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Inter-arm differences in blood pressure among subjects with disseminated atherosclerosis scheduled for vascular surgery

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Abstract

Background: The measurement of blood pressure (BP) is routinely performed in perioperative care. The reliability of results is essential for the implementation of treatment ensuring haemodynamic stability. The aim of the present study was to assess the prevalence and basic determinants of inter-arm BP differences among patients with advanced peripheral atherosclerosis undergoing vascular surgical procedures of the lower limbs.

Methods: The prospective study was carried out in patients scheduled for elective lower limb vascular surgery. One-time non-invasive BP measurements were performed sequentially on the brachial arteries of both upper extremities before the induction of anaesthesia, maintaining the shortest possible interval between measurements. The systolic blood pressure (SBP), diastolic blood pressure (DBP) and mean arterial pressure (MAP) were recorded.

Results: The results of 173 patients (including 123 men aged 67 ± 8 years) were analysed. In 16 (9.3%) patients, an inter-arm difference in BP was already observed during the preoperative examination. SBP and DBP was higher in the right limb in 86 (49.7%) an 80 (46.3%) patients, respectively. Moreover, the medians of inter-arm differences in SBP, DBP and MAP were 9 (IQR 4–17), 5 (IQR 3–10) and 7 mm Hg (IQR 3–12), respectively. An evaluation of the determinants of BP differences related to the presence of additional diseases demonstrated that patients with arterial hypertension were characterised by higher SBP and MAP disproportions ($P = 0.04$ and $P = 0.01$).

Conclusions: In the population of patients with disseminated atherosclerosis, the inter-arm differences in BP substantially exceed the measurement error limits and are likely to be associated with arterial hypertension. If in doubt about BP disproportions, intraoperative monitoring of BP should be recommended using an invasive method on the limb presenting higher non-invasively measured values.

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Key words: perioperative care, vascular surgery, blood pressure, measurements, atherosclerosis

The measurement of blood pressure (BP) is routinely ordered and performed during perioperative care [1]. Preoperative BP values often affect the decision whether to perform surgery as scheduled or postpone it in order to modify the hypotensive treatment [2]. In many cases, anesthetists rely on home or ambulatory measurements, paying attention to the distortive effects of numerous factors associated with hospitalization. In the operating theatre, BP is usually monitored non-invasively and the measurements are automatically repeated at determined time intervals. The values obtained enable immediate implementation of a suitable treatment option to stabilize the cardiovascular function. BP fluctuations can result from anesthetic factors, including inappropriate analgesia and anaesthesia, excessive sympathetic block accompanied by vasoplegia or the type of surgery. The postoperative BP measurement is equally important for monitoring haemodynamic stability to identify hypotension due to hypovolemic or cardiogenic shock or hypertension related to sympathetic hyperactivity.

The above arguments demonstrate that reliable BP measurements should be performed since their results often decide about the necessity to undertake an appropriate intervention and enable one to monitor its effectiveness, which, in turn, affects the outcome [3, 4].

The aim of the study was to assess the prevalence and basic determinants of inter-arm BP differences among patients with advanced peripheral atherosclerosis undergoing lower limb vascular surgery.

METHODS

As this cross-sectional, observational study was performed based on the data routinely used during the perioperative care, no additional patient's consent was required. Patients undergoing lower limb vascular surgical procedures were included in the study. The inclusion criterion was a history of severe atherosclerotic intermittent claudication requiring vascular surgery. The patients in the analyzed group underwent one of the following procedures: open lower limb revascularisation; aortic and iliac artery surgery; angioplasty of the peripheral arteries; or other. The following demographic and clinical data were collected during the anaesthesiological preassessment visit: gender; age; body weight and height; the American Society of Anesthesiology physical status (ASA-PS); smoking status; concomitant diseases (arterial hypertension, ischaemic heart disease, coronary artery bypass grafting (CABG) stroke, chronic renal failure, chronic obstructive pulmonary disease (COPD) coronary artery bypass grafting (CABG) stroke, chronic renal failure, chronic obstructive pulmonary disease, and diabetes mellitus). Additionally, a short questionnaire regarding the patient's knowledge about possible asymmetric blood pressures was completed.

BP was measured on entering the operating theatre using the Infinity C500 device (Drager, Germany) or Datex-Ohmeda S5 Anaesthesia Monitor (Datex-Ohmeda Inc., USA). A one-time measurement was performed before the induction of anaesthesia on the brachial arteries of both upper extremities using a non-invasive method in a random sequence (left/right limb). The values of systolic blood pressure, (SBP), diastolic blood pressure (DBP) and mean arterial pressure (MAP) were recorded.

One hundred and thirty-five patients (77.6%) were premedicated with with oral midazolam in a dose 3.75 mg–7.5 mg 30-45 minutes before the BP measurement. The study protocol assumed that patients had received beta-adrenolytics, dihydropyridine derivatives of calcium channel antagonists and RAS inhibitors (chronically used by them) in the morning hours on the day of the surgery.

Statistical analysis was based on MedCalc v14 software. Quantitative variables were presented as an arithmetic mean and standard deviation (normal distribution) or a median and interquartile range (IQR) (non-normal distribution). The nature of variables was verified using the Shapiro-Wilk test. Qualitative variables were presented as an absolute value and percentage. The differences in quantitative variables were evaluated using the Student t-test or Mann-Whitney U test; the qualitative variables were assessed by the chi-square test. The Friedman test was applied for dependent variables. $P < 0.05$ was considered statistically significant.

RESULTS

One hundred and eighty-five patients were preliminarily qualified for the study. Twelve patients were excluded due to the infeasibility of performing bilateral blood pressure measurements (spastic paresis of the upper limbs n = 2; dialysis fistula n = 1; limb contracture n = 1; post-injury or post-limb amputation n = 2), re-surgery needed during the period of observation (n = 5) and emergency procedures ("E") (n = 1).

The data of 173 patients were analyzed, including 123 men and 50 women, aged 67 ± 8 years. The ASA-PS III patients constituted the largest group (76.9%). The detailed characteristics of the patients are presented in Table 1.

The inter-arm difference in BP was found already during history taking in 16 (9.3%) patients. The mean values of SBP in the right and left upper limb were 158 ± 27 mm Hg and 156 ± 30 mm Hg, respectively ($P = 0.4$). The mean values of DBP in the right and left upper limb were 82 ± 12 mm Hg and 81 ± 14 mm Hg, respectively ($P = 0.9$). The mean values of MAP on the right and left upper limb were 112 ± 17 mm Hg and 111 ± 20 mm Hg, respectively ($P = 0.9$). Systolic BP was higher in the right limb in 86 (49.7%) patients while diastolic BP was higher in 80 (46.3%) patients.

The medians of inter-arm differences in SBP, DBP and MAP were 9 mm Hg (IQR 4–17), 5 mm Hg (IQR 3–10) and 7 mm Hg (IQR 3–12), respectively. The distribution of differences in SBP, DBP and MAP is presented in Figure 1.

Table 1. Characteristics of patients

Variable	Value
Age [years ± SD]	67 ± 8
Males [n, %]	123 (71.1%)
BMI [kg m^{-2} ± SD]	26 ± 4
ASA-PS 1/ 2/ 3/ 4/ 5 [n, %]	0/17 (6.2%)/133 (76.9%)/23 (13.3%)/0
Nicotinism [n, %]	157 (90.2%)
Arterial hypertension[n, %]	151 (87.3%)
Ischaemic heart disease [n, %]	85 (49.1%)
Post-myocardial infarction[n, %]	43 (24.9%)
Post-CABG [n, %]	14 (8.1%)
Post-stroke[n, %]	19 (11%)
Chronic renal failure [n, %]	13 (7.5%)
Chronic obstructive pulmonary disease [n, %]	42 (24.3%)
Diabetes [n, %]	65 (37.6%)

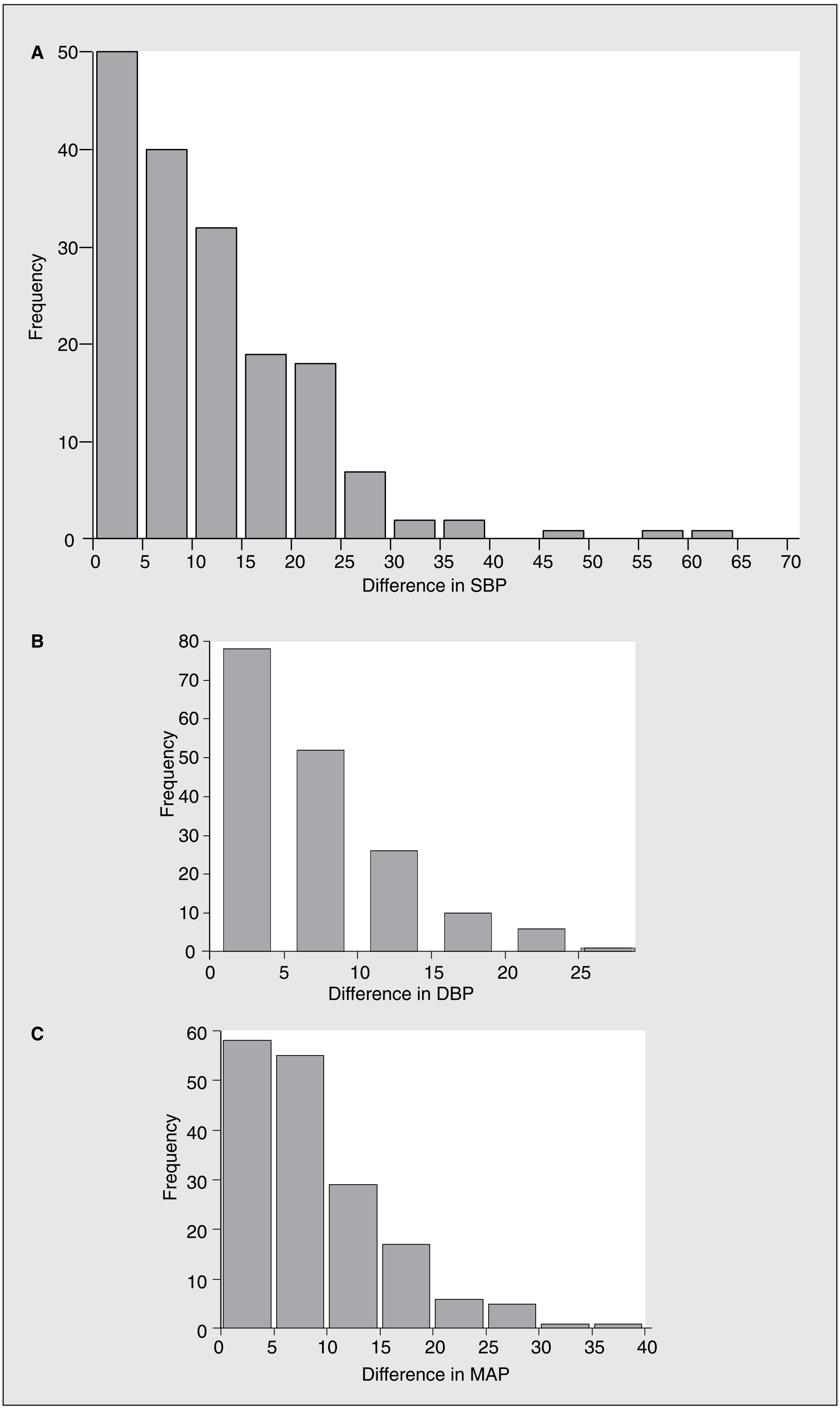

Figure 1. Histograms of differences in blood pressure: systolic (**A**), diastolic (**B**) and mean (**C**)

Table 2. Potential determinants of inter-arm differences in blood pressure

Variable		ΔSBP	ΔDBP	ΔMAP	*P* < 0.05
Age*	Older (> 67 years)	9 [4–15.3]	5 [3–9]	7 [3.8–12]	–
	Younger (≤ 67 years)	8.5 [4–17]	5 [3–10]	6.5 [3–13]	
Gender	Males	8 [4–16.8]	5 [3–9]	6 [3–12]	–
	Females	10 [5–16]	4.5 [3–9]	7 [2–12]	
BMI*	>26 kg m^{-2}	10 [5–15.3]	5 [3–10]	6 [3.8–11]	–
	≤26 kg m^{-2}	7 [3–16.5]	5 [2.5–9]	7 [3–12.5]	
ASA–PS class	3+	9 [4–16.5]	5 [3–10]	7 [3–12]	–
	1–2	6 [3.8–12]	4 [2.8–8.3]	5 [3.5–12.8]	
Nicotinism	Yes	10 [4–17]	5 [3–9]	7 [3–12]	–
	No	6 [4–9.25]	5 [3–12]	5 [2.8–9.5]	
Arterial hypertension	Yes	10 [4–17.8]	5 [3–10]	7 [3.3–12.8]	SBP, MAP
	No	5.5 [4–10]	4.5 [3–8]	5 [2–7]	
Ischaemic heart disease	Yes	9.5 [4–18]	5 [3–9]	5.5 [3–12]	–
	No	9 [4–15.8]	6 [3–9.75]	7 [4–11.8]	
History of myocardial infarction	Yes	6 [3–15]	5 [3–9]	5 [3–12]	–
	No	10 [4–17]	5 [3–10]	7 [4–12]	
History of CABG	Yes	7.5 [3–18]	9 [4–11]	4.5 [3–11]	–
	No	9 [4–16]	5 [3–9]	7 [3–12]	
History of stroke	Yes	9 [5–23]	5 [2.8–8]	5 [2–8.3]	–
	No	9 [4–16]	5 [3–10]	7 [3–12]	
Chronic renal failure	Yes	8.5 [4–15]	6.5 [4–9]	6 [4–10]	–
	No	9 [4–16]	5 [3–9.8]	7 [3–12]	
COPD	Yes	8 [4–19.5]	4 [2–10.5]	7 [3–13.5]	–
	No	9 [4–16]	5 [3–9]	6 [3–11.3]	
Diabetes	Yes	9 [5–15.3]	5 [2.8–9]	5 [3.8–12]	–
	No	9 [4–17]	5 [3–10]	7 [3–12]	

Values were presented as medians and interquartile intervals (in brackets)
ΔDBP: inter–arm difference in diastolic blood pressure; ΔMAP: inter–arm difference in mean arterial pressure; ΔSBP: inter–arm difference in systolic blood pressure
ASA–PS: the American Society of Anesthesiologists Physical Status; BMI: body mass index; CABG: coronary artery bypass grafting; COPD: chronic obstructive pulmonary disease

The potential determinants of disproportions are listed in Table 2. The only parameter found to differentiate the groups was arterial hypertension — patients with hypertension were characterised by a higher disproportion in SBP ($P = 0.04$) and MAP ($P = 0.01$).

DISCUSSION

The aim of our study was to identify main determinants of inter-arm blood pressure differences in patients with advanced atherosclerosis. The mean blood pressure differences between the arms could have been associated with arterial hypertension. It is important, because major difference has been associated with poor outcome [5, 6] and increased mortality [7], especially in individuals with arterial hypertension [8, 9].

This correlation was also investigated by other authors. In their study Clark at al. [5] summarize the data of 20 studies investigating the relationship between the inter-arm difference in SBP and the presence of cardiovascular diseases and mortality. The authors reported that the incidence of cerebrovascular diseases was higher in patients with an SBP difference of ≥ 15 mm Hg (relative risk = 1.6). In PVD similar correlation was found not only for an SBP difference of ≥ 15 mm Hg (relative risk = 2.5), but also for an SBP difference of ≥ 10 mm Hg SBP (relative risk = 2.4). Different study made by the same authors has shown that in the population of diabetic patients, the incidence of an SBP difference of > 10 mm Hg was three times higher in individuals with PVD. Moreover, according to the Framingham Study, blood pressure asymmetry could be associated with older age, diabetes mellitus, higher blood pressure and hypercholesterolaemia [6].

It has also been reported previously that SBP difference exceeding 10 mm Hg may concern 40.3% of patients after stroke [10], 11.2% of those with arterial hypertension, 7.4% of diabetic patients and 3.6% of the general adult population [11]. Among the patients with high cardiovascular risk, inter-arm differences of ≥10 mm Hg are likely to occur even in 38% [8]. In general population the difference exceeding 20 mm Hg is estimated at 4.2% [12], while in our study, a difference of 20 mm Hg and higher was observed in 16.2% of the patients. This discrepancy can result from the specificity of our patients' population.

Surgical treatment of PVD concerns patients with advanced and symptomatic atherosclerosis. The prevalence of PVD in the population aged 60-90 years is estimated at about 18% [13]. One third of the patients with peripheral arterial diseases have symptomatic intermittent claudication – others have often asymptomatic course and are identified incidentally, mainly during the diagnostic procedures for coexisting diseases [13]. The inter-arm blood pressure differences was first described by Cyriax [14] in 1920. Although it can be associated with an increased risk of cardiovascular events, its epidemiological meaning is still questioned [5]. Atherosclerosis can manifest as coronary disease, stroke, abdominal angina or limb ischemia, but it have to be noted that this multiple health problems can often be seen in single patient. A significant intra-arm blood pressure difference should be considered as pathology and mainly associated with PVD [15].

Another diagnostic examination based on BP measurements, which is used to identify individuals with atherosclerosis, is the ankle-brachial index (ABI). ABI < 0.9 is considered abnormal and usually allows to diagnose lower limb arterial disease; a further decrease in ABI correlates with more severe intermittent claudication [13]. However, this examination requires additional training and specialized equipment which can be found in the ambulatory settings but not in the operating room. Therefore, the BP measurement in both arms prior the surgery seems to be an important screening procedure [16].

Although the non invasive BP monitoring is nowadays the basis of the physical examination, despite recommendations measurements from both arms are not routinely recorded. In our study we found that only minority of patients were aware about their inter-arm asymmetry; thus, medical history can be unreliable. According to our results, patients with arterial hypertension are particularly predisposed to have BP asymmetry. The bilateral measurement in this group can help to decide whether the other diagnostic procedures should be performed to exclude PVD [17].

Moreover, physicians should emphasize patient's awareness of bilateral blood pressure measurement in their everyday home routine. In the hospital, especially in the perioperative period, clinical decisions are often based on non invasive BP (NIBP). What more, blood pressure monitoring enables adequate monitoring of therapy, and can help to evaluate homeostasis of the patient. Due to the physical basis of inter-arm pressure differences, physician should always consider only the higher value.

STUDY LIMITATIONS

The main limitation of our study was an inability to generalise the results over the population of patients with PVD as the study was performed on a group with the most highly advanced symptomatic lesions. Another limitation is the one-time and simultaneous measurement, which can lead to overestimation of the incidence of differences [18, 19]. This issue is of higher significance in individuals with haemodynamically unstable cardiac arrhythmias, like atrial fibrillation. In our study, 13 individuals had such arrhythmias so the risk of measurement errors was highest in this group. In addition, the use of standard monitoring devices available in the operating theatre actually makes it impossible to perform measurements simultaneously — in the recommended way. Restrictions regarding the measurements are, however, mostly associated with the diagnosis of arterial hypertension in epidemiological studies. Of note is the fact that the automated oscillatory method applied during pressure measurements carries the risk of the error concerning extreme values significantly underestimating high and overestimating low values of the real blood pressure. For time-related reasons, the values obtained were not verified with another measurement. The conclusions are also limited by a small population studied, especially in subgroups defined by potential risk factors of BP differences (e.g. stroke, diabetes, chronic renal disease). It should be kept in mind that the differences observed (Table 2) could become statistically significant once the number of observations is higher. Finally, our analysis did not consider the effects of hypotensive therapy, the types of drugs, their doses and the periods in which they were used prior the surgery.

CONCLUSIONS

1. In the population of patients with disseminated atherosclerosis, the inter-arm differences in BP are statistically significant and can be associated with concomitant arterial hypertension.
2. In this group of patients, arterial blood pressure should be routinely measured on both arms when the non-invasive measurement method is used. Intraoperative invasive or non-invasive BP monitoring should be performed in the limb with higher values.
3. Since individuals with arterial hypertension are predisposed to higher inter-arm blood pressure differences, unilateral measurement in this group of patients can lead to wrong therapeutic decisions.

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