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Factors associated with inter-arm blood pressure differences in patients admitted to critical care units

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ABSTRACT

Background: Experts recommend obtaining one-time dual- (inter)-arm blood pressure (BP) measurements to predict cardiovascular morbidity risk.
Objectives: To determine differences in inter-arm systolic (S)/diastolic (D) BPs obtained simultaneously and sequentially and examine associations between patient factors and clinical outcomes and inter-arm BP differences.
Method: A comparative study of adults treated in intensive care; multivariable logistic models were created to determine the extent that inter-arm BP differences predicted outcomes.
Results: Of 427 adults in intensive care units, 31.8% had differences of >10 mmHg on simultaneous measurement and 35.1% had differences of >10 mmHg on sequential measurement; differences >15 mmHg were 17.9% and 19.8%, respectively. After controlling for patient factors, simultaneous inter-arm DBP differences >15 mmHg were associated with shorter hospital and longer intensive care length of stay ($p = 0.031$ and 0.029, respectively) and a 79% reduction in the likelihood of discharge to home ($p = 0.009$).
Conclusions: Simultaneous inter-arm DBP differences >15 mmHg were associated with clinical outcomes.

Background

Blood pressure (BP) measurement is part of routine assessment in any hospital setting. Lower than normal blood pressure is a sign of hemodynamic compromise and high blood pressure is associated with stroke and other vascular complications. Dual- (inter)-arm BP measurements may vary within patients. In systematic reviews of inter-arm BP differences, 6–27% of healthy adults treated in outpatient settings and those with multiple cardiovascular diagnoses (including hypertension, stroke, diabetes, coronary artery disease, hyperlipidemia obesity and metabolic syndrome), human immunodeficiency virus and non-cardiac surgery had systolic BP inter-arm differences ≥10 mmHg,[1,2] and 5–8% had systolic inter-arm BP differences ≥15 mmHg.[1]

The degree of inter-arm BP differences during simultaneous and sequential and systolic and diastolic measurements may reflect the presence of vascular, cerebrovascular, and cardiovascular comorbid conditions and more importantly, it may be a signal of future cardiovascular risk and mortality. In a systematic review and meta-analysis of systolic BP, inter-arm differences ≥10 mmHg were associated with subclavian stenosis and peripheral vascular disease.[1,3] Inter-arm systolic BP differences ≥15 mmHg were associated with peripheral vascular disease,[3] pre-existing cerebrovascular disease,[3,4] metabolic syndrome,[5] cardiovascular disease in patients with chronic kidney disease,[6] cardiovascular mortality and all-cause mortality.[3,7] The degree of inter-arm diastolic BP differences during simultaneous and sequential measurements also varied; for example, normotensive adults were more likely to have inter-arm differences >10 mmHg compared to adults who were treated for hypertension or other vascular diseases.[2] Although a meta-analysis included diastolic inter-arm BP measurement differences,[2] clinical outcomes were not reported. Further, in meta-analyses, both simultaneous and sequential inter-arm BP differences were reported, and often, differences were greater with sequential BP measurements.[2,3,8,9] leading researchers to label simultaneous inter-arm BP measurements as the gold standard.[3]

Abbreviations: AACN, American Association of Critical Care Nurses; BP, blood pressure; DBP, diastolic blood pressure, mm Hg, millimeters mercury; SAS, Statistical Analysis System; SBP, systolic blood pressure; SD, standard deviation.

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One group questioned the value of routinely completing single inter-arm BP measurements among hospitalized elderly patients, since inter-arm systolic BP differences were not associated with mortality.[10] Although an American Association of Critical-care Nurses (AACN) practice alert[11] suggested that initial BP measurement include inter-arm readings on the first examination, and the American Heart Association[12] and hospital coronary care unit procedure manuals recommended the same procedure, the extent to which differences in initial inter-arm BP measurement, obtained in an acute critical-care environment, are similar to those obtained in ambulatory and medical-surgical hospital environments is unknown. The extent to which differences >10 mmHg and 15 mmHg are associated with clinical outcomes of importance to the immediate condition and hospital stay is also unknown.

In a review of the literature, researchers characterized differences between inter-arm BP among healthy individuals,[11] and those with medical conditions[4–7,13]; however, no papers were specifically focused on a need for assessing inter-arm BP in patients admitted to an intensive care unit environment. These studies also focused solely on mortality and morbidity related to specific medical conditions. Physiologically, BP is normalized by autonomic nervous system responses, capillary fluid shifts, hormonal responses and kidney and fluid balance mechanisms.[11] In acutely ill patients, vasoactive and neurohormonal drugs and intravenous fluids may be used erroneously if the extent of inter-arm BP differences are not understood at unit admission. It is important to understand the degree of inter-arm BP measurement differences in acutely ill patients and to understand the extent to which inter-arm BP differences are associated with patient characteristics and hospital clinical outcomes. Additionally, inter-arm BP differences that occur after sequential measurements may be erroneous; due to a higher initial reading and lower second reading regardless of the arm used in the first measurement.[2] Thus, experts warned that simultaneous measurements needed to be assessed when completing inter-arm BP readings to prevent overestimation of inter-arm differences.[2] The caveat is that simultaneous BP measurements require 2 BP devices and could increase the cost of care. Thus, both simultaneous and sequential BP values are needed to guide policies and procedures regarding initial BP measurements. The primary aim of this research study was to determine the frequency of inter-arm systolic and diastolic BP differences when obtained simultaneously and sequentially by inter-arm measurements among acutely ill adult patients. We also examined the extent to which inter-arm admission BP readings >10 mmHg and >15 mmHg were associated with patient characteristics, comorbid medical conditions, cardiac arrest/resuscitation, hospital and intensive care unit length of stay and discharge disposition (including hospital mortality).

Methods

We used a prospective, comparative research design. The health system institutional review board approved the study. Patients were not required to provide informed consent, as the institutional review board deemed this study minimal risk since obtaining an admission BP was usual care.

Setting and sample

We conducted the study in a 500-bed, tertiary-care community hospital in northeast Ohio. The sample was consecutively enrolled from newly-admitted adult critically-ill patients in the coronary care, cardiovascular, or medical surgical intensive care units. Inclusion criteria were an ability to obtain BP measurements in both arms during the admission assessment and no upper arm anatomy abnormalities that precluded BP measurements in both arms (bulky arm dressings, arm cast, arteriovenous fistula, suspected aortic dissection, mastectomy, peripherally inserted central catheter, and arm splint, amputation, burns, wounds, or deep vein thrombosis). Since patients generally arrived to an intensive care unit from emergency care, post-anesthesia care unit, as a transfer from an out-of-hospital setting or as an in-hospital transfer, they were included regardless of receiving vasoactive drug therapies used to enhance or maintain hemodynamic stability; however, they had to be in a non-arrest status and not receiving emergency medical attention.

Exclusion criteria included age under 18 years, patient refusal, inability to get two automated oscillometric BP devices at the bedside for simultaneous inter-arm BP measurement, physician order (due to unusual anatomy abnormalities), re-admission to an intensive care unit during the current hospitalization and admission to the intensive care unit due to regular unit bed capacity issues.

The anticipated sample size was based on a power analysis that used the data from the Verberk et al. meta-analysis, in which the absolute difference in inter-arm BP was 5.6 mmHg, and there was a large variation in the reported means.[2] The number of estimated pairs of arms needed to detect inter-arm measurement differences of at least 5 mmHg was a minimum of 65, based on 80% power and an alpha of 0.05. The calculation was based on comparing inter-arm measurements by multiple patient characteristics, since the proportion of factors associated with differences in inter-arm BP measurements among patients managed in intensive care was not previously published. To allow for a conservative mean difference in inter-arm BP measurements and to assure a large enough sample to determine differences by adult intensive care unit type, a minimum sample size of 385 subjects was planned.

Inter-arm BP measurement procedure

We developed a procedure to ensure systematic BP measurement based on American Heart Association guidelines that included proper cuff size, placement of cuffs on the upper arms above the elbow crease and arm position at the level of the heart.[12] All BP measurements were obtained by portable automated oscillometric BP devices (DINAMAP™ ProCare 200, GE Healthcare, Milwaukee, WI). Use of an oscillometric automated device was considered an acceptable technique by the American Heart Association in intensive care environments.[12] We placed new batteries in the devices and clinical engineering personnel calibrated them before initiation of the study. They were also labeled with a sign indicating that they were to be solely used for research. Readings were recorded as mm mercury (Hg). Nurses and patient care nursing assistants followed usual care guidelines.

We used multiple procedures to assure interrater reliability. We provided in-service education for nurses on all 3 units prior to study start-up. On the day of study start up, investigators observed and assisted with data collection for each newly admitted patient. Each unit had multiple data collection experts who were trained by the investigator team, including nurses from the critical care nurse float pool. Experts were available to mentor nurses in following the BP measurement procedure, assure consistent and accurate placement of automated BP devices and support optimal data collection. During data collection, the quality of obtaining and documenting BP measurements by clinical staff were assessed daily by 2 co-investigators (JR and SM). Finally, the case report form included the BP procedures to ensure systematic data collection for both sequential and simultaneous BP measurements.

Variables and measures

Blood pressure measurements were obtained simultaneously and recorded; then, sequentially and recorded using a health care system