EMERGENCY NURSES ASSOCIATION

Clinical Practice Guideline: Non-Invasive Blood Pressure Measurement

In emergency department patients, what non-invasive blood pressure (NIBP) measurement techniques provide acceptable measurements throughout the lifespan?

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Background and Significance

Blood pressure (BP) is a core vital sign used for patient diagnosis, management and treatment. Accurate blood pressure measurement is critical as inaccuracies may delay treatment of a serious condition and/or result in clinical decisions that under- or over-treat the patient's medical condition. Invasive blood pressure measurement using arterial access is considered the "gold" standard to accurately and reliably determine the patient's BP. The previous Clinical Practice Guideline (CPG): Non-invasive Blood Pressure Measurement (NIBP) with Automated Devices (initially published in 2012) provided evidence for an acceptable correlation between auscultatory and automatic, or oscillometric, non-invasive blood pressure measurement. Therefore, this Clinical Practice Guideline CPG will use upper arm non-invasive blood pressure as the standard reference by which other methods are evaluated.

The primary focus of emergency departments is to provide initial patient management and stabilization. NIBP monitoring is a readily available method to ascertain BP, and therefore is the most common method of BP measurement in the emergency setting. Clinicians should be aware of the limitations and potential biases of various non-invasive BP measurement techniques in different patient populations and under different conditions to ensure the BP measurement technique used is appropriate and evidence-based. This CPG focuses on evidence-based practices regarding the use of noninvasive, oscillometric BP measurement for patients across the lifespan in the emergency care setting.

Methods

This CPG revision was created based on a review and critical analysis of the literature following ENA's CPG Development Manual (ENA, 2018). Articles relevant to the topic were identified through a comprehensive literature search. The following searches were performed: PubMed, HelioBLAST, CINAHL, the Cochrane Library, the British Medical Journal, the Agency for Healthcare Research and Quality, National Guideline Clearinghouse and Google Scholar. The search strategy used various combinations of key words including "NIBP", "blood pressure", "measuring", "measurement", "monitoring", "effect of clothing", "alternative cuff sites", "interval", "overweight", "bariatric", "obese", "wrist", "upper arm", "finger" and "cuff size". The initial development of this guideline in 2012 was limited to English language articles on human subjects from 1988-Novmember, 2011. This update includes articles published from 2012-November 2018 and included additional keywords "alternative cuff sites", "interval", "overweight", "bariatric", "obese", "wrist", "upper arm", "finger" and "cuff size". In addition, the reference lists in the selected articles were reviewed for pertinent citations. Research articles from ED settings, non-ED settings, position statements and guidelines from other sources were also reviewed. Clinical findings and levels of recommendations regarding patient management were made by the 2018 Emergency Nurses Association (ENA) CPG Committee according to ENA's classification of levels of recommendation for practice (Table 1). The articles were reviewed to formulate the recommendations in this CPG. Twelve additional research articles were found to augment pertinent research literature from the 2015 noninvasive blood pressure CPG addressing the revised PICOT: In emergency department patients, what non-invasive blood pressure measurement techniques provide acceptable measurements throughout the lifespan? The articles reviewed to formulate the recommendations in this CPG are described in Appendix 1.

Table 1. Levels of Recommendation for Practice

Level A Recommendations: High
• Reflects a high degree of clinical certainty • Based on availability of high-quality level I, II and/or III evidence available using Melnyk & Fineout-Overholt grading system (Melnyk & Fineout-Overholt, 2019) • Based on consistent and good quality evidence; has relevance and applicability to emergency nursing practice • Is beneficial
Level B Recommendations: Moderate
• Reflects moderate clinical certainty • Based on availability of Level III and/or Level IV and V evidence using Melnyk & Fineout-Overholt grading system (Melnyk & Fineout-Overholt, 2019) • There are some minor or inconsistencies in quality evidence; has relevance and applicability to emergency nursing practice • Is likely to be beneficial
Level C Recommendations: Weak
• Level V, VI and/or VII evidence available using Melnyk & Fineout-Overholt grading system (Melnyk & Fineout-Overholt, 2019) - Based on consensus, usual practice, evidence, case series for studies of treatment or screening, anecdotal evidence and/or opinion • There is limited or low-quality patient-oriented evidence; has relevance and applicability to emergency nursing practice • Has limited or unknown effectiveness
Not Recommended for Practice
• No objective evidence or only anecdotal evidence available, or the supportive evidence is from poorly controlled or uncontrolled studies • Other indications for not recommending evidence for practice may include: ◦ Conflicting evidence ◦ Harmfulness has been demonstrated ◦ Cost or burden necessary for intervention exceeds anticipated benefit ◦ Does not have relevance or applicability to emergency nursing practice • There are certain circumstances in which the recommendations stemming from a body of evidence should not be rated as highly as the individual studies on which they are based. For example: ◦ Heterogeneity of results ◦ Uncertainty about effect magnitude and consequences ◦ Strength of prior beliefs ◦ Publication bias

Summary of Literature Review

This summary of the literature is organized by the major topics of intermittent and continuous blood pressure measurement. The effect of cuff location, cuff size and clothing associated with intermittent BP measurement; as well as BP measurement considerations for body habitus and age are addressed. Elements within the blood pressure measurement location topic include wrist, forearm, and lower extremity measurements. Sizing of blood pressure cuffs and accuracy are summarized. The overview below includes general statistical trends; including comparative trends of systolic BP (SBP), diastolic BP (DBP), and mean arterial pressure (MAP). For the detailed findings of each study, please refer to the Evidence Table in Appendix 1.

INTERMITTENT NIBP: EFFECT OF BLOOD PRESSURE MEASUREMENT LOCATION

Wrist Blood Pressure Measurement

The results of two studies showed blood pressure measured at the wrist results in lower systolic blood pressure (SBP) measurements when compared to other measurement locations (Furgeson & Mickels-Foster, 2013; Guggiari, Bula, Iglesias, & Waeber, 2014). Mean wrist manometer measurements compared to the upper arm control was significantly lower ($p< 0.001$) for systolic and diastolic measurements (Furgeson & Mickels-Foster, 2013). Similarly, in another study, wrist systolic BP was significantly lower ($p<0.001$) when upper arm measurements (120.0 +/- 2.2mmHg) were compared with wrist measurements (130.5 +/- 1.3mmHg) (Guggiari, et al., 2014). The difference between upper arm and wrist measurements was greater than 10 mmHg in 54.2% of subjects. In a systematic review with meta-analysis, Irving, Holden, Stevens, and McManus (2016) reported a high degree of sensitivity 0.87 (95% CI [0.79, 0.93]) and specificity 0.85 (95% CI [0.64, 0.95]) when using the wrist location for BP measurement. Irving et al. (2016) recommended using wrist BP measurement only when a correctly fitting upper arm cuff is not available. Given these findings, use of the wrist location for blood pressure measurement is acceptable when upper arm measurement is not available. However, the clinician should be aware that wrist BP measurements will trend lower than upper arm measurements.

Forearm Blood Pressure Measurement

Authors of five studies report forearm blood pressures to be higher than upper arm measurement comparisons (Leblanc et al., 2013; Schell et al., 2006; Schell, Morse, & Waterhouse, 2010; Taksande, Jadhav, & Nair, 2015; Watson, 2017). LeBlanc et al. (2013) reported a strong correlation ($r = 0.90$, $P < 0.001$) between forearm and intra-arterial (IA) BP of patients with BMI >30. Compared to IA, the forearm method overestimated systolic (6 ±16 mm Hg, $P < 0.001$) and underestimated diastolic blood pressure (2 ±11 mm Hg, $P = 0.03$) in the same population (Leblanc et al., 2013). Schell et al. (2006), compared forearm BP to upper arm BP in adult patients, concluding forearm blood pressure measurements are not interchangeable with upper arm measurements but could be used if necessary, if clinicians used properly sized cuffs and realized the BP could be as much as 30 mmHg higher. There were significant and strong positive correlations between forearm and upper arm BP across patient positions of supine or head of bed (HOB) at 45° (SBP supine ($r (220) = .896$ $P<.001$), SBP HOB 45° ($r (220) = .878$ $P<.001$); DBP supine ($r(220) = .855$ $P<.001$) (HOB) at 45°($r (220) = .853$ $P<.001$); MAP supine ($r (220) = .891$ $P<.001$) (HOB) at 45 ($r(220) = .874$ $P<.001$). Additionally, statistically significant differences were found between mean SPB, DBP and MAP forearm measurements when participants were in a supine or HOB 45° position (Table 2).

Table 2. Supine vs Head of Bed Blood Pressure Measurements

Results of paired *t* tests for measurement of blood pressure in the forearm and the upper arm with patients supine vs with the head of the bed elevated 45°

	Supine		HOB 45°	
Variable	*t*	*P*	*T*	*P*
Systolic BP	-12.48*	<.001	-19.67*	<.001
Diastolic BP	-9.82*	<.001	-23.14*	<.001
Mean Arterial Pressure	-12.99*	<.001	-24.47*	<.001

*Significant at the 0.05 level

Adapted From: Schell et al. (2006), page 201

In 2010, Schell et al. repeated the study with critical care patients in supine or HOB at 30° positions. Limits of agreement were set a priori at 5 mmHG, which was exceeded in all cases (SBP Upper Arm/FA differences supine/30°: 6.2/-9.4mmHg; DBP differences supine/30°: -3.2/-6.2mmHg; MAP differences supine/30°: -4.2/-7.26 mmHg). In a pediatric patient study, Taksande et al. (2015) reported statistically ($p<0.0001$) higher forearm BPs than upper arm BPs by an approximate average of 3 mm Hg. Finally, 56% of adult post-operative patients in a study by Watson et al. (2015) had forearm measurement 10 mmHg or higher than the upper arm measurement. Conversely, Keidan, Sidi, Ben-Menachem, Tene, & Berkenstadt (2014) reported lower mean SBP using forearm measurements compared to upper arm measurements (upper arm to forearm DBP and SBP differences were statistically significant [$p=<0.001$]: SBP: Mean 1.75 mmHg, SD 13.60 mmHg; DBP Mean -1.46 mmHg, SD 11.63 mmHg).

In summary, Schell et al. (2010), studying critically ill patients, and Keidan et al. (2014) studying anesthetized pediatric patients, concluded forearm blood pressures are not interchangeable with upper arm measurements. Keidan et al. (2014) did find consistency in trending forearm blood pressures when three consecutive readings agreed, supporting forearm BPs as a viable option. Taksande et al. (2015) concluded forearm blood pressures are an acceptable alternative only when upper arm measurements cannot be obtained. Leblanc et al. (2013) found forearm measurements are more accurate than upper arm measurements in the severely obese (BMI >40kg/m2) related to the availability of appropriately sized blood pressure cuffs. Given these findings, the use of the forearm location for blood pressure measurement is acceptable when upper arm measurement is not possible, but the clinicians should be aware forearm BP measurements will trend higher than upper arm measurements.

Lower Extremity Blood Pressure Measurement

Few studies examined the accuracy of lower extremity blood pressure measurements. A study comparing IA BP with ankle and thigh BPs concluded IA BP and NIBP were significantly and positively correlated (ankle; $r2=0.67$ $p<.001$; thigh $r2=0.84$ $p<.001$) with poor agreement reporting a mean bias of 3.1 mmHg +7.7 mmHg and 5.7 mmHg +6.8 mmHg respectively (Lakhal, Macq, Ehrmann, Boulain, & Capdevila, 2012). Research comparing upper arm BP to that taken at the ankle found 73% of sample calf SBP were higher than arm, 58% for MAP, 52.7% for DBP (Schell, Briening, Lebet, Pruden, Rawheiser, & Jackson, 2011). Of note is the finding from Schell et al. (2011) that over 20% of all ankle samples had differences of 10 mmHg or more. Paired t-test results indicated the SBP and MAP differences were statistically significant, $p=0.000$ and $p=0.001$ respectively. In another study of pediatric patients, Keidan et al. (2014) examined anesthetized supine patients finding that arm to ankle DBP and SBP differences were statistically significant ($p=<0.001$) (SBP mean -9.54 mmHg, SD 16.05 mmHg; DBP mean -2.11 mmHg, SD 9.87 mmHg). A total of 29% SBP ankle readings were within +/-10% of arm measurements and 67% were within 20%. DBP ankle measurements were 44% and 74% respectively.

In the given research, on this topic, contradictions remain. Lakhal et al. (2012) concluded thigh and ankle blood pressures could be used in the critically ill population to detect therapy response and hypotension if there are contraindications to the use of upper arm measurements. However, Schell et al. (2011) studied the accuracy of calf blood pressure measurements and Keidan et al. (2014) studied ankle blood pressures, both in pediatric patients, and concluded lower extremity measurements are not interchangeable with upper arm measurements. Consecutive arm and ankle BP measurements of patients aged 1-8 under general anesthesia showed no significant relationship (Keidan et al., 2014). In Schell et. al's examination (2011) of patients in intensive care aged 1-8, calf blood pressure measurements were found to have differences greater 20 mmHg for 21.4% of SBP measurements and greater than 10 mmHg for 26.3% of SBP measurement with higher SBP measurements in a total of 73% of the study sample. Although Schell et al., (2011) recommend calf measurements should not be used on patients aged 2-5 years; if calf blood pressures must be used, all blood pressures should be taken using the calf location for more accurate trending. Given these findings, there is not enough evidence available to make a recommendation on the accuracy of lower extremity locations, including thigh, calf, or ankle for blood pressure measurement.

INTERMITTENT NIBP: SIZE OF BLOOD PRESSURE CUFF

Appropriate sized blood pressure cuffs, following manufacturer recommendations and/or arm circumference were included in protocol criteria for several studies (Anast, Olejnizak, Ingrande, & Brock-Utne, 2016; Keidan et al., 2014; Lakhal et al., 2012; O'Shea and Dempsey, 2009; Leblanc et al., 2013; Schell et al., 2006; Schell et al., 2010; Schell et al., 2011; Taksande et al., 2015; Umana, Ahmed, Fraley, & Alpert, 2006; Watson et al 2017). Only Umana et al. (2006) concluded that even with appropriately sized blood

pressure cuffs, NIBP, as opposed to invasive intra-aortic BP, is associated with measurement errors regardless of patient BMI. Conversely, the systematic review with meta-analysis by Irving et al. (2014) reported that blood pressure measurement with a correctly fitting cuff is sensitive (0.87, 95% CI [0.79,0.93]) and specific 90.85, 95% CI [0.64,0.95]) in detecting hypertension in the patient with BMI >30 when compared to invasive measurements. Similarly, individual studies by Schell et al. in 2006 and 2011 suggested appropriately sized cuffs are essential in accurate BP measurements, regardless of BP location. In summary, an appropriately sized BP cuff is more important for accuracy than location, population, or BMI.

INTERMITTENT NIBP: EFFECT OF CLOTHING

Measuring BP on the upper arm over clothing can be an alternative method to obtain accurate measures when indicated by patient condition or setting. Several studies have examined BP measurement when taken over clothing on the upper arm of the patient. No significant BP differences occurred in comparing auscultatory and oscillometric measures on sleeved (< 2mm thickness) and bare arms of hypertensive patients (Liebl, Holzgreve, Schulz, Crispin, & Bogner, 2004; Pinar, Ataalkin, & Watson, 2010). Similarly, bare and sleeved arm (mean thickness 4.3 mm) BPs of adult patients were not significantly different (Ma, Sabin, & Dawes, 2008). Measures were not significantly different over a sleeve compared to below "rolled-up" sleeve (< 4 mm) (Ertug, Cakat, Ozturk & Verim, 2017). Comparing BPs obtained over three clothing conditions (one layer of patient's own clothing, standardized fleece sleeve, and bare arm) found BP measurements were not significantly different (Thien, Keltjens, Lenders & Deinum, 2015).

In a study of 147 older adult patients (mean age of 87.2 years), BPs were measured over bare arms and over three standardized clothing conditions: over a thin shirt [< 1mm]; a thin shirt with cardigan [< 2mm cardigan]; a thin shirt with cardigan rolled to elbow (Ozone, et al., 2018). There were significant differences between the bare arm compared to the other three clothing conditions (mean BP measurements over: bare arm [128.8 ± 20/69.3 ±13.2 mmHg], shirt [131.0 ±22.2/73.9 ±15.2 mmHg], sleeved arms [136.9 ±22.2/78.9 ±15.8 mmHg] and rolled-up sleeved arms [136.4 ±26.0/80.7 ±15.9 mmHg]). In summary, small differences in BP may occur when taken over clothing compared to bare arm. Given the significant differences in BP with clothing for elderly patients, evidence indicates that the elderly may be more susceptible to the effects of clothing. Overall the evidence supports the use of BP measurement over a sleeved arm or below a "rolled-up" sleeve for practicality or patient comfort in the ED setting.

CONTINUOUS NIBP MONITORING (cNIBP)

Continuous noninvasive blood pressure (cNIBP) monitoring is becoming more readily available for use in emergency departments (Gratz, et al, 2017; Nowak, et al., 2011). The continuous NIBP devices use finger cuff arterial pulsations to derive BP wave shapes using sensors. The approved cNIBP devices have met the recommended testing standards established by the Association for the Advancement of Medical Instrumentation. Nowak et al. (2011) compared continuous NIBP and heart rate measures with intermittent oscillometric measures among 40 adult ED patients. There were significant correlations between the intermittent and continuous diastolic ($r=0.75$, $p<.0001$) and systolic BP readings ($r=0.83$, $p<.0001$). Similarly, heart rates by intermittent and continuous measurements were significantly correlated ($r=0.97$, $p<.0001$). Bland-Altman plots showed 95% agreement between two types of BP measurement. In a study of adult surgical patients, continuous NIBP using finger cuff was compared to intra-arterial monitoring (Gratz, et al., 2017), finding that the two were significantly correlated (<.0001). Systolic, diastolic and mean pressure correlations were: 0.92, 0.86 and 0.91 respectively. The use of cNIBP may be a useful alternative to invasive arterial BP monitoring for ED patients.

SPECIAL POPULATIONS

Obesity and BP Measurement

There are diagnostic accuracy variations by method of BP measurement in patients with obesity (Body Mass Index [BMI] ≥ 30 kg/m2) or a large upper arm circumference (≥ 35cm). In a high-quality systematic review with meta-analysis by Irving et al. (2016), BP measurement with a correctly fitting upper arm cuff was found to be most accurate when compared to invasive BP in detecting HTN in obese patients (Sensitivity of 0.87 [0.79 to 0.93] and specificity of 0.85 [0.64 to 0.95]). However, if a correctly fitting upper arm cuff was not available, wrist BP measurement was the next best alternative (sensitivity of 0.92, 95% CI [0.64, 0.99] and specificity

of 0.92, 95% CI [0.85,0.87]) (Irving et al., 2016). In another study involving 34 patients, researchers found that use of a conically shaped forearm cuff accurately measured BP (absolute average error of 5 mmHg or less with an SD of 8 mmHg or less) compared to invasive BP measurements in patients with large upper arm circumference (Hersh et al., 2014). Similarly, LeBlanc, et al. (2013) found in a study of 51 severely obese patients undergoing surgery, the forearm systolic and diastolic BP to be closely correlated with the intra-arterial BP ($r2=0.90$, $p < 0.001$) but forearm measurements tended to overestimate SBP ($M=6 \pm 16$ mm Hg, $p < 0.001$) and underestimate DBP (2 ± 11 mm Hg, P 5 0.03). Upper arm BP was also closely associated with intra-arterial BP ($r2=0.89$, $p < 0.001$) but tended to underestimate SBP ($M=8 \pm 16$ mm Hg, $P < 0.01$) and overestimate DBP ($M=9 \pm 7$ mm Hg, $p< 0.001$) (Leblanc et al., 2013).

Conversely, other evidence indicates that BP accuracy may be affected by use of alternative cuff positions in patients with obesity or those with large arm circumference (Anast et al., 2016; Watson et al., 2017; Verkhovsky, Smit, Levin, & Coetzee, 2018). Watson et al. (2017) compared forearm BP (upper, middle, and lower) to upper arm BP in patients with large arm circumferences. Fifty-six percent of the 48 patients studied had a difference of at least 10 mmHg in one or more BP from each of the three forearm positions compared to the upper arm (Watson et al., 2017). Consequently, researchers concluded that the BP measurements at the forearm location were not equivalent to the BPs obtained at the upper arm location in patients with large arm circumference (Watson et al., 2017). Similarly, in a study comparing proximal forearm NIBP to intra-arterial BP measurement in 30 obese patients undergoing surgery, researchers concluded that forearm NIBP was not equivalent to direct intra-arterial BP measurement (Verkhovsky et al, 2018). The evidence revealed that forearm NIBP overestimated mean intra-arterial MAP by -2.2 mm Hg (SD 8.1; range from -3.8 to 19.4 mmHg; $p = 0.011$, 95% CI [-3.9,0.5]) and Bland–Altman analyses revealed a wide distribution of mean arterial pressures, exceeding the specified acceptable ranges (Verkhovsky et al, 2018). Anast et al. (2017) found that both upper arm BP, with the cuff using two different wrapping techniques (cylindrical and conical), as well as forearm BP had unacceptable precision and bias compared with IABP measurement. Cuff placement on obese patients influences the accuracy of readings.

AGE CONSIDERATIONS FOR BP MEASUREMENT

Patient age considerations for blood pressure measurement is grouped into ages: neonate/pediatric or elderly. O'Shea & Dempsey (2009) conducted a study using a convenience sample of newborns to compare upper limb and lower limb NIBP to an invasive BP measurement. They found an overestimation of NIBP in neonates with an average difference between mean invasive and noninvasive BP of 5.1 (±8.08) mm Hg. Keidan et al. (2014), Schell et al. (2011), and Taksande et al. (2015) conducted studies of pediatric patients over 1 year and under 16 years of age and found upper arm measurements are more accurate than other locations. In a study involving 101 pediatric patients, aged 1-8 years, Keidan et al. (2014) found that there were substantial differences between the upper arm, forearm, and ankle BP measurements, with only 63% of simultaneous forearm SBP measurements being within 10% of the upper arm values, and only 29% of ankle SBP measurements within this limit. However, the researchers report confidence in trending forearm BPs after three consecutive measurements in agreement (Keidan et al., 2014). Schell et al. (2011) concluded calf and arm BP measurements are not interchangeable in pediatric patients age 1-8 years with the greatest BP difference occurring in children aged 2-5 years. Overall, calf SBPs were 10 mm Hg or greater than arm SBP for 49.6% ($n= 111$) and calf MAPs were 10 mm Hg or greater for 35.3% ($n = 79$) of the sample (Schell, et al., 2011). Schell et al. (2011) recommended calf BP measurements not be used in 2-5-year-old patients, but if the calf location must be used, it should be the only method used. Taksande et al. (2015) found forearm BP to be an accurate and reliable method of BP monitoring when upper arm BP cannot be used. Comparisons of NIBP FA and UA systolic BP ($r=0.843$, $p<.0001$) and diastolic BP ($r=8.46$, $p<.0001$) were significantly correlated.

Of the research studies reporting data for BP measurements on adults over age 65, none included techniques specific to measuring BP on patients with advanced age (Anast et al., 2016; Guggiari et al., 2014; Irving et al., 2016; Lakhal et al., 2012; Liebl et al., 2004; Ma et al., 2008; Ozone et al., 2018; Pinar et al., 2010; Schell et al., 2010; Thien et al., 2015; and Umana et al., 2006). Measurement of BP in adults over 65 years requires no special consideration.

Description of Decision Options/Interventions and the Level of Recommendation

Description of Decision Options/Interventions and the Level of Recommendation		
Intermittent BP: Location of NIBP Measurement	Use of the wrist for blood pressure measurement is acceptable when upper arm measurement is not possible. Wrist BP measurements will trend lower than upper arm measurements. (Furgeson & Mickels-Foster, 2013; Guggiari, et al., 2014; Irving, et al., 2016)	B
	Use of the forearm for blood pressure measurement is acceptable when upper arm measurement is not possible. Forearm BP measurements will trend higher than upper arm measurements. (Keidan, et al., 2014; Leblanc et al., 2013; Schell et al., 2006; Schell, et al., 2010; Taksande, et al., 2015; Watson, 2017)	B
	There is insufficient evidence to make a recommendation on the accuracy of lower extremity locations (thigh, calf, or ankle) for blood pressure measurement. (Keidan, et al., 2014; Lakhal, et al., 2012; Schell, et al., 2011)	I/E
Intermittent NIBP: Cuff Size	An appropriately sized BP cuff is more important for accurate measurement than location, population, or BMI. (Anast, et al., 2016; Keidan et al., 2014; Leblanc et al., 2013; Lakhal et al., 2012; O'Shea and Dempsey, 2009; Schell et al., 2006; Schell et al., 2010; Schell et al., 2011; Taksande et al., 2015; Umana, et al., 2006; Watson, et al., 2017)	A
Intermittent NIBP: Effect of Clothing	Measuring BP on the upper arm over sleeved or bare arm below a rolled sleeve is usually comparable to bare arm measurements among adults. Measurements over thicker clothing will trend towards higher BP than on bare arm. (Ertug, et al., 2017; Ma, et al., 2008; Ozone, et al., 2018; Pinar, et al., 2010; Liebl et al., 2004; Thien, et al., 2015). Older adults may be more susceptible to variances in blood pressure associated with the effect of clothing (Ozone, et al.)	B
Continuous NIBP (cNIBP)	Use of continuous noninvasive blood pressure (cNIBP), using a finger cuff sensor, is acceptable for emergency department patients. (Gratz, et al., 2017; Nowak, et al., 2011)	B
Obesity	In patients with obesity or large upper arm circumference, wrist and forearm BP measurement may be acceptable when a correctly fitting cuff for the upper arm is not available. Forearm SBP measurements will trend higher than upper arm measurements. (Anast, et at., 2016; Hersh et al., 2014; Irving et al., 2016; Leblanc, et al., 2013; Verhosvsky et al., 2018; Watson et al., 2017)	B
Age	Measuring BP of adults over 65 requires no special technique. (Anast et al., 2016; Guggiari et al., 2014; Irving et al., 2016; Lakhal et al., 2012; Liebl et al., 2004; Ma et al., 2008; Ozone et al., 2018; Pinar et al., 2010; Schell et al., 2010; Thien et al., 2015; Umana et al., 2006)	B
	Use of arm, ankle, or calf BP locations in children aged 1-15 years may not be as reliably accurate when compared to upper arm measurements and should be used only when upper arm is not available. (Keidan et al., 2014; Schell et al., 2011; Taksande et al., 2015)	C
	There is insufficient evidence to recommend for or against use of NIBP in the neonatal population. (O'Shea & Dempsey, 2009)	I/E

Level A (High)	Based on consistent and good quality of evidence; has relevance and applicability to emergency nursing practice.
Level B (Moderate):	There are some minor inconsistencies in quality evidence; has relevance and applicability to emergency nursing practice.
Level C (Weak)	There is limited or low-quality patient-oriented evidence; has relevance and applicability to emergency nursing practice.
N/R Not Recommended	Based upon current evidence.
I/E:	Insufficient evidence upon which to make a recommendation.
N/E:	No evidence upon which to make a recommendation.

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Appendix 1: Evidence Table

Reference	Research Purpose Questions, Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Anast, N., Olejniczak, M., Ingrande, J., & Brock-Utne, J. (2016). The impact of blood pressure cuff location on the accuracy of noninvasive blood pressure measurements in obese patients: an observational study. *Canadian Journal of Anesthesia/ Journal Canadien d'Anesthésie, 63*(3), 298-306. doi:10.1007/ s12630-015-0509-6	Accuracy of non-invasive blood pressures (NIBP) of obese patients based on placement location of cuff as compared to intra-arterial blood pressures	Prospective, observational. Data analyst WAS blinded. IRB approval received. Ind Var: twice in each of 3 BP options: cylinder on upper arm, conical on upper arm, cylinder on forearm. Dep Var: Blood pressure measurements (SBP, DBP, MAP). Comparison: arterial BP. 10mmHg difference considered clinically significant (a priori) Convenience sample. N=30. Power analysis suggested 22. Setting was operative suite with patients supine and under anesthesia	Phillip BP machines. Bland-Altman for precision and Bias. ANOVA and Welch's T test for differences in bias. Linear or logistic regression for relationships	Bland Altman indicated imprecision throughout. Linear indicated no relationship between BP and BMI or total/lean weights. Only statistical different position was conical upper arm compared to arterial BP. Mean difference 7.2 95% CI [-12.1,26.5]; p=0.027. Both upper arm cuff positions underestimate BP. Ultimately – NO recommendation.	2	VI
Ertug, N., Cakal, T., Ozturk, S. B., & Verim, M. (2017). The effect of clothes on blood pressure measurement. *Pakistan Journal of Medical Sciences, 33*(1), 205-209. doi:10.12669/pjms.331.11811	To examine the effect of clothes on BP measurement	Prospective, one-group, pre-posttest. BP was measured X2 for each subject; using the sequence of BP over the sleeve AND below a rolled-up sleeve using mercury sphygmomanometer. Clothing thickness of each par Sample: Convenience sample of undergraduate nursing students; 162 participants; all Caucasians, 6.8% (n=11) smoked, Mean Age 20.71 (+2.16); Mean BMI 22.08 (+2.99) Setting: University skills lab in Turkey	Using mercury sphygmomanometer for BP measurements. Clothing thickness of each participant measured using "skinfold caliper". Utilized Wilcoxon and Mann-Whitney U tests to compare differences. IRB obtained.	BP comparison for each condition: Mean BP over the sleeve= systolic 110.07(+11.31) & diastolic=69.56 (+8.95); Mean BP below the rolled-up sleeve =systolic: 110.37 (+10.94) & diastolic 69.59 (+9.03). There were no statistically significant differences between SBP or DBP for the 2 measurement conditions. Clothing thickness did not exceed 2mm in any of the subjects.	2	IV
Furgeson, D., & Mickels-Foster, N. (2013). Accuracy of digital arm and wrist manometers: Clinical implications for the dental hygienist. *American Dental Hygienists Association, 87*(5), 309-314.	To examine the accuracy of digital, automated arm and wrist cuffs	Prospective, RCT (subjects randomized to modality of having upper arm or wrist measured first). Sample: 100 subjects; adults > 18 yrs old. Setting: Dental Clinic	Used aneroid manometer as control measure of BP; and the upper arm and wrist BPs taken with automated manometer. Trained dental hygienists obtained BP readings. Readings obtained in both upper arm and wrist with digital manometer. Used Pearson chi-square and t-test analyses. IRB approval	1) Inter-rater reliability among the measurements taken by the PIs was not significantly different. 2) Mean for control was 129.1 mm Hg compared to upper arm of 127.3 mm Hg---Not significantly different (p=0.274). 3) Mean for wrist manometer compared to control was significantly lower (p=0.000) for both systolic and diastolic BP readings.	2	II

Clinical Practice Guideline:
Non-Invasive Blood Pressure Measurement
Appendix 1: Evidence Table

Reference	Research Purpose Questions, Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Gratz, I., Deal, E., Spitz, F., Baruch, M., Allen, I. E., Seaman, J. E., … Jean, S. (2017). Continuous non-invasive finger cuff CareTaker® comparable to invasive intra-arterial pressure in patients undergoing major intra-abdominal surgery. *BMC Anesthesiology, 17*(1), 48. doi:10.1186/s12871-017-0337-z	To compare non-invasive arterial pressure values to invasive arterial pressures.	A descriptive, comparative design using a convenience sample of 24 adult patients, undergoing major, open abdominal surgery, requiring hemodynamic monitoring. Investigators state that no power analysis conducted, as purpose of study was to determine difference between BP measurements. Investigators noted that sample was larger than the required sample size of 15 patients using the Association of Medical Instrumentation (AAMI) standard when an arterial line is used for comparison. Post-hoc analysis validated that 24 patients corresponded to a power greater than 80% to detect differences of 10% at the 0.05 level	The CareTaker® (CT) device was used to measure noninvasive BP using finger cuff. The BP is derived from a pulse contour algorithm called the "Pulse Decomposition Analysis" (PDA). The CT is a sensing system communicates physiological data wirelessly. Uses a cuff around the finger. Investigators used a specific protocol for standardization of calibration and data collection. Statistical analysis: Bland-Altman plots, correlations conducted.	A 4-Quadrant plot and Polar plot calculated--demonstrated a 99%concordance between BP's, with differences <10; and 95% concordance between BP's with differences <5. Bland-Altman (overall mean differences) were -0.57, -2.52 & 1.01 mm Hg for systolic, diastolic and mean arterial pressures respectively, p<0.001)	2	III
Guggiari, C., Büla, C., Iglesias, K., & Waeber, B. (2014). Measurement with an automated oscillometric wrist device with position sensor leads to lower values than measurements obtained with an automated oscillometric arm device from the same manufacturer in elderly persons. *Blood Pressure Monitoring, 19*(1), 32-37. doi:10.1097/MBP.0000000000000013	To examine accuracy of wrist manometers for use in BP self-monitoring among older adults.	Prospective, cohort study of older adults. Sequence of BP measurements (upper arm or wrist) was randomized. Ethical Committee Approval. Sample: Total of 48 subjects aged 65 and older; 15 men & 33 women; convenience sample. Setting: Post-acute care rehabilitation facility. Sample size determined by power analysis to detect a 2.0+ 2.0 mm Hg difference between BP of upper arm and wrist.	Standardized protocol for obtaining BP. Including upper arm measurement by oscillometric BP cuff. This included also keeping wrist cuff at level of the heart during measurement. Statistical analysis included use of Chi-squared and Fischer's exact tests for categorical data; and t-test and Wilcoxon rank-sum test for the continuous variables. Bland-Altman used to examine agreement between BP measures.	Systolic BP (SBP) in wrist was significantly lower (p<0.001); upper arm 120.0 +2.2/66.0 +1.3 compared to 130.5 +2.2/69.7 +1.3 for the wrist. In 54.2% of subjects the difference was greater than 10 mm Hg.	2	IV
Hersh, L. T., Sesing, J. C., Luczyk, W. J., Friedman, B. A., Zhou, S., & Batchelder, P. B. (2014). Validation of a conical cuff on the forearm for estimating radial artery blood pressure. *Blood Pressure Monitoring, 19*(1), 38-45. doi:10.1097/MBP.0000000000000011	Comparison of GE developed cone shaped forearm blood pressure cuff with arterial BP in obese patients	Quasi-experimental observation 34 patients specifically recruited for study Inclusion: obese with mid-upper arm 40cm r more &/0r conical upper arm shape &/or undersized upper arm length. Held in research clinic. NIBP compared with radial arterial line. Patients supine with forearm level with art line transducer.	Radial arterial reading. 30 seconds later conical forearm reading. 30 seconds later another radial arterial reading. All with MAP. Accuracy gauged by average error of 5mmHg or less and SD of 8mmHG or less. Bland-Altman plots. Mean and SD.	Forearm cuff is comparable to radial artery readings. Systolic mean error / SD = -0.82mmHG / 6.08mmHg. Diastolic mean error / SD = 1.53mmHG / 3.83mmHG. MAP mean error / SD = 2.58mmHG / 4.24mmHG. Bland-Altman indicated random error distribution	2	III

Appendix 1: Evidence Table

Reference	Research Purpose Questions, Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Irving, G., Holden, J., Stevens, R., & McManus, R. J. (2016). Which cuff should I use? Indirect blood pressure measurement for the diagnosis of hypertension in patients with obesity: a diagnostic accuracy review. *BMJ Open, 6*(11), e012429. doi:10.1136/bmjopen-2016-012429	To examine the accuracy of various methods of non-invasive BP measurement compared to the reference standard in detecting hypertension in obese patients with large arm circumference	Systematic Review with meta-analysis 37 studies included including 1 randomized trial, 1 case-control study, and 35 cross-sectional studies. 20 studies with extractable data; 3 studies with individual patient data	Study quality assessed with QUADAS2. Forest plots of sensitivity and specificity created for each study. STATA V.13.0. Bland-Altman method for individual patient data.	BP measurement with a correctly fitting upper arm cuff is sensitive and specific in detecting HTN in obese patients (compared to IBP). Sensitivity of 0.87 (0.79 to 0.93) and specificity of 0.85 (0.64 to 0.95); If a correctly fitting upper arm cuff is not available, wrist BP measurement is the next best alternative Sensitivity of 0.92 (0.64 to 0.99) and specificity of 0.92 (0.85 to 0.87).	1	I
Keidan, I., Sidi, A., Ben-Menachem, E., Tene, Y., & Berkenstadt, H. (2014). Inconsistency between simultaneous blood pressure measurements in the arm, forearm, and leg in anesthetized children. *Journal of Clinical Anesthesia, 26*(1), 52-57. doi:10.1016/j.jclinane.2013.10.005	Examine accuracy of NIBP taken in arm, forearm, and ankle of anesthetized children	Randomized prospective. Dependent variable: blood pressure locations of arm, forearm, and ankle – taken simultaneously using same size cuff in each location for each patient BUT assigned for data collection via table of random numbers. Independent Variable: SBP and DBP 101 consecutive patients aged 1-8 years undergoing specific elective surgeries. 80% power to detect 5% level of significance. Excluded significant heart, lung, vascular disease and children overweight OR with significant skin lesions. In PeriOp setting with patients supine.	Paired T-test. Mean +/_ 2SD. Bland-Altman figures. Arbitrary decision of BP differences 20% or less between locations were clinically acceptable.	Number of measures per individual: Mean 10.3; SD 7.3. Arm to forearm DBP and SBP differences were statistically significant (p=<0.001): SBP Mean 1.75mmHg; SD 13.60mmHg & DBP Mean -1.46; SD 11.63. 63% SBP forearm within +/- 10 or arm and 85% were within +/-20%. DBP forearm was 42% and 67% respectively. Arm to ankle DBP and SBP were statistically significant (p=<0.001): SBP -9.54; SD 16.05 & DBP Mean -2.11; SD 9.87. 29% of SBP ankle was within +/-10% of arm and 67% of within 20%. DBP ankle measurements were 44% and 74% respectively. CONCLUSIONS: forearm and ankle BP locations result in inconsistent and unreliable readings for children under anesthesia. AND when first three consecutive reading agree, subsequent consistency is likely leading to recommendation of the forearm as a possible viable option.	2	II

Appendix 1: Evidence Table

Reference	Research Purpose Questions, Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Leblanc, M. É., Croteau, S., Ferland, A., Bussieres, J., Cloutier, L., Hould, F. S., ... & Poirier, P. (2013). Blood pressure assessment in severe obesity: validation of a forearm approach. *Obesity, 21*(12), E533-E541. doi:10.1002/oby.20458	To compare accuracy between Intra-arterial BP measurement and forearm and upper-arm BP measurement method in the severely obese patient	Prospective cohort study. Severely obese patients were separated in two groups. The first group had BP measured with ABP and non-invasive forearm method in the OR and recovery rooms (upper-arm blood pressure not measured as it was not technically possible). The second group had their BP measured in the recovery room only using NIBP upper arm and forearm methods on the same arm in the addition to the intra-arterial blood pressure taken at the contra-lateral arm. N=51 severely obese adults undergoing biliopancreatic diversion with duodenal switch surgery Inclusion: > 18yrs with BMI ≥40 or ≥ 35 kg=m2. Exclusion: significant peripheral arterial disease, resulting in at least a 20 mm Hg blood pressure difference between both arms Setting: academic medical center in Canada	Data are reported as mean 6 standard deviation (SD). Unpaired t-test for independent samples. Chi-square analysis was performed to determine differences between groups in categorical variables. Differences between the mean of first 3 readings were calculated for systolic=diastolic BP and compared with a paired t-test. A Bland-Altman graphic was drawn to assess the relationship between methods.	Forearm BP method is a more accurate alternative to upper-arm measurement to assess blood pressure in severely obese patients as compared to ABP. Correlation between the intra-arterial and the forearm measures was 0.90 ($P < 0.001$) for the 2570 data (systolic and diastolic). Compared to intra-arterial, the forearm method overestimated systolic (6 6 16 mm Hg, $P < 0.001$) and underestimated diastolic blood pressure (2 6 11 mm Hg, P 5 0.03). Compared to intra-arterial, upper-arm underestimated systolic (8 6 16 mm Hg, $P < 0.01$) and overestimated diastolic blood pressure (9 6 7 mm Hg, $P < 0.001$).	1	IV

Appendix 1: Evidence Table

Reference	Research Purpose Questions, Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Lakhal, K., Macq, C., Ehrmann, S., Boulain, T., & Capdevila, X. (2012). Noninvasive monitoring of blood pressure in the critically ill: reliability according to the cuff site (arm, thigh, Lakhal, K., Macq, C., Ehrmann, S., Boulain, T., & Capdevila, X. (2012). Noninvasive monitoring of blood pressure in the critically ill: reliability according to the cuff site (arm, thigh, or ankle). *Critical Care Medicine, 40*(4), 1207-1213. doi:10.1097/CCM.0b013e31823dae42	To examine the reliability of noninvasive BP readings at anatomic sites of thigh and ankle	Prospective, observational design; Patients in ICU underwent BP measurement (3-pairs) at arm, ankle and thigh--comparing Cuff (non-invasive BP -NIBP) to intra-arterial BP (IABP);; * if participant needed circulatory support--volume expansion and/or dose of catecholamine adjusted) then 2nd set of BP measurements obtained. Sample: N=150 (159 patients of 1042 patients met the inclusion criteria over 18-month period; and 4 patients not included due to other patient/clinical issues). Subjects all had arterial lines present. Setting: Medical-surgical ICU in University hospital in France.	NIBP and IABP measurements used following protocol for study participants. Statistical analysis: Correlations and use of linear regression and Bland-Altman analyses.	Arm: IABP and NIBP had significantly correlated (r2=0.85; p<.0001); agreement was acceptable; mean bias of 3.4 +5.0 mmHg). Ankle & Thigh: IABP and NIBP were significantly correlated (r2=0.67 & r2=0.84) or positively correlated Their agreement was poor; mean bias of 3.1 +7.7 and 5.7 +6.8 mmHg respectively). The higher the IABP, the underestimation of arm NIBP. Concluded: critically ill patient, arm BP accurate; if there are contraindications alternative site (ankle/thigh can detect hypotension and therapy response. Age: IABP in thigh for patients > 60 years old had significantly higher (better) mean bias -0.06 +4.8 mm Hg (n=37), compared to younger patients 8.2 +6.0 mm Hg (n=87); for ankle: mean bias 2.0 +9.1 mm Hg, (n=48).	2	IV

Appendix 1: Evidence Table

Reference	Research Purpose Questions, Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Liebl, M., Holzgreve, H., Schulz, M., Crispin, A., & Bogner, J. (2004). The effect of clothes on sphygmomanometric and oscillometric blood pressure measurement. *Blood Pressure, 13*(5), 279-282.	Does a layer of clothing affect BP during auscultatory BP measurement and oscillometric blood pressure measurement	Design: sleeved and non-sleeved BP taken with auscultatory on left and oscillometric on right after 5 min resting and at least 1min b/w readings. Body and arm position standardized. All auscultatory BP by same observer. Oscillometric clothing blinded by screen. N=201 Setting: Hospital in Germany Inclusion criteria: 18yrs or older and informed consent Exclusion criteria: Obese arm size and cardiac arrhythmias.	Pearson's correlation of sleeved arm and bared arm. Bland-Altman to detect potential error with measurement level. Linear regression and equivalence test. Data analyzed using SPSS Software System Version 11.5	Measuring BP over a sleeve does not differ from the non-sleeved arm using both methods of BP measurement and is true for both normotensive and hypertensive patients. Findings: In each category, the measurements correlated to a high degree. Pearson's correlation coefficients lay between 0.79 in SPH DIA and 0.90 in SPH SYS (0.89 in OSC SYS, 0.81 in OSC DIA). The differences in each category showed approximately normal distribution. Distribution of values was specified by standard deviations ranging from 6.3 mmHg in SPH DIA to 9.3 mmHg in OSC SYS (8.6 in SPH SYS, 6.5 in OSC DIA). Evaluation was conducted with 95% CI for the averaged differences of the individual BP readings. On average, with sphygmomanometer, sleeve effects led to an overestimation of 1.0 mmHg in SYS and of 0.8 mmHg in DIA; 95% CI [0.2; 2.1] for the systoles and [0.1,1.7] for the diastoles. In oscillometric, sleeved measurements also showed a slight tendency towards overestimation. They were 1.1 mmHg (SYS) and 0.5 mmHg (DIA) higher than the average; 95% CI [0.2; 2.4] in OSC SYS and [0.4,1.4] in OSC DIA" p. 280. No significant differences noted in the HTN subgroup.	1	VI

Appendix 1: Evidence Table

Reference	Research Purpose Questions, Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Ma, G., Sabin, N, & Daws, M. (2008). A comparison of blood pressure measurement over a sleeved arm versus a bare arm. *Canadian Medical Association Journal, 178*(5), 585-589. doi:10.1503/cmaj.070975	To evaluate the effect of clothing on accurate BP in comparison to a bare arm.	Patient were randomized to either have 2 consecutive BP's on bare arm or 1st BP on bare arm and 2nd BP on clothed arm. BP's taken 3min apart. 5 examiners trained to use BP machine. N=376 - recruited 400 consecutive participants. Stats-Direct used to estimate minimum sample size to demonstrate significance. Inclusion: 18-85yrs and informed consent; Exclusion: pts unable to use right arm, sleeves ended at or above elbow. Setting: Family Medicine Clinic in Quebec, Canada	Student's T-test to examine overall difference in mean BP's. Analysis of covariance to examine effect of variables such as clothing thickness on 2nd readings.	No significant difference in BP with bare arm versus BP over clothing. The mean differences between the 1st and 2nd readings for patients in bare-arm group were 4.1 mm Hg, 95% CI [2.8,5.5] for SBP and 0.1 mm Hg, 95% CI [–0.7,0.9] for DBP. The mean differences between the 1st and 2nd readings for patients in the sleeved-arm group were 3.4 mm Hg,95% CI [2.1,4.7] for SBP and 0.4 mm Hg 95% CI [–0.4,1.3] for DBP. The between-group differences in these values was 0.76 mm Hg 95% CI[–1.13,2.65] for SBP and –0.31 mm Hg 95% CI [–1.48,0.86] for DBP	1	II
Nowak, R. M., Sen, A., Garcia, A. J., Wilkie, H., Yang, J. J., Nowak, M. R., & Moyer, M. L. (2011). Noninvasive continuous or intermittent blood pressure and heart rate patient monitoring in the ED. *American Journal of Emergency Medicine, 29*(7), 782-789. doi:10.1016/j.ajem.2011.05.014	Does the use of the Nexfin noninvasive continuous BP and HR monitoring device produce the same values as the noninvasive intermittent brachial cuff device in the ED?	Prospective, observational, exploratory, convenience study. Measured SBP, DBP, MAP & HR at baseline then Q15 minutes for 2 hours on Upper arm and opposite finger. no treatment decisions made using Nexfin device (clinicians blinded to finger cuff readings). n = 40 convenience sample of >18 yrs, acutely ill, triaged at level 1 or sent to the resuscitation room (25 Male, 15 Female) Setting: Henry Ford Hospital ED, Detroit MI	Simultaneous use of Nexfin device and automated NIBP brachial cuff device, along with lead 2 cardiac monitoring (HP, Agilent-PT, Philips). Pearson product-moment correlation coefficients used for HR & BP correlations. Scatter and Bland-Altman plots were used.	Pearson correlation coefficient 0.83, P<0.001 SBP Mean 143.56 (SD 36.88) SBP Nexfin Mean 142.69 (SD 42.70) DBP Mean 77.19 (SD 22.94) DBP Nexfin Mean 78.43 (SD 19.97) HR Mean 83.90 (SD 22.48) HR Nexfin Mean 83.81 (SD 22.48) Nexfin results indicate validated use in ED patients, especially for HR monitoring. BUT reported variability in non-sedated / non-intubated patients	1	III

Appendix 1: Evidence Table

Reference	Research Purpose Questions, Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
O'Shea, J., & Dempsey, E. M. (2009). A comparison of blood pressure measurements in newborns. *American journal of perinatology, 26*(2), 113-116. doi:10.1055/s-0028-1091391	The authors sought to compare the Dinamap, Marquette, and Dash (3 oscillometric methods of BP measurement) to invasive BP measure and simultaneously compare upper and lower limb BP measurements	Descriptive, correlational Study. Convenience sample. N=25(21 premature) Median birth weight = 1790 g (560 - 4050 g). 6 umbilical lines, 15 radial, 3 posterior tibial arterial lines. All required respiratory support, 5 (20%) required ionotropic support.	Bland Altman plot (compared mean invasive and mean noninvasive BP measurements, along with comparing the non-invasive upper and lower limb measurements. Regression analysis performed to determine the correlation coefficient of mean invasive and noninvasive BP and the noninvasive BP measurements on the upper and lower limbs	Good correlation found between all invasive and noninvasive BP measurements r = 0.67 (p<0.001). All noninvasive recorders overestimated MBP 5.1 (+8.08). In all 3 recorders, the higher the BP the larger the difference between recordings. Upper and lower limb average difference between readings was 0.13+9.97mm Hg. Pearson correlation r = 0.68 (p<.001). These findings support previous research that there is an overestimation of noninvasive BP in the newborn. When managing a newborn without invasive BP measurement, it is important to consider the overestimation of noninvasive BP measurements.	2	VI
Ozone, S., Sato, M., Takayashiki, A., Sato, T., Matsushita, A., Yoshimoto, H., & Maeno, T. (2018). Blood pressure measurements over thin and thick sleeves in the frail elderly. *Blood Pressure Monitoring, 23*(1), 9-11. doi:10.1097/MBP.0000000000000294	To assess the differences in BP between measurement on bare arms and with clothing of various thicknesses in older adults.	Design: Cohort, Randomization using 24 patterns of measurement order for the 4 BP measurement conditions (Bare arm, sleeve, sleeve + cardigan & rolled sleeve) and assigned randomized measurement to participants in a continuous order. Sample: 147 participants; 35 males (23.8%); mean age of 87.2 (+7.8)l; 72 (49%) had hypertension Setting: Long-term care facilities	Measures: BP measures (diastolic and systolic) using protocol. Used standardized protocol for BP measurement of separate conditions: bare arm, shirt (<0.5mm thick) shirt+ cardigan (1.0 mm thick) and with rolled sleeve (shirt + cardigan rolled up elbow). The shirts & cardigans provided for participants to wear during testing)	Findings: Mean BP for Bare arm (128.8 + 20.0/69.3 + 22.2), shirt (131.0 + 22.2/73.9 + 15.2), shirt + cardigan (136.9 + 22.2/78.9 + 15.8) and rolled sleeve (136.4 + 26.0/80.7 + 15.9). Multivariate ANOVA demonstrated: BP measurements over sleeves with cardigan and rolled up sleeves were significantly different from bare arm BP measurements. ? estimates for systolic BP was 8.15 +2.63 for sleeve + cardigan (p=0.002); systolic BP was 7.59 + 2.63 for rolled sleeve (p=0.004) Findings support the need to have BP of frail elderly taken on bare arms is preferable, however use of BP over a thin-sleeved shirt would be comparable to bare arm readings.	1	II

Appendix 1: Evidence Table

Reference	Research Purpose Questions, Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Pinar, R., Ataalkin, S. Watson, R. (2010) The effect of clothes on sphygmomanometric blood pressure measurement in hypertensive patients. *Journal of Clinical Nursing, 19*(13-14), 1861-1864. doi:10.1111/j.1365-2702.2010.03224.x	Test if there is a difference in BP measurement in patients wearing clothes or on bare arms.	N = 258, >18 yrs with dx HTN; BP arm sleeve must be max. of 2 mm. thickness; Age of pts 33-85 with mean of 61.7 (SD 11.6). Women = 52.7%. Dx of HTN mean was 8.6 yrs. 58.1% co-existing disease. Setting outpatient HTN clinic at university hospital in Istanbul between July 2005-February 2006.	Mercury-filled column sphygmomanometers were used. Use normal and large adult cuff sizes determined by mid arm circumference. Data was analyzed using SPSS v. 15.0. One-way repeated measures ANOVA used to compare BP scores with statistics test. Significance level set at $p<0.05$.	Bared arm test 1 =Mean SBP 137.33;DBP 80.51 Sleeved arm test 2 = mean SBP 136.89; DBP 80.37 Bared arm test 3 = mean SBP 136.75; DBP 80.62; multivariate eta squared SBP 0.02; DBP 0.007 with $p>0.05$ for both SBP/ DBP Conclusions: Sleeved arm didn't make difference related to accuracy.	2	III
Schell, K., Lyons, D., Bradley, E., Bucher, L., Seckel, M. et al., (2006) Clinical comparison of automatic, noninvasive measurements of blood pressure in the forearm and upper arm with the patient supine or with the head of the bed raised 45°: A follow-up study. *American Journal of Critical Care, 15*(2), 196-205.	NIBP of forearm compared with upper arm in med-surg patients positioned supine or at HOB 45 degrees.	Design: descriptive correlational comparison. Independent Variable: Site (upper arm or forearm) and patient position (supine or HOB 45*) Dependent Variable: SBP, DBP, MAP METHOD: Single arm of patient. Positioned, first NIBP location, 1-2 minutes wait, other NIBP location, change position, wait 2 min. repeat. Sample: 221 med-surg patients. Exclusions: cuff didn't fit, isolation, patient couldn't tolerate positions, patient in other than bariatric specialty bed. Power analysis indicated 203 needed. Setting: 5 med-surg units in 780 bed US acute care hospital.	Paired T test. Bland Altman.	CONCLUSION: Forearm and Upper arm NIBPs are NOT interchangeable. FINDINGS: Forearm higher (SBP, DBP, MAP) in both positions. Statistically significant differences. Significant and strong positive correlation between forearm and upper arm NIBP (SBP, DBP, MAP, & Heart Rate) across patient positions. SBP of supine patients had 95% of forearm computed upper and lower limits of agreement between +11mmHg and -27.6 of upper arm measures. Greater differences were seen with HOB 45*. BMI didn't influence differences. IMPLICATIONS: if forearm MUST be used, attention to correct cuff size selection is critical. Clinicians must realize forearm BPs may differ by over 30mmHg from upper arm.	1	VI

Appendix 1: Evidence Table

Reference	Research Purpose Questions, Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Schell, K., Briening, E., Lebet, R., Pruden, K., Rawheiser, S. & Jackson, B. (2011). Comparison of arm and calf automatic noninvasive blood pressures in pediatric intensive care patients. *Journal of Pediatric Nursing, 26*(1), 3-12. doi:10.1016/j.pedn.2009.11.007	Compare calf NIBP with upper arm in Pediatric patients	Design: descriptive comparison Independent Variable: location of BP cuff (upper arm or calf) Dependent Variable: DBP, DBP. MAP, Heart Rate METHOD: Properly sized BP cuffs on arm and calf positioned supine with HOB at 30* and wait 5 minutes after position change Assess pain and sedation before BP. Arm and calf BPs measured simultaneously. Sample: 224 patients aged 1-8 admitted to PICU. Convenience sample. Excluded: unable to tolerate position, unable to be consented, critically ill, dwarfism, congenital heart disease, on CRRT or vasoactive IV meds. Setting: 180 bed US academic hospital	Pain: FLACC, COMFORT, Wong-Baker Faces, Numeric Rating, RASS SpaceLabs BP monitor Paired t test, Multiple regression, Bland Altman. a priori p value set at less that 0.05	CONCLUSIONS: Calf and arm BPs are NOT interchangeable. FINDINGS: 73% of sample calf SBP were higher than arm, 58% for MAP, 52.7% for DBP. 37.7% of sample population SBP had differences of 10mmHg or more. 35.3% had MAP differences over 10mmHg or more. 21.8% of DBP was difference by 10mmHg or more. SBP and MAP differences were statistically significant. Other considerations, such as Age, gender, race, BMI, calf circumference, and agitation were not indicated as influencing arm–calf BP differences. BP difference was greatest in children aged 2-5. Calf should NOT be used in 2-5 year population BUT if MUST be used, should be the ONLY method used. Recommend taking arm and calf BP upon arrival to allow for accurate trending potential. Implications: Appropriate cuff size is essential. Documentation of site is critical. Clinicians need to know calf will trend higher than arm.	2	VI

Appendix 1: Evidence Table

Reference	Research Purpose Questions, Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Schell, K., Morse, K., Waterhouse, J. K. (2010). Forearm and upper-arm oscillometric blood pressure comparison in acutely ill adults. *Western Journal of Nursing Research, 32*(3), 322-340. doi:10.1177/0193945909351887	To examine if upper arm and forearm NIBP are interchangeable in critically ill patient in supine or HOB 30 degrees.	Descriptive comparison study. Repeated measures cross-over design. Independent Variable: Supine position or HOB 30 degrees. Dependent variable: NIBP of Forearm and Upper Arm. METHOD: 5 data collectors – trained. Properly fit BP cuffs. 3 BPs on each site 1 minute apart in each position with 2 minutes between positions (starting position and site randomized by coin toss) Sample: N = 70. Convenience sample of adults (18 and older) in 14 bed ICU of suburban, community hospital. Excluded if unstable or if they had specific comorbid conditions, such as Hemodialysis, on IABP machine, high risk for coagulopathy, lymphedema in upper extremity, or unable to tolerate IV positions.	A priori limits of agreement for clinical significance were set at over 5mmHg, meaning comparison BPs of 5mmHg or under are clinically significant. (Sample size of 70 met this expectation). Descriptive stats. Bland Altman. Multiple regression.	CONCLUSIONS: Forearm and upper are NOT interchangeable in critically ill patients. FINDINGS: Mean Forearm DBP, SBP, and MAP higher than upper arm in both positions. Limits of agreement exceeded 5mmHg in all cases. Regression analysis indicated forearm skin fold measurements or infection diagnosis were significantly predictive of forearm / upper arm SBP differences – smaller skin folds without infection associated with higher differences.	1	VI
Taksande, A. M., Jadhav, A., & Nair, J. (2015). Is it reliable to measure the forearm blood pressure in children? *Journal of Family & Community Medicine, 22*(2), 85-87. doi:10.4103/2230-8229.155376	In children, is a forearm blood pressure accurate and reliable compared with the upper arm?	Cross-sectional study. N=72 children aged 5-15yrs (mean 10.13yrs). Sampling method not described. Setting: Pediatric Dept of a rural hospital in Wardha, India.	Upper arm and forearm BP taken using appropriate sized cuffs in supine position 2 min apart. BP's taken with mercury sphygmomanometer and with an automated BP machine (order randomly assigned). SPSS 14.0.1 statistical software used for statistical analysis. Paired t-tests and Pearson's correlation coefficient also used.	Forearm BP is accurate and reliable method of BP monitoring when upper arm BP can't be used. FA BP slightly higher than UA BP (average 3mmHg). Pearson's correlation coefficient between FA and UA SBP measured by mercury was 0.782, and for diastolic BP (DBP) it was 0.824; Pearson's correlation coefficient between FA and UA SBP measured with an automated device was 0.843, and for DBP it was 0.846.	2	IV
Thien, T., Keltjens, E., Lenders, J. W., & Deinum, J. (2015). Should blood pressure be measured with the cuff on a bare arm? *Blood Pressure Monitoring, 20*(6), 320-324. doi:10.1097/MBP.0000000000000142	To determine whether clothing affects blood pressure accuracy when compared to a bare arm	Prospective cohort study Sample: N=133. Convenience sample. Inclusion criteria: age > 18years Setting: Outpatient clinic in Netherlands	BP measured at intervals according to protocol under three conditions: bare arm, one layer of patient's own clothing, and one layer of standardized clothing. Statistical analysis using Bland-Altman plots and linear mixed model analysis in SPSS	There was no significant difference in MAP, SBP, and DBP when BP was measured on a bare arm versus a single layer of clothing and findings independent of BP level.	1	IV

Appendix 1: Evidence Table

Reference	Research Purpose Questions, Hypothesis	Design/Sample Setting	Variables/Measures Analysis	Findings/Implications	Quality of Evidence	Level of Evidence
Umana, E., Ahmed, W., Fraley, M., Alpert, M. (2006). Comparison of oscillometric and intra-arterial systolic and diastolic blood pressures in lean, overweight, and obese patients. *Angiology, 57*(1), 41-45.	Effect of BMI on non-invasive blood pressure (NIBP) accuracy	Non-randomized interventional study. Independent Variable: BMI (Lean through morbidly obese using WHO definitions). Dependent Variable: Intraaortic (IA) BP or NIBP METHOD: Using appropriately sized NIBP cuff, IA and NIBP pressures measures concurrently. Convenience (consecutive) sample of 188 Heart Cath patients. Included all BMIs and included patients on medications for HTN. Excluded if unequal pulse or BP left to right sided. Also excluded if critically ill, such as MI, CPR, unstable rhythms, or IV medications for BP. Sampling included more women and a generally younger age in higher BMI groups. Setting: Cardiac Cath lab (IRB approved for U of So AL: Academic Medical Center)	Student t test to determine BP means from each BMI group. One-way ANOVA to determine differences between BP types and BMI groups. Linear Regression to determine relationships between blood pressure types and BMI. P value set at less than 0.05	CONCLUSION: Even with properly sized cuffs, NIBP is associated with measurement errors, regardless of BMI. FINDINGS: Significant positive correlations between IA and NIBP systolic AND diastolic across BMI groups. Mean IA SBP was significantly higher than mean NIBP SBP in all BMI groups. Mean IA DBP was significantly lower than mean NIBP DBP in all BMI groups. Magnitude of error between SBP or DBP in either IA or NIBP was not significantly different across BMI groups.	1	III
Watson, S., Aguas, M., Colegrove, P., Foisy, N., Jondahl, B., & Anastas, Z. (2017). Level of agreement between forearm and upper arm blood pressure measurements in patients with large arm circumference. *Journal of PeriAnesthesia Nursing, 32*(1), 15-21. doi:10.1016/j.jopan.2014.08.145	To examine the differences in BP measured in patients with large upper arm circumference, compared to 3 measures of forearm BP (lower, middle and upper).	Prospective, cohort study of adult PACU patients with large upper arm circumference (>34 cm, with range from 35-43 cm)---range for use of Large Adult BP cuff. Comparison of Upper arm BP (using large adult BP cuff) to forearm BP taken with regular adult BP Cuff using AHA guidelines for BP measurement. There were 3 forearm comparison (upper, mid and lower forearm) Randomization of order of forearm BP measurement Sample: Convenience sample of post-anesthesia care unit (PACU) 48 patients with large upper arm circumference	Forearm BP measures using adult size cuff: lower, middle and upper forearm. Measures for lower=3 cm above radial artery pulse, middle--between wrist and elbow, and upper--Cuff edge 3 cm below antecubital fossa. Upper arm BP--large adult BP cuff--lower cuff edge 3 cm above antecubital fossa (per AHA guideline). Participants supine, with HOB elevated 30 degrees; BP cuffs at phlebostatic axis	Upper arm BP 100-166 (M=125.1 + 17.2) mm hg SBP and 44-89 (M 65.9 +9.7) DBP. Upper forearm BP 88-175 (M=131.6 + 19.4) mm hg SBP and 42-93 (M 68.0 +12.0) DBP. Mid-forearm BP 100-167 (133.7 + 17.3) mm hg SBP and 56-98 (M 74.3 +10.5) SBP. Lower forearm BP 99-169 (131.0 + 18.1) mm hg SBP and 57-100 (M 70.6 +11.8) DBP. Bland Altman analysis; Average differences between upper arm BP and forearm---exceeded acceptable range of < 5mm Hg in 5 of 6 comparisons Summary-BP measurements in forearm was higher than recommended for upper arm BP; majority of subjects (56%) had one or more forearm BP that were 10 mm Hg higher than upper arm BP	1	IV

GRADING THE QUALITY OF THE EVIDENCE

I. Acceptable Quality: No concerns

II. Limitations in Quality: Minor flaws or inconsistencies in the evidence

III. Major Limitations in Quality: Many flaws and inconsistencies in the evidence

IV. Not Acceptable: Major flaws in the evidence

GRADING THE LEVELS OF THE EVIDENCE (MELNYK & FINEOUT-OVERHOLT, 2015)

I. Evidence from a systematic review or meta-analysis of all relevant, randomized, controlled trials or evidence-based clinical practice guidelines based on systematic reviews of RCTs

II. Evidence obtained from at least one properly designed, randomized, controlled trial

III. Evidence obtained from well-designed controlled trials without randomization

IV. Evidence obtained from well-designed case control and cohort studies

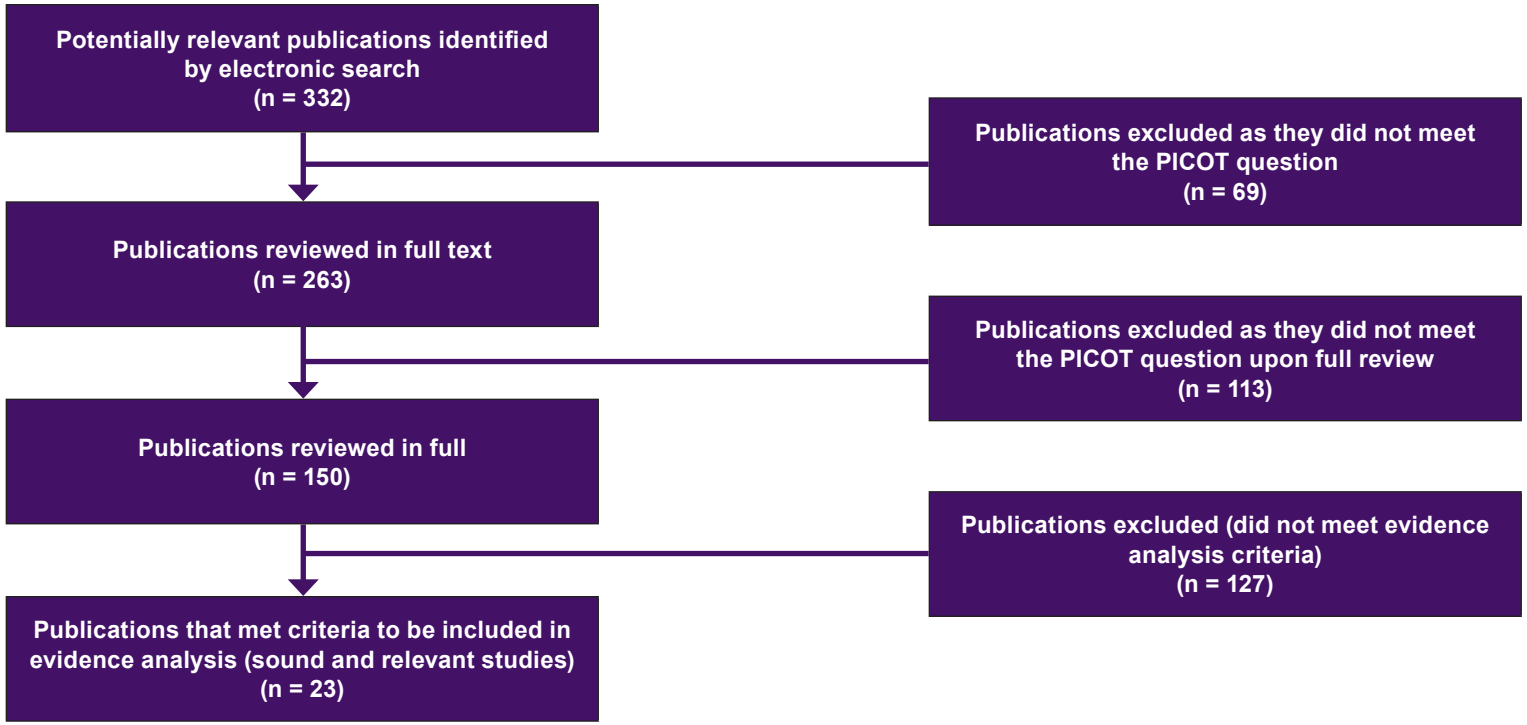
V. Evidence from systematic reviews of descriptive and qualitative studies

VI. Evidence from a single descriptive or qualitative study

VII. Evidence from opinion of authorities and/or reports of expert committees

Reference	Description	Conclusions
O'Brien, E., Petrie, J., Littler, W., de Swiet, M., Padfield, P. L., O'Malley, K., . . . Atkins, N. (1990). The British Hypertension Society protocol for the evaluation of automated and semi-automated blood pressure measuring devices with special reference to ambulatory systems. *Journal of Hypertension, 8*(7), 607-619.	Standards for the use of noninvasive blood pressure monitoring.	Recommends oscillometric measurements be compared to auscultatory measurements for accuracy.
Ogedegbe, G., & Pickering, T. (2010). Principles and techniques of blood pressure measurement. *Cardiology Clinics, 28*(4), 571-586.	Review article of evidence-based principles supporting blood pressure measurement.	Excellent overview of techniques pertaining to blood pressure measurement.
Pickering, T. G., Hall, J. E., Appel, L. J., Falkner, B. E., Graves, J., Hill, M. N., . . . Roccella, E. J. (2005). Recommendations for blood pressure measurement in humans and experimental animals: Part 1: Blood pressure measurement in humans: A statement for professionals from the subcommittee of professional and public education of the American Heart Association council on high blood pressure research. *Hypertension, 45*(1), 142-161.	Standards for blood pressure measurement.	Standards to support accuracy and precision of blood pressure monitoring.

Appendix 3: Study Selection Flowchart and Inclusion/Exclusion Criteria



Inclusion Criteria	Exclusion Criteria
Studies published in English	Studies not published in English
Studies involving human subjects	Non-human studies
January 2007 - December 2018	Studies not in the timeframe listed
Studies addressing the PICOT question	Studies not addressing the PICOT questions

A search of the following was conducted: PubMed, Helioblast, CINAHL, Cochrane Library, British Medical Journal, Agency for Healthcare Research and Quality, the National Guideline Clearinghouse and Google Scholar.

Search terms included: NIBP, blood pressure, measuring, measurement, monitoring, effect of clothing, alternative cuff sites, interval, overweight, bariatric, obese, wrist, upper arm, finger, and cuff size, using a variety of different search combinations.