Hypertension Research (2016) 39, 4–5

www.nature.com/hr

COMMENTARY

Estimation of pulse wave velocity in patients with peripheral artery disease: a word of caution

Victor Aboyans, Ileana Desormais, Aida Oueslati and Philippe Lacroix

Hypertension Research (2016) **39,** 4–5; doi:10.1038/hr.2015.115; published online 22 October 2015

We thank Zagura *et al.*[1] for their research on the metabolomic signature of arterial stiffness in male patients with peripheral artery disease (PAD), which was reported recently in this journal. Aortic stiffness has commonly been estimated non-invasively using the carotid-femoral pulse wave velocity (cfPWV) after recording the pulse wave in these two vascular sites via tonometry. This method has been shown to be a reliable marker of aortic stiffness and a good prognostic marker for cardiovascular events in population studies.[2,3] However, we would like to warn the scientific community on the pitfalls of aortic stiffness estimation using this method in patients with PAD.

PAD patients frequently have aortic atherosclerotic disease, and aortic stiffness has been shown to be increased in these patients.[4,5] Patients with PAD are at an increased risk of cardiovascular events and mortality,[6,7] with a higher risk in case of proximal disease.[8]

However, patients with proximal (aorto-iliac) PAD may have an inaccurate estimation of aortic PWV.

Using the same sphygmocor machine (AtCor Medical, Sydney, New South Wales, Australia) as Zagura *et al.*,[1] we studied the cfPWV in 76 patients hospitalized for PAD at our institution without clinical history of coronary artery disease and compared them with 86 patients hospitalized during the same period for severe coronary artery disease (CAD) requiring coronary bypass grafting. Patients with CAD were included after verifying that they had no PAD, as confirmed by a normal ankle-brachial index (>1.0). Our study sought to compare aortic stiffness in CAD patients with that in PAD patients and to investigate whether cfPWV was prognostic in the latter group by assessing mortality, cardiovascular events and limb amputations.

The general characteristics of the two patient groups are reported in the Table 1. Lower body mass index and higher rates of diabetes were observed in PAD patients; other general data did not significantly differ between groups. Peripheral pulse pressure was higher in patients with PAD, whereas central pressures were similar overall. A higher cfPWV and augmentation index were observed in patients with PAD compared with those with CAD, confirming previous reports on heart-femoral PWV.[9]

However, lower cfPWV was observed in PAD patients who had aorto-iliac disease ($n=23$, cfPWV $=9.5\pm2.5$ m s^{-1}) compared with those without aorto-iliac disease ($n=53$, cfPWV $=11.8\pm3.9$ m s^{-1}, $P=0.03$) based on imaging assessments. This difference remained significant after adjusting for risk factors and heart rate. In addition, after a

Table 1 Characteristics of patients with PAD and CAD in our study

Factors	*PAD (n = 76)*	*CAD (n = 86)*	P-*value*
Clinical data			
Age (years)	68.8 (5.8)	66.7 (4.5)	0.25
Females	21 (27.6%)	15 (17.4%)	NS
Ever smokers	52 (68.%)	59 (68.6%)	NS
Diabetes	41 (53.9%)	17 (19.8%)	<0.0001
Hypertension	52 (68.4%)	55 (64.0%)	NS
Dyslipidemia	52 (68.4%)	59 (68.6%)	NS
BMI (kg m^{-2})	26.2 (5.8)	28.3 (4.5)	0.01
History of CVD	11 (14.5%)	7 (8.1%)	0.30
GFR (ml mn^{-1} 1.73 m^{-2})	88.3 (60.8)	83.9 (17.0)	0.53
SBP (mm Hg)	136.9 (21.5)	134.2 (15.1)	0.36
DBP (mm Hg)	71.6 (13.5)	74.1 (10.2)	0.17
PP (mm Hg)	65.3 (16.8)	60.1 (13.3)	0.03
Tonometric data			
Central SBP (mm Hg)	123.7 (18.8)	123.0 (14.9)	0.80
Central DBP (mm Hg)	72.7 (13.2)	74.9 (10.2)	0.23
Central PP (mm Hg)	51.0 (15.1)	48.1 (13.2)	0.20
Augmentation index$_{(HR75)}$ (%)	29.5 (11.3)	21.0 (11.0)	<0.0001
PWV (m s^{-1})	11.3 (3.7)	9.8 (3.0)	0.007

Abbreviations: BMI, body mass index; CAD, coronary artery disease; CVD, cardiovascular disease; DBP, diastolic blood pressure; GFR, glomerular filtration rate; HR, heart rate; NS, not significant; PAD, peripheral artery disease; PP, Pulse pressure; PWV, pulse wave velocity; SBP, systolic blood pressure.
The results are presented as *N* (%) for qualitative data and mean (s.d.) for quantitative data.

V Aboyans is at Department of Cardiology, Dupuytren University Hospital, Limoges, France; I Desormais, A Oueslati and P Lacroix are at Department of Thoracic and Cardiovascular Surgery and Angiology, Dupuytren University Hospital, Limoges, France
E-mail: aboyans@unilim.fr
Published online 22 October 2015

follow-up of 10.5 ± 4.5 months, no significant association between PWV and outcome in PAD patients was observed after univariate and multivariate analyses, whereas PWV was predictive of events in CAD patients.

Our results were initially surprising because when using a similar method, we found that cfPWV was a prognostic marker in CAD patients but not in PAD patients. However, these preliminary results require further confirmation with a larger cohort and a longer follow-up period. Nonetheless, the slower PWV in case of proximal PAD is counter-intuitive because more stiffened arteries in the trajectory of pulse waves arriving at the femoral site would be expected in patients with aorto-iliac disease than in patients with more distal disease.

We believe that measuring cfPWV via tonometry is flawed as severe lesions disturb the physiological process leading to the propagation of PWV. As estimated by the Moens and Korteweg equation,[10] PWV depends on not only arterial wall stiffness but also on arterial diameter, and arterial diameter is strongly affected by stenotic lesions and arterial remodeling. The presence of an abdominal aortic aneurysm is common and may affect cfPWV.[11] In addition, collateral circulation may develop in these cases, with reinjection of the blood flow downstream of the stenotic lesion, which is also involved in PWV perturbation.

However, we advocate avoiding tonometric methods to assess cfPWV in patients with severe PAD and suggest other methods to estimate aortic stiffness that do record the lower-extremities pulse.[12,13]

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGEMENTS

This project has been supported by a grant from the Fondation de Recherche sur l'Hypertension Artérielle, Paris, France.

1 Zagura M, Kals J, Kilk K, Serg M, Kampus P, Eha J, Soomets U, Zilmer M. Metabolomic signature of arterial stiffness in male patients with peripheral arterial disease. *Hypertens Res* 2015; **38**: 840–846.
2 Shahin Y, Barakat H, Barnes R, Chetter I. The Vicorder device compared with SphygmoCor in the assessment of carotid-femoral pulse wave velocity in patients with peripheral arterial disease. *Hypertens Res* 2013; **36**: 208–212.
3 Vlachopoulos C, Xaplanteris P, Aboyans V, Brodmann M, Cífková R, Cosentino F, De Carlo M, Gallino A, Landmesser U, Laurent S, Lekakis J, Mikhailidis DP, Naka KK, Protogerou AD, Rizzoni D, Schmidt-Trucksäss A, Van Bortel L, Weber T, Yamashina A, Zimlichman R, Boutouyrie P, Cockcroft J, O'Rourke M, Park JB, Schillaci G, Sillesen H, Townsend RR. The role of vascular biomarkers for primary and secondary prevention. A position paper from the European Society of Cardiology Working Group on peripheral circulation: endorsed by the Association for Research into Arterial Structure and Physiology (ARTERY) Society. *Atherosclerosis* 2015; **241**: 507–532.
4 van Popele NM, Grobbee DE, Bots ML, Asmar R, Topouchian J, Reneman RS, Hoeks AP, van der Kuip DA, Hofman A, Witteman JC. Association between arterial stiffness and atherosclerosis: the Rotterdam Study. *Stroke* 2001; **32**: 454–460.
5 Coutinho T, Turner ST, Kullo IJ. Aortic pulse wave velocity is associated with measures of subclinical target organ damage. *JACC Cardiovasc Imaging* 2011; **4**: 754–761.
6 Criqui MH, Langer RD, Fronek A, Feigelson HS, Klauber MR, McCann TJ, Browner D. Mortality over a period of 10 years in patients with peripheral arterial disease. *N Engl J Med* 1992; **326**: 381–386.
7 Tendera M, Aboyans V, Bartelink ML, Baumgartner I, Clément D, Collet JP, Cremonesi A, De Carlo M, Erbel R, Fowkes FG, Heras M, Kownator S, Minar E, Ostergren J, Poldermans D, Riambau V, Roffi M, Röther J, Sievert H, van Sambeek M, Zeller TESC Committee for Practice Guidelines. ESC Guidelines on the diagnosis and treatment of peripheral artery diseases: document covering atherosclerotic disease of extracranial carotid and vertebral, mesenteric, renal, upper and lower extremity arteries: the Task Force on the Diagnosis and Treatment of Peripheral Artery Diseases of the European Society of Cardiology (ESC). *Eur Heart J* 2011; **32**: 2851–2906.
8 Aboyans V, Desormais I, Lacroix P, Salazar J, Criqui MH, Laskar M. The general prognosis of patients with peripheral arterial disease differs according to the disease localization. *J Am Coll Cardiol* 2010; **55**: 898–903.
9 Tsuchikura S, Shoji T, Kimoto E, Shinohara K, Hatsuda S, Koyama H, Emoto M, Nishizawa Y. Central versus peripheral arterial stiffness in association with coronary, cerebral and peripheral arterial disease. *Atherosclerosis* 2010; **211**: 480–485.
10 Bergel DH, Schultz DL. Arterial elasticity and fluid dynamics. *Prog Biophys Mol Biol* 1971; **22**: 1–36.
11 Bailey MA, Davies JM, Griffin KJ, Bridge KI, Johnson AB, Sohrabi S, Baxter PD, Scott DJ. Carotid-femoral pulse wave velocity is negatively correlated with aortic diameter. *Hypertens Res* 2014; **37**: 926–932.
12 Ring M, Eriksson MJ, Zierath JR, Caidahl K. Arterial stiffness estimation in healthy subjects: a validation of oscillometric (Arteriograph) and tonometric (SphygmoCor) techniques. *Hypertens Res* 2014; **37**: 999–1007.
13 Marwick TH, Gillebert TC, Aurigemma G, Chirinos J, Derumeaux G, Galderisi M, Gottdiener J, Haluska B, Ofili E, Segers P, Senior R, Tapp RJ, Zamorano JL. Recommendations on the use of echocardiography in adult hypertension: a report from the European Association of Cardiovascular Imaging (EACVI) and the American Society of Echocardiography (ASE). *Eur Heart J Cardiovasc Imaging* 2015; **16**: 577–605.