size is not "extra-long."

Clinical Implications

Blood pressure is a vital component for determining the status of the PACU patient. Inaccurate BP values

Table 4. Blood Pressure, Bias (average of comparison BP, reference standard values), and Precision (SD of the bias), and Percent of Individual BP Differences ≥10 and ≥20 mm Hg for Upper Arm and Forearm BP Measurements in 49 Postanesthesia Patients

BP Location		Blood Pressure (mm Hg) Range	Blood Pressure (mm Hg) Average*	Bias and Precision (mm Hg)	BP Differences From Reference Standard BP (mm Hg) ≥10	BP Differences From Reference Standard BP (mm Hg) ≥20
Upper arm/large cuff	Systolic	98-167	128.0 ± 14.0			
(reference standard)	Diastolic	47-99	67.9 ± 10.7			
Forearm (comparison BP)	Systolic	102-173	135.9 ± 16.6	7.8 ± 10.2	39%	14%
	Diastolic	38-125	72.9 ± 14.1	5.0 ± 8.5	27%	6%
Upper arm/extra-long	Systolic	96-172	134.4 ± 15.2	6.3 ± 8.2	31%	10%
cuff (comparison BP)	Diastolic	47-93	70.6 ± 11.8	2.7 ± 7.7	23%	4%

BP, blood pressure.
*Mean ± SD.

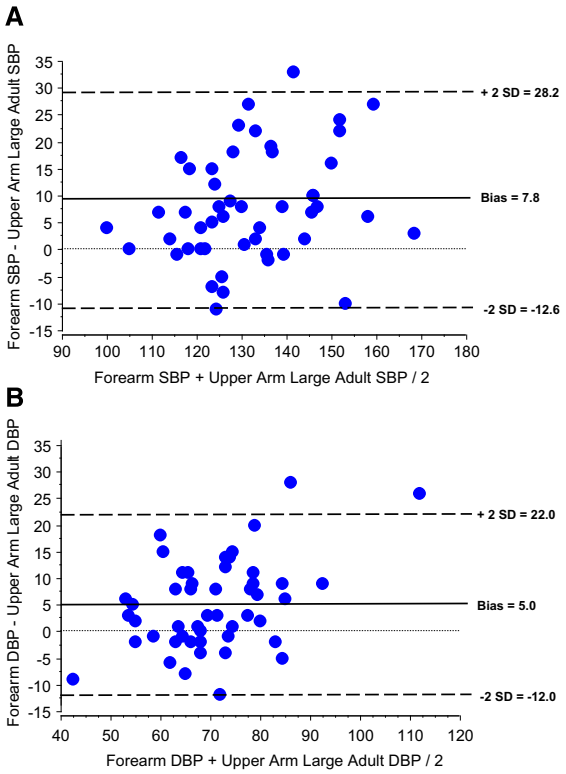

Figure 1. Bland-Altman plots of blood pressure differences (bias) and limits of agreement (±2 SD) between the forearm and upper arm blood pressure (BP) cuff sites for (A) systolic BP and (B) diastolic BP, in 49 postanesthesia patients with large arm circumference. This figure is available in color online at www.jopan.org.

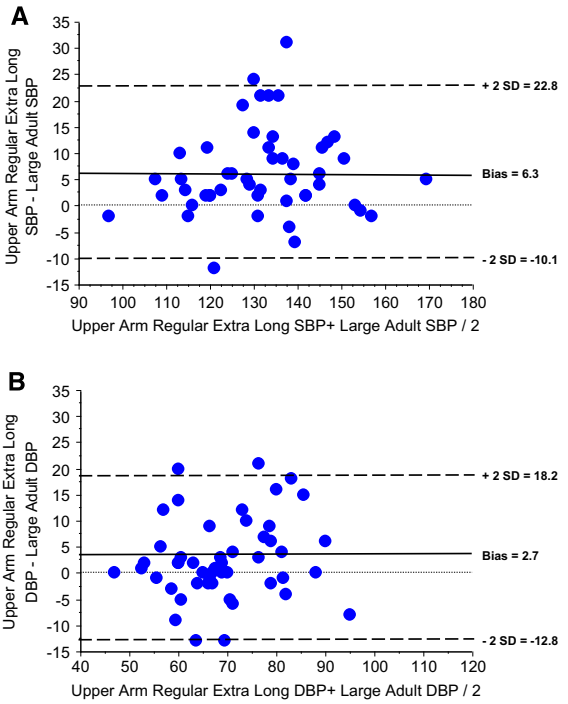

Figure 2. Bland-Altman plots of blood pressure differences (bias) and limits of agreement (±2 SD) between BP obtained in the upper arm with an extra-long, regular BP cuff and a large cuff for (A) systolic BP and (B) diastolic BP, in 49 postanesthesia patients with large arm circumference. This figure is available in color online at www.jopan.org.

could lead to inappropriate assessments and management of the patient, and could potentially harm the patient. This study's findings confirm that in patients with large arm circumference, PACU nurses should avoid the use of the forearm for BP measurement or the use of an extra-long BP cuff with a standard cuff bladder on the upper arm, because both lead to inaccurate BP values. The magnitude of the discrepancies in BP measurements could lead clinicians to incorrectly identify or miss hypotension or hypertension in PACU patients, predisposing them to serious complications.

Blood pressure cuffs currently available for automated devices are limited and not sized to properly fit obese patients with large arm circumferences but short upper arm lengths. Inclusion criteria for our study had to limit upper arm circumference to 43 cm because BP cuffs meeting AHA guidelines were not available for use with the automated BP device used at our facility for individuals with an arm circumference >43 cm. Given the number of patients with arm circumferences >43 cm,[22,23] manufacturers of automated BP devices need to develop more appropriately sized BP cuffs for this population if accurate BPs are to be obtained in these patients.

Limitations

This study only evaluated stable, adult PACU patients with large upper arm circumferences between 34 and 43 cm. Whether similar results would be found in other patient populations, such as children or individuals with arm circumferences >43 cm, or with other models of automated BP devices or manual BP devices, is not known. Additional studies are needed to determine whether the findings of this study can be generalized to those situations.

Another limitation was the location of the forearm cuff 2 to 3 cm above the radial artery at the wrist

area. Because clinicians sometimes locate the forearm cuff in the middle of the forearm length, significantly higher than the wrist area we studied, future studies should evaluate this location for forearm BP measurement.

Conclusions

In PACU patients with large arm circumferences, forearm BP measurements were found to be significantly higher than AHA-recommended upper arm BP. The common clinical practice of using an extra-long cuff for BP measurement in PACU patients with large upper arm circumference was also found to result in significantly higher BP measurement than those found with the AHA-recommended adult large BP cuff.

Acknowledgments

Special thanks to Marianne Chulay, RN, PhD, FAAN, for assistance with study design, data analysis, and manuscript preparation.

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