



## Clinical Practice Guideline: Non-Invasive Blood Pressure Measurement with Automated Devices Full Version

Are blood pressures obtained using automated oscillometric devices as accurate as auscultatory blood pressures in patients throughout the lifespan?

### **Authored by the 2012 ENA Emergency Nursing Resources Development Committee**

Susan Barnason, PhD, RN, APRN-CNS, CEN, CCRN, FAAN

Jennifer Williams, MSN, RN, CEN, CCRN, CNS

Vicki C. Patrick, MS, RN, SRPN, ACNP, CEN, FAEN

Andrew Storer, DNP, RN, ACNP, CRNP, FNP

Carla Brim, MN, RN, CEN, CNS

Judith Halpern, MS, RN, APRN

Sherry Leviner, MSN, RN, CEN

Cathleen Lindauer, MSN, RN, CEN

Jean A. Proehl, MN, RN, CEN, CPEN, FAEN

Judith Young Bradford, DNS, RN, FAEN

### **2012 Board of Directors Liaison:**

Deena Brecher, MSN, RN, APRN, ACNS-BC, CEN, CPEN

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**Publication Date:** December 2012

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## **Background/Significance**

Blood pressure (BP) is a core vital sign used as a basis for diagnosis, management and treatment of patients in the emergency care setting. Clinical measurement of blood pressure can be accomplished both invasively and non-invasively. 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. However, invasive blood pressure techniques are not usually available during the patient's initial assessment in the emergency department (ED) and are rarely performed in the ED setting. Therefore, this Clinical Practice Guideline (CPG) will use non-invasive auscultatory (sphygmomanometer) blood pressure as the standard reference by which other methods are evaluated.

The focus in the emergency department is to initially manage and stabilize patients. Non-invasive blood pressure (NIBP) monitoring is a readily available method to ascertain BP, and therefore is the most common method of measurement in the emergency setting. Non-invasive BP measurements can be obtained using either an automated oscillometric or manual auscultatory sphygmomanometer. Clinicians need to recognize the limitations and potential biases of various non-invasive BP measurement techniques in different patient populations and under different conditions to assure that the BP measurement technique chosen is appropriate and based on evidence. This CPG focuses on evidence-based practices regarding use of non-invasive, oscillometric BP measurement for patients across the lifespan in the emergency care setting.

## **Methodology**

This CPG was created based on a thorough review and critical analysis of the literature following [ENA's Guidelines for the Development of Clinical Practice Guidelines](#). All articles relevant to the topic were identified via a comprehensive literature search. The following databases were searched: PubMed, Google Scholar, MEDLINE, CINAHL, Cochrane Library, Agency for Healthcare Research and Quality (AHRQ; [www.ahrq.gov](http://www.ahrq.gov)), and the National Guideline Clearinghouse ([www.guideline.gov](http://www.guideline.gov)). Searches were conducted using a variety of different search combinations of key words including blood pressure, blood pressure measurements, automated blood pressure, oscillometric blood pressure, auscultatory blood pressure, alternative cuff sites for blood pressure measurements, monitoring blood pressure, intermittent blood pressure, non-invasive blood pressure measurement, blood pressure monitoring, and effect of clothing on blood pressure measurement. Initial searches were limited to English language articles from January 1990-November 2012. In addition, the reference lists in the selected articles were scanned for additional pertinent references. Research articles from ED settings, non-ED settings, other emergency care settings, position statements and guidelines from other sources were also reviewed.

Articles that met the following criteria were chosen to formulate the CPG: research studies, meta-analyses, systematic reviews, and existing guidelines relevant to the topic of non-invasive BP monitoring using automated devices. Other relevant articles relevant to the topic (e.g., BP monitoring standards) were reviewed and included as additional information. Articles that did not include a comparison of oscillometric BP measurements to auscultatory or arterial pressure measurements were not included in the evidence summary. Auscultatory and arterial pressure

measurements are representative of the most accurate non-invasive and invasive BP measurements respectively; therefore, without this comparison accuracy of oscillometric devices could not be determined for purposes of this systematic review of evidence. All BP measurement devices described in this review are currently commercially available.

Articles that were included meta-analyses or systematic reviews were not considered independently unless there were factors not addressed in the meta-analysis/systematic review. The CPG authors used a standardized reference table to collect information and assist with preparation of tables of evidence ranking each article in terms of the level of evidence, quality of evidence, and relevance and applicability to practice. Clinical findings and levels of recommendations regarding patient management were then made by the ENA 2012 Emergency Nursing Resources Development Committee according to the ENA’s classification of levels of recommendation for practice, which include: Level A High, Level B Moderate, Level C Weak or Not recommended for practice (See Table 1).

**Table 1. Levels of Recommendation for Practice**

<p><b><u>Level A recommendations: High</u></b></p> <ul style="list-style-type: none"> <li>• Reflects a high degree of clinical certainty</li> <li>• Based on availability of high quality level I, II and/or III evidence available using Melnyk &amp; Fineout-Overholt grading system (Melnyk &amp; Fineout-Overholt, 2005)</li> <li>• Based on consistent and good quality evidence; has relevance and applicability to emergency nursing practice</li> <li>• Is beneficial</li> </ul>
<p><b><u>Level B recommendations: Moderate</u></b></p> <ul style="list-style-type: none"> <li>• Reflects moderate clinical certainty</li> <li>• Based on availability of Level III and/or Level IV and V evidence using Melnyk &amp; Fineout-Overholt grading system (Melnyk &amp; Fineout-Overholt, 2005)</li> <li>• There are some minor or inconsistencies in quality evidence; has relevance and applicability to emergency nursing practice</li> <li>• Is likely to be beneficial</li> </ul>
<p><b><u>Level C recommendations: Weak</u></b></p> <ul style="list-style-type: none"> <li>• Level V, VI and/or VII evidence available using Melnyk &amp; Fineout-Overholt grading system (Melnyk &amp; Fineout-Overholt, 2005) - Based on consensus, usual practice, evidence, case series for studies of treatment or screening, anecdotal evidence and/or opinion</li> <li>• There is limited or low quality patient-oriented evidence; has relevance and applicability to emergency nursing practice</li> <li>• Has limited or unknown effectiveness</li> </ul>
<p><b><u>Not recommended for practice</u></b></p> <ul style="list-style-type: none"> <li>• No objective evidence or only anecdotal evidence available; or the supportive evidence is from poorly controlled or uncontrolled studies</li> <li>• Other indications for not recommending evidence for practice may include: <ul style="list-style-type: none"> <li>○ Conflicting evidence</li> <li>○ Harmfulness has been demonstrated</li> <li>○ Cost or burden necessary for intervention exceeds anticipated benefit</li> <li>○ Does not have relevance or applicability to emergency nursing practice</li> </ul> </li> <li>• 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: <ul style="list-style-type: none"> <li>○ Heterogeneity of results</li> <li>○ Uncertainty about effect magnitude and consequences,</li> <li>○ Strength of prior beliefs</li> <li>○ Publication bias</li> </ul> </li> </ul>

## Evidence Table and Other Resources

The articles reviewed to formulate the CPG are described in the [Evidence Table](#). Other articles relevant to non-invasive blood pressure were reviewed to serve as additional resources (See [Other Resources Table](#)).

## Summary of Literature Review

Blood pressure (BP) is an important hemodynamic parameter that is usually measured non-invasively or indirectly among patients in the ED setting. Accuracy of the patient's BP is often a critical parameter that will impact the initial triage decision and subsequent diagnosis and medical management. Although the auscultatory measurement of BP\* is considered the most accurate method of obtaining non-invasive BPs, automated devices that use oscillometric† methods are widely used in the ED setting (Ogedegbe & Pickering, 2010). Therefore, it is important that ED nurses and clinicians are aware of the accuracy and precision of non-invasive oscillometric devices based on patient population, cuff location and use in ED-specific conditions. Standards set by the Association for the Advancement of Medical Instrumentation (AAMI) and the British Hypertension Society (BHS) recommend that accuracy and precision of NIBP automated devices should be compared to non-invasive auscultatory measures. It is recommended that the differences between devices, for both systolic pressures and diastolic pressures, should not exceed a mean of 5 mm Hg (measure of accuracy) or standard deviation of 8 mm Hg (measure of precision) (Association for the Advancement of Medical Instrumentation, 1993; O'Brien et al., 1990).

### ***Use of Non-invasive Oscillometric Blood Pressure Devices for Emergency Department Patient Populations***

Emergency department patients span the age spectrum and present with a wide range of clinical conditions. The use of non-invasive oscillometric BP methods for the diverse patient populations served in the ED must take into consideration variations in accuracy of BP measurements to determine the conditions under which it is appropriate to use these BP monitoring devices.

#### *Adults*

Auscultatory BP measurements are more accurate than oscillometric readings (Skirton, Chamberlain, Lawson, Ryan, & Young, 2011). Discrepancies in the mean differences between oscillometric and auscultatory readings range from +5.4 to -11.2 mm Hg systolic and from -0.5 to -8.3 mm Hg for diastolic (Amadasun & Isa, 2005; Braam, de Maat, & Thien, 2002; J. Cameron, Worrall-Carter, Riegel, Lo, & Stewart, 2009; Chiolero, Paradis, & Lambert, 2010; Heinemann, Sellick, Rickard, Reynolds, & McGrail, 2008; Jones, Engelke, Brown, & Swanson, 1996; Landgraf, Wishner, & Kloner, 2010; Manolio et al., 1988; Shahriari, Rotenberg, Nielsen, Wiinberg, & Nielsen, 2003; Vera-Cala, Orostegui, Valencia-Angel, López, & Bautista, 2011). Although auscultatory BP measures are considered to be more accurate than oscillometric, studies

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\* *Auscultatory BP measurement* = obtained by using the sphygmomanometer to audibly detect Korotokoff sounds.

† *Oscillometric BP measurement* = obtained by automated device using an electronic sensor to detect or monitor the pulsatile changes in pressure that are caused by the flow of blood through an artery that is restricted by an occluding cuff.

demonstrate that oscillometric and auscultatory readings of both systolic and diastolic BPs in hospitalized adults are highly correlated. Systolic BP correlations range from 0.98-0.73 mm Hg and from 0.94-0.51 mm Hg for diastolic pressures (Amadasun & Isa, 2005; Graettinger, Lipson, Cheung, & Weber, 1988; Manolio et al., 1988).

### *Pregnancy*

Similar to findings among the general adult population, oscillometric readings differ from auscultatory BP measurements among pregnant women. Oscillometric readings for both the systolic and diastolic BP measures were found to be significantly higher ( $p < 0.001$ ) than auscultatory readings (Green & Froman, 1996). Pregnant women in their second and third trimester being treated for hypertension, had systolic mean differences in BP per oscillometric method were +5 mm Hg compared to auscultatory, and were -2 mm Hg diastolic (Pomini et al., 2001). Among pregnant women, including those with diabetes, systolic pressures were overestimated by the oscillometric method from 6-12 mm Hg, and diastolic pressures were 1-2.6 mm Hg higher in comparison to auscultatory BP measurements (Lauszus et al., 2007).

### *Pediatrics*

In normotensive pediatric populations, auscultatory BP readings compared to oscillometric BP measures varied (Chiolero et al., 2010; Menard, Park, & Yuan, 1999; Midgley, Wardhaugh, Macfarlane, Magowan, & Kelnar, 2009; Park, Menard, & Yuan, 2001; Wattigney, Webber, Lawrence, & Berenson, 1996; Weaver, Park, & Lee, 1990; Wong, Tz Sung, & Leung, 2006). Reported mean differences between auscultatory and oscillometric pressures ranged from +10 to -0.09 mm Hg for systolic pressures and from +5 to -8.7 mm Hg for diastolic pressures (Chiolero et al., 2010; Menard et al., 1999; Park et al., 2001; Wattigney et al., 1996; Weaver et al., 1990; Wong et al., 2006).

### *Neonates*

In a small study of neonates, non-invasive and intra-arterial line (direct) BPs were compared. The neonates (N=25) had oscillometric pressures taken on an upper limb, lower limb and opposite upper limb. The oscillometric BPs overestimated mean arterial pressures (MAPs), with a mean difference of 5.1 (+ 8.08) mm Hg (O'Shea & Dempsey, 2009).

### *Hypertension*

Among patients with hypertension, the differences between auscultatory and oscillometric blood pressures demonstrated wider ranges of discrepancies, with differences attributable to increased arterial stiffness (van Popele et al., 2006). Non-invasive BPs obtained with both automated devices and sphygmomanometers were correlated; correlations for BPs were: 0.73 mm Hg systolic and 0.51 mm Hg diastolic (Gupta, Mittal, Rizzo, Bikkina, & DeBari, 2009). The BP readings using the auscultatory method were usually higher when compared to using an automated device, with mean differences between the auscultatory and oscillometric pressures ranging from -7.8 to -10.5 mm Hg for systolic pressures and from 6.6 to 7.3 mm Hg for diastolic pressures (Braam et al., 2002; Gupta et al., 2009).

### *Atrial Fibrillation*

Few studies have been conducted comparing auscultatory and oscillometric blood pressures in patients with atrial fibrillation (AF). In one study, there was greater variation when comparing BPs of patients with AF; with 25% of patients with AF having oscillometric readings that differed from auscultatory pressures by greater than 10mm Hg (Lamb, Thakrar, Ghosh, Wilson, & Wilson, 2010). Furthermore the differences included both “falsely high” and “falsely low” blood pressures obtained by oscillometric versus auscultatory methods. These variations in oscillometric BPs may be attributed to the irregular pulse intensity or pulse strength that occurs with AF. As accuracy of BP by the oscillometric devices is dependent upon determining the maximal pulse pressure, variances are greater as the pulse intensity or strength is variable with each beat in patients with AF (Geddes, Voelz, Combs, Reiner, & Babbs, 1982)

### *Trauma and Hypotension*

Low blood pressure or hypotension, associated with trauma or orthostatic hypotension, is often not detected by automated BP measurements (Dind, Short, Ekholm, & Holdgate, 2011; Skirton et al., 2011). In evaluating patients in triage with orthostatic hypotension, using an oscillometric device had a sensitivity of only 30% in detecting hypotension (Dind et al., 2011). Similarly, among trauma patients with hypotension, oscillometric BP readings were significantly ( $p<0.001$ ) higher than auscultatory BP readings reported in the Davis et al study (Skirton et al., 2011). In 49% of trauma patients ( $n=45$ ) who had an auscultatory BP less than 90 mm Hg, the oscillometric BP readings were equal to or greater than 100 mm Hg. In clinically unstable pediatric patients, the hypotensive pediatric patients had higher oscillometric BPs than auscultatory BPs; and lower oscillometric BPs than auscultatory sphygmomanometer BPs in hypertensive conditions (Holt, Withington, & Mitchell, 2011).

### *Implications of Findings*

Oscillometric BPs can both overestimate and underestimate BP measurements. This implies that use of NIBP oscillometric devices may result in clinical decisions that both under and over treat patients’ conditions based on these BP measurements. It is important that clinicians consider the implications of these differences in the management of ED patients. Researchers do not agree on measures of clinical significance. Although reported differences between oscillometric (automated) and auscultatory (sphygmomanometer) BPs were statistically significantly different, the reported differences were not considered clinically significant because they did not exceed 10% of baseline BP (Amadasun & Isa, 2005). Similarly, researchers in another study of critically ill patients reported that comparisons between oscillometric and intra-arterial BP measurements were not considered clinically significant unless discrepancies exceeded more than 10 mm Hg (Bur et al., 2003). Devices demonstrated consistency in measuring fluctuations in BP over time for the same patient (Braam et al., 2002), which is useful for ongoing monitoring in the clinical setting.

### ***Location of Cuff when Measuring Blood Pressure with Oscillometric Device***

The usual cuff placement location for obtaining non-invasive BP measurements is the upper arm. However, there are conditions when the upper arm is cannot be used (e.g., body habitus, trauma to extremity) (Pickering et al., 2005). Therefore, clinicians often use alternative sites for placing BP cuffs in order to obtain patients’ blood pressure non-invasively. Recognizing the physiological variances in blood pressure at different anatomic sites (Pickering et al., 2005), with

blood pressures higher in locations distal to the upper arm (e.g., forearm, wrist) which are associated with increased resistance to blood flow in smaller diameter arteries.

### *Forearm*

In one study, measurements of BP in the forearm were compared to the upper arm measurements of adult subjects positioned with the head of the bed flat and elevated 45 degrees (K. Schell et al., 2006), oscillometric BP measurements were significantly different ( $p < 0.001$ ) from auscultatory with mean values and limits of agreement ranging from 15-33 mm Hg. In a similar study when comparing oscillometric BPs to auscultatory measurements among acutely ill adults positioned with head of bed elevated 30 degrees and in supine positions, the differences were greater in the elevated head position as opposed to supine position (Schell, Morse, & Waterhouse, 2010). These findings indicate that forearm BPs measurements differed the most when patient position was between 30-45 degrees of head elevation.

### *Wrist*

Wrist oscillometric devices tended to overestimate hypotensive BPs and underestimate hypertensive BP measurements (Latman & Latman, 1997). Several studies have reported close approximation or good agreement between auscultatory upper arm and oscillometric wrist measurements among adult patients (Latman & Latman, 1997; Nelson, Kennedy, Regnerus, & Schweinle, 2008). However, in several other studies mean differences in systolic BP of oscillometric wrist measurements ranged from +3.9 to -8.5 mm Hg compared to auscultatory upper arm measurements, and diastolic differences from +7 to -4.4 mm Hg were reported (Rogers, Burke, Stroud, & Puddey, 1999; Rutschmann et al., 2005; Shahriari et al., 2003). The technique of using mid-arm auscultatory BPs taken with the arm positioned at mid-sternum level were not significantly different from oscillometric wrist BP readings, thus reinforcing the clinical importance of appropriate arm positioning when comparing BP measurements (Mourad, Gillies, & Carney, 2005).

### *Finger/Thumb*

A limited number of studies have examined the use of thumb or finger for BP cuff placement. Oscillometric (automated) thumb BPs in adults were obtained with a neonatal BP cuff and compared to invasive mean arterial pressures (MAPs), with mean differences of oscillometric pressures of -9.1 mm Hg systolic and +7.9 mm Hg diastolic compared to the invasive MAP (Green, 1996). When using continuous oscillometric upper arm BPs compared finger BPs there was a high correlation ( $r^2 = 0.97$ ), with levels of agreement ranging from +11.38 to -11.21 mm Hg (Nowak et al., 2011). In another study using a finger BP cuff, the oscillometric pressures had a mean difference of +1.8 mm Hg from the MAP; however, when vasoconstriction was applied, the mean difference was +5.6 mm Hg (Jagomägi, Raamat, & Talts, 2001).

### *Calf*

In a study of pediatric patients (N=221, age 1 to 8 years old) calf pressures taken with an oscillometric device compared to auscultatory BPs of the upper arm found calf oscillometric BPs significantly higher ( $p < 0.001$ ) than auscultatory arm pressures for 73% of systolic pressures and 52.7% of diastolic pressures (K. Schell et al., 2011). Considerations for the differences in BP readings obtained with the BP cuff on the calf need to be recognized by the clinician.

### *Implications of Findings*

Use of alternative sites for BP cuff location demonstrated discrepancies between the auscultatory upper arm BPs compared to alternative sites (forearm, wrist, finger/thumb, calf). Reliability between oscillometric wrist and upper arm auscultatory BPs was improved when the upper arm was held at the level of the heart (mid-sternum level). When using a BP cuff placed on the finger, one should be aware of vasoconstricting activities (e.g., “hand grasping” activities by the patient or cold environment) which would falsely elevate the BP measurement (Jagomägi et al., 2001; Nowak et al., 2011). Therefore, it is important to document the site when alternative sites are used for BP cuff placement (Schell et al., 2011).

### ***Effect of Clothing with Oscillometric Blood Pressure Devices***

Several studies have examined the use of oscillometric BP measurements with BP cuffs applied over clothing on the upper arm of the patient. Sleeved and bare arm BP measurements comparing auscultatory and oscillometric methods did not demonstrate any significant differences in hypertensive patients (Pinar, Ataalkin, & Watson, 2010). In comparing auscultatory and oscillometric BPs on a sleeved arm, the effect on auscultatory measurements overestimated systolic 1 mm Hg systolic and 0.8 mm Hg diastolic, while oscillometric readings with sleeved arm overestimated systolic BP by 1.1 mm Hg and 0.5 mm Hg diastolic (Liebl, Holzgreve, Schulz, Crispin, & Bogner, 2004). Comparing bare arm and sleeved arm measurements demonstrated no statistically significant differences; with only small mean differences of 0.76 mm Hg systolic, and -0.31 mm Hg diastolic (Ma, Sabin, & Dawes, 2008). In another study, the measurements on shirt-sleeved arm underestimated diastolic pressure by 2.2 mm Hg, and underestimated systolic pressure by 4 mm Hg. For measurements on an arm with a shirt plus sweater the diastolic pressure was underestimated by 0.8 mm Hg, and the systolic BP was overestimated by 0.5 mm Hg (Holleman, Westman, McCrory, & Simel, 1993). When comparing bare arm versus sleeved arm, systolic differences were +0.02 mm Hg and +1.27 mm Hg diastolic, and when comparing bare arm to cuff below a rolled sleeve mean differences were -0.54 mm Hg systolic and +0.56 mm Hg diastolic (Kahan, Yaphe, Knaani-Levinz, & Weingarten, 2003). Sleeve thickness of shirts, blouses, rolled sleeves and sweaters was measured ranging from 1.7 to 4.3 mm in multiple studies, with no significant differences when comparing bare arm versus sleeved arm BP measurements (Holleman et al., 1993; Kahan et al., 2003; Liebl et al., 2004; Ma et al., 2008).

### *Implications of Findings*

In summary there were small mean differences in oscillometric measurements over bare arms. Sleeve thickness of shirts, blouses, rolled sleeves and sweaters was measured from 1.7 to 4.3 mm in multiples studies demonstrated minimal differences that were not statistically or clinically significant (Holleman et al., 1993; Kahan et al., 2003; Liebl et al., 2004; Ma et al., 2008).

#### **Recommendations to Promote Accuracy and Precision of NIBP Readings**

(Association for the Advancement of Medical Instrumentation, 1993; O'Brien et al., 1990; Ogedegbe & Pickering, 2010; Pickering et al., 2005):

- Compare individual oscillometric NIBP readings with auscultatory BP readings,
- Use the appropriate size of BP cuff, and
- Follow manufacturers' recommendations for oscillometric NIBP equipment use and

## Description of Decision Options/Interventions and the Level of Recommendation

*Please note that the references listed after each recommendation represent the evidence considered when making the recommendation. This does not mean that the evidence in each individual reference supports the recommendation*

1. Non-invasive oscillometric blood pressure measurement is appropriate for adult populations. **Level A – High** (Amadasun & Isa, 2005; Braam et al., 2002; Bur et al., 2003; J.D. Cameron et al., 2008; Jones et al., 1996; Landgraf et al., 2010; Manolio et al., 1988; Roubanthisuk, Wongsurin, Saravich, & Buranakitjaroen, 2007; Shahriari et al., 2003; Skirton et al., 2011; Tao, Chen, Wen, & Bi, 2011; Vera-Cala et al., 2011).
2. Non-invasive oscillometric blood pressure measurement is appropriate for patients with trauma and shock. **Level A – High** (Dind et al., 2011; Skirton et al., 2011).
3. Non-invasive oscillometric blood pressure measurement is appropriate for children, including neonates. **Level B – Moderate** (Chiolero et al., 2010; Holt et al., 2011; Menard et al., 1999; Midgley et al., 2009; O’Shea & Dempsey, 2009; Park et al., 2001; Wattigney et al., 1996; Weaver et al., 1990; Wong et al., 2006)
4. Non-invasive oscillometric blood pressure measurement is appropriate for patients with comorbid conditions or other health conditions:
  - Patients who are pregnant. **Level B – Moderate** (Green & Froman, 1996; Lauszus et al., 2007; Pomini et al., 2001).
  - Patients with hypertension. **Level B – Moderate** (Gupta et al., 2009).
  - Patients with atrial fibrillation. **Level C – Weak** (Lamb et al., 2010).
5. Alternative cuff sites for non-invasive oscillometric blood pressure measurement is appropriate for blood pressure monitoring of adults:
  - Forearm cuff site. **Level B – Moderate** (Schell et al., 2010; Schell et al., 2006).
  - Wrist cuff site. **Level B – Moderate** (Brennan et al., 2001; latman & latman, 1997; Mourad et al., 2005; Nelson et al., 2008; Rutschmann et al., 2005; Shahriari et al., 2003).
  - Thumb/Finger site. **Level B – Moderate** (Jagomägi et al., 2001; Nowak et al., 2001; Green, 1996).
6. Alternative cuff sites for non-invasive oscillometric blood pressure measurement is appropriate for blood pressure monitoring of pediatric patients:
  - Calf cuff site. **Level C – Weak** (Schell et al., 2011).
7. Non-invasive oscillometric blood pressure measurements with BP cuff on upper arm over sleeved arm or on bare arm below a rolled sleeve is appropriate for adult patients. **Level B – Moderate** (Holleman et al., 1993; Kahan et al., 2003; Liebl et al., 2004; Ma et al., 2008; Pinar et al., 2010).

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## **Acknowledgements**

ENA would like to acknowledge the following members of the 2012 Institute for Emergency Nursing Research (IENR) Advisory Council for their review of this document:

### *IENR Director*

Lisa Wolf, PhD, RN, CEN, FAEN

### *IENR Advisory Council Members*

Margaret Carman, DNP, MSN, RN, CEN, ACNP-BC

Deborah Henderson, PhD, MA, RN

Mary Kamienski, PhD, APRN, CEN, FAEN

Anne Manton, PhD, APRN, FAEN, FAAN