Inter-Arm Blood Pressure Differences in Young, Healthy Patients

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The prevalence and magnitude of inter-arm BP difference (IAD) in young healthy patients is not well characterized. Flight academy applicants and designated aviators undergo annual evaluation that includes blood pressure (BP) measurement on both arms. All BP measurements performed from January 1, 2012, to April 30, 2012, were recorded and IAD was calculated. Results were compared between patients in whom BP was initially measured in the right arm (group 1), those in whom BP was initially measured in the left arm (group 2), and those in whom the arm in which BP was initially measured was not recorded (group 3). A total of 877 healthy patients had BP measured during the study period. In the entire group, mean systolic BP was the same in both arms. Absolute IAD was 5.6±5.5 mm Hg for systolic and 4.7±4.5 mm Hg for diastolic BP. IAD >10 mm Hg was recorded in 111 (12.6%) and 77 (8.8%) patients for systolic and diastolic BP, respectively. IAD was the same in the 3 groups and was unrelated to age, body mass index, and heart rate, but was related to systolic BP. IAD is common in young healthy patients, is not dependent on which arm was measured first, and unrelated to age, body mass index, and heart rate. *J Clin Hypertens (Greenwich).* 2013;15:575–578.

It is recommended that blood pressure (BP) be measured in both arms at the first visit because differences exist in the values measured in both arms, and measurement in only one arm may lead to underdiagnosis of hypertension.[1,2] Inter-arm BP difference (IAD) has received increasing attention in recent years because it has been found to be associated with peripheral vascular disease[3] and was identified as a risk factor for cardiovascular morbidity.[4,5] The prevalence of IAD in the general population has been evaluated only in older adults,[6] adults with underlying diseases that may affect vascular integrity such as diabetes and hypertension,[6,7] and pregnant women.[8] The clinical significance of IAD in young healthy patients is unclear. In order to evaluate this clinical significance, it is essential to know the true prevalence of IAD in this population. Yet, there are no large-scale studies addressing the prevalence of IAD in this population. This study evaluates the prevalence and magnitude of IAD in a cohort of young healthy patients. To identify whether alert reaction may contribute to IAD, we evaluated whether BP levels are higher in the first arm measured.

METHODS

Study Population

The study was approved by the ethics committee of the Medical Corps of the Israel Defense Force. All applicants to the Israeli Air Force (IAF) undergo a comprehensive medical evaluation prior to their enlistment to the IAF, whereas designated aviators undergo an annual evaluation. As a routine part of these evaluations, height, weight, body mass index (BMI), heart rate, and sequential BP measurement in both arms are performed. This study retrospectively evaluates IAD in consecutive applicants and designated aviators attending the IAF Aero Medical Center from January 1, 2012, to April 30, 2012. In order to evaluate the effects of the initial arm in which BP was measured on BP values in both arms, patients were divided into 3 groups: group 1, patients in whom BP was initially measured in the right arm; group 2, patients in whom BP was initially measured in the left arm; and group 3, patients in whom the initial arm in which BP was measured was not recorded. Inter-arm systolic and diastolic BP difference in each group was recorded. IAD was divided arbitrarily into 5 groups: no difference, 1- to 2-mm Hg difference, 3- to 5-mm Hg difference, 6- to 10-mm Hg difference, and >10 mm Hg difference.

BP Measurement

BP measurement was performed by a designated technician in a quiet room with the patient in the sitting position following at least 5 minutes of rest. BP was measured twice in each arm using an automatic device (Vital Signs Monitor 52 NTP model; Welch Allyn Protocol, Inc, Beaverton, OR) that was calibrated according to manufacturer's recommendations, and the values were averaged. BP was measured in one arm and sequentially in the other arm. The initial arm in which BP was measured was randomly selected by the technician performing the BP measurement and was recorded in about two thirds of the patients. In one third of the group, the initial measured arm was not recorded.

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Statistical Analysis

IAD was defined as the difference between the average BP in the right arm and the average BP in the left arm. Results are reported as mean±standard deviation. The data were analyzed for the entire cohort and separately for the 3 groups defined according to the initial arm measured. Analysis of variance repeated-measures analysis with one nested variable (the 3 groups) was used to assess the BP levels in both arms and to assess whether the arm first measured affected BP levels in both arms and the IAD. An independent *t* test was used to compare means between men and women. The chi-square test was used to compare prevalence of inter-arm difference categories between groups. Pearson's correlation test was used to evaluate the association between IAD and age, BMI, heart rate, and systolic BP. Values of $P<.05$ were considered significant.

RESULTS

Patients

During the study period, 877 patients (71 women, mean age 26±10 years, mean BMI 23.7±3.4) underwent routine evaluation at the IAF Aero Medical Center and all were included in the study. All patients were healthy (not medicated) and none were known to have hypertension or diabetes mellitus. In 281 of the patients, BP was initially recorded in the right arm; in 304 patients, BP was initially recorded in the left arm; and in 292 patients, the initial arm in which BP was measured was not recorded (Table I).

BP Levels

All patients had normal BP levels (Table I). Mean systolic and diastolic BP was the same in both arms and was not affected by groups (Table I, *P*=not significant). In the entire group, the mean IAD was 0.31±7.81 for systolic BP and 0.01±6.53 for diastolic BP. The absolute IAD was 5.6±5.4 mm Hg for systolic BP and 4.7±4.5 mm Hg for diastolic BP. The mean and the absolute IAD was the same in all groups and was not affected by sex (*P*=not significant for all parameters).

Systolic BP was the same in both arms in 75 patients (9%), was higher in the right arm in 422 patients (48%), and was higher in the left arm in 380 patients (43%). Diastolic BP was the same in both arms in 81 patients (9.2%), was higher in the right arm in 399 patients (45.5%), and was higher in the left arm in 397 patients (45.3%). The inter-arm systolic and diastolic BP difference by categories in the entire cohort and in the 3 groups is presented in Table II. IAD was not dependent on the arm in which BP measurement was initially performed (Table II). The prevalence of IAD >10 mm Hg was 12.6% for systolic BP and 8.8% for diastolic BP. The prevalence of IAD >10 mm Hg was the same in all groups (Table II; *P*=not significant for all parameters).

IAD was not correlated with age, BMI, or heart rate, but was correlated with systolic BP ($r=0.36$, $P<.01$).

DISCUSSION

The prevalence of IAD varies between reports and tends to be more significant in known hypertensive patients.[9] Recently, it has been shown that IAD is associated with increased cardiovascular morbidity.[4,5,10] The hypothesis that IAD signifies diffuse atherosclerosis has significant clinical implications and emphasizes the importance of BP measurement in both arms in patients at risk for cardiovascular morbidity.[11,12] Whether these findings are applicable to young healthy patients without significant cardiovascular risk factors is less clear, as only one small study was performed in this population.[13] The prevalence of inter-arm systolic BP difference >10 mm Hg (12.6%) in our cohort is higher than a previous report by Fotherby and colleagues[13] and is similar to a previous report by Arnett and colleagues,[14] but is lower than previously reported by Clark and colleagues[4] and Lane and colleagues.[2] Our results are in accordance with a recent meta-analysis that reported a prevalence of 14% and 7% for systolic and diastolic IAD $\geq$ 10 mm Hg, respectively.[15] Our findings suggest that IAD is also common in young, healthy patients. In this group it is unlikely to explain IAD by atherosclerosis and thus the mechanism and prognostic value of IAD are unclear. The IAD is more accurate and is lower when BP is measured simultaneously.[15,16] Therefore, Verberk and colleagues[15] recommended to assess BP simultaneously in both arms. However, this method of measuring IAD is not practical in a clinical setting, and therefore the meaning of inter-arm difference recorded by sequential measurements should be evaluated. The consistency of IAD has been challenged. Eguchi and colleagues[17]

TABLE I. Demographic and Clinical Measurements in the Study Population

				Systolic BP, mm Hg			Diastolic BP, mm Hg		
	No.	Mean age, y	BMI, kg/m^2	Right Hand	Left Hand	Absolute Difference	Right-Hand	Left-Hand	Absolute Difference
All patients	877	26±10	23.7±3.4	120±10	120±10	5.6±5.4	68±9	68±9	4.7±4.5
Right hand first	281	26±10	23.9±3.1	120±11	120±11	5.9±7.1	67±8	68±9	5.4±5.6
Left hand first	304	27±11	23.6±4.2	119±10	119±10	5.2±4.0	69±9	68±9	4.3±3.9
First hand not recorded	292	27±10	23.5±2.8	121±10	120±10	5.7±5.0	69±9	69±9	4.6±3.7

Abbreviations: BMI, body mass index; BP, blood pressure. Data are presented as mean±standard deviation.

TABLE II. Mean Inter-Arm Blood Pressure (BP) Difference for the Entire Study Population

	Systolic BP			Diastolic BP		
Mean Inter-Arm BP Difference	All	Right Arm>Left Arm	Left Arm>Right Arm	All	Right Arm>Left Arm	Left Arm>Right Arm
Entire cohort						
0 mm Hg	75			81		
0–2 mm Hg	191	97	94	226	113	113
3–5 mm Hg	261	146	115	303	151	152
6–10 mm Hg	239	120	119	190	93	97
>10 mm Hg	111	59	52	77	42	35
All	877	422	380	877	399	397
Initial BP measurement right arm						
0 mm Hg	22			23		
0–2 mm Hg	72	39	33	59	29	30
3–5 mm Hg	73	40	33	105	51	54
6–10 mm Hg	80	40	40	60	20	40
>10 mm Hg	34	14	20	34	16	18
All	281	133	126	281	116	142
Initial BP measurement left arm						
0 mm Hg	26			27		
0–2 mm Hg	60	27	33	95	48	47
3–5 mm Hg	96	52	44	96	48	48
6–10 mm Hg	83	40	43	67	37	30
>10 mm Hg	39	21	18	19	11	8
All	304	140	138	304	144	133
Initial BP measured arm not recorded						
0 mm Hg	27			31		
1–2 mm Hg	59	31	28	72	36	36
3–5 mm Hg	92	54	38	102	52	50
6–10 mm Hg	76	40	36	63	36	27
>10 mm Hg	38	24	14	24	15	9
All	292	149	116	292	139	122

showed that IAD was consistent only in 2 of 147 patients who had obstructive arterial disease, whereas Agarwal and colleagues[10] showed that IAD is reproducible. We did not measure the reproducibility of IAD, but we evaluated the possibility that alert reaction to initial BP measurement may be responsible for IAD.[18] We found no difference in BP levels and in IAD between those who measure BP first in the right and those who measure first in the left arm, suggesting that the alert reaction is not an important contributor for IAD.

Previous reports have shown a bias toward higher BP readings from the right arm,[2,17,19] whereas other reports failed to show such a tendency.[3,6] Our study did not show any bias toward the right arm, and the arm in which the higher BP measurement was recorded was not influenced by the initial arm in which it was recorded. Therefore, it seems that even in young, healthy patients, it is difficult to predict in which arm the higher BP measurement will be recorded, and at least one recording of BP in both arms is required in order to correctly identify the arm in which BP is higher and in which future measurements should be performed.

STUDY LIMITATIONS

Unlike Arnett and colleagues,[14] we did not find an association between obesity and higher rate of IAD. However, we did find an association between systolic BP levels and IAD. This study has several limitations. Because of the retrospective nature, BP was recorded on a single occasion. A previous meta-analysis noted that the prevalence of IAD $\geq$10 mm Hg was roughly doubled when diagnosis was based on one pair of measurements compared with multiple measurements,[19] and thus the prevalence of IAD >10 mm Hg may have been an overestimation. BP was measured sequentially in our study, which may explain the higher prevalence of IAD compared with that observed in a similar population in which BP was measured simultaneously.[13] We believe that sequential BP measurements in a large group of young, healthy patients better represent the real-life prevalence of IAD. We lack long-term follow-up, therefore we are unable to reach conclusions regarding the long-term implications of our findings.

CONCLUSIONS

Significant IAD (>10 mm Hg) is common in young, healthy patients. Since there is no consistent lateralization of BP in this population, BP should be measured in both arms. The clinical significance of IAD in young, healthy individuals requires long-term follow-up.

References

1. Clark CE, Campbell JL, Evans PH, Millward A. Prevalence and clinical implications of the inter-arm blood pressure difference: a systematic review. *J Hum Hypertens*. 2006;20:923–931.
2. Lane D, Beevers M, Barnes N, et al. Inter-arm differences in blood pressure: when are they clinically significant? *J Hypertens*. 2002;20:1089–1095.
3. Clark CE, Campbell JL, Powell RJ, Thompson JF. The inter-arm blood pressure difference and peripheral vascular disease: cross-sectional study. *Fam Pract*. 2007;24:420–426.
4. Clark CE, Taylor RS, Shore AC, Campbell JL. The difference in blood pressure readings between arms and survival: primary care cohort study. *BMJ*. 2012;344:e1327.
5. Clark CE, Taylor RS, Shore AC, et al. Association of a difference in systolic blood pressure between arms with vascular disease and mortality: a systematic review and meta-analysis. *Lancet*. 2012;379:905–914.
6. Orme S, Ralph SG, Birchall A, et al. The normal range for inter-arm differences in blood pressure. *Age Ageing*. 1999;28:537–542.
7. Clark CE, Greaves CJ, Evans PH, et al. Inter-arm blood pressure difference in type 2 diabetes: a barrier to effective management? *Br J Gen Pract*. 2009;59:428–432.
8. Poon LC, Kametas N, Strobl I, et al. Inter-arm blood pressure differences in pregnant women. *BJOG*. 2008;115:1122–1130.
9. Kristensen BO, Kornerup HJ. Which arm to measure the blood pressure? *Acta Med Scand*. 1982;670:69–73.
10. Agarwal R, Bunaye Z, Bekele DM. Prognostic significance of between-arm blood pressure differences. *Hypertension*. 2008;51:657–662.
11. Mancia G, De Backer G, Dominiczak A, et al; The task force for the management of arterial hypertension of the European Society of Hypertension Society of C, The task force for the management of arterial hypertension of the European Society of C. 2007 Guidelines for the management of arterial hypertension: The task force for the Management of Arterial Hypertension of the European Society of Hypertension (ESH) and of the European Society of Cardiology (ESC). *Eur Heart J*. 2007;28:1462–1536.
12. Su HM, Lin TH, Hsu PC, et al. Association of interarm systolic blood pressure difference with atherosclerosis and left ventricular hypertrophy. *PLoS ONE*. 2012;7:e41173.
13. Fotherby MD, Panayiotou B, Potter JF. Age-related differences in simultaneous interarm blood pressure measurements. *Postgrad Med J*. 1993;69:194–196.
14. Arnett DK, Tang W, Province MA, et al. Interarm differences in seated systolic and diastolic blood pressure: the Hypertension Genetic Epidemiology Network study. *J Hypertens*. 2005;23:1141–1147.
15. Verberk WJ, Kessels AG, Thien T. Blood pressure measurement method and inter-arm differences: a meta-analysis. *Am J Hypertens*. 2011;24:1201–1208.
16. Harrison EGJr, Roth GM, Hines EA Jr. Bilateral indirect and direct arterial pressures. *Circulation*. 1960;22:419–436.
17. Eguchi K, Yacoub M, Jhalani J, et al. Consistency of blood pressure differences between the left and right arms. *Arch Intern Med*. 2007;167:388–393.
18. Mancia G, Parati G, Pomidossi G, et al. Alerting reaction and rise in blood pressure during measurement by physician and nurse. *Hypertension*. 1987;9:209–215.
19. Cassidy P, Jones K. A study of inter-arm blood pressure differences in primary care. *J Hum Hypertens*. 2001;15:519–522.