American Heart Association
Hypertension
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Title: Identifying isolated systolic hypertension from upper arm cuff blood pressure compared with invasive measurements

Manuscript number: HYPE/2020/16109

Author(s): James Sharman, University of Tasmania
Dean Picone, University of Tasmania
Martin Schultz, University of Tasmania
Matthew Armstrong, University of Tasmania
J. Andrew Black, Royal Hobart Hospital
Willem Jan Bos, St Antonius Hospital, Nieuwegein
Chen-Huan Chen, Taipei Veterans Geneneral Hospital
Hao-Min Cheng, Taipei Veterans Geneneral Hospital
Antoine Cremer, University Hospital of Bordeaux, Hôpital St André
Nathan Dwyer, Royal Hobart Hospital

Alun Hughes, University College London

Hack-Lyoung Kim, Boramae Medical Center

Peter Lacy, University College London and the National Institute for Health Research University College London Hospitals Biomedical Research Centre, Institute of Cardiovascular Science, London, WC1E 6BT, UK

Esben Laugesen, Aarhus University Hospital

Fuyou Liang, Shanghai Jiao Tong University and Chiba University International Cooperative Research Centre

Nobuyuki Ohte, Nagoya City University Graduate School of Medical Science

Sho Okada, Chiba University Graduate School of Medicine

Stefano Omboni, Italian Institute of Telemedicine

Christian Ott, University of Erlangen-Nuremberg

Telmo Pereira, Polytechnic Institute of Coimbra, ESTES

Giacomo Pucci, University of Perugia

Roland Schmieder, Friedrich-Alexander-University Erlangen-Nuernberg

Manish Sinha, Guys & St Thomas's NHS Foundation Trust

George Stouffer, University of North Carolina

Kenji Takazawa, Shinanozaka clinic

Philip Roberts-Thomson, University of Tasmania

Ji-Guang Wang, The Shanghai Institute of Hypertension

Thomas Weber, Klinikum Wels-Grieskirchen

Berend Westerhof, University of Twente

Bryan Williams, University College London

Identifying isolated systolic hypertension from upper arm cuff blood pressure compared with invasive measurements

Dean S. Picone, PhD[1], Martin G. Schultz, PhD[1], Matthew K. Armstrong, BSc(Hons)[1], J. Andrew Black, MBBS(Hons)[1,2], Willem J. Bos, MD, PhD[3,4], Chen-Huan Chen, MD[5], Hao-Min Cheng, MD, PhD[5], Antoine Cremer, MD[6], Nathan Dwyer, MBBS, PhD[1,2], Alun D. Hughes, MBBS, PhD[7], Hack-Lyoung Kim, MD, PhD[8], Peter S. Lacy, PhD[9], Esben Laugesen, MD, PhD[10], Fuyou Liang,[11] Nobuyuki Ohte, MD, PhD[12], Sho Okada, MD, PhD[13], Stefano Omboni, MD[14,15], Christian Ott[16], Telmo Pereira, PhD[17], Giacomo Pucci, MD[18], Roland E. Schmieder, MD[16], Manish D. Sinha, PhD[19], George A. Stouffer, MD[20], Kenji Takazawa[21], Philip Roberts-Thomson,[1,2] Jiguang Wang, MD, PhD[22], Thomas Weber, MD[23], Berend E. Westerhof, PhD[24], Bryan Williams, MD[7,9], James E. Sharman, PhD[1,2] for the InvaSive blood PressurE ConsorTium

[1]Menzies Institute for Medical Research, University of Tasmania, Hobart, Australia

[2]Royal Hobart Hospital, Hobart, Tasmania

[3]St Antonius Hospital, Department of Internal Medicine, Nieuwegein, The Netherlands

[4]Department of Internal Medicine, Leiden University Medical Center, Leiden, The Netherlands

[5]Department of Medicine, National Yang-Ming University School of Medicine, Department of Medical Education, Taipei Veterans General Hospital, Taipei, Taiwan

[6]Department of Cardiology/Hypertension, University Hospital of Bordeaux, Bordeaux, France

[7]Institute of Cardiovascular Sciences, University College London, London, United Kingdom

[8]Division of Cardiology, Seoul National University Boramae Hospital, Seoul, South Korea

[9]Institute of Cardiovascular Sciences University College London (UCL) and National Institute for Health Research (NIHR) UCL/UCL Hospitals Biomedical Research Centre, London, United Kingdom

[10]Department of Endocrinology and Internal Medicine, Aarhus University Hospital, Aarhus, Denmark

[11]School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University, Shanghai, China

[12]Department of Cardio-Renal Medicine and Hypertension, Nagoya City University Graduate School of Medical Sciences, Nagoya, Japan

[13]Department of Cardiovascular Medicine, Chiba University Graduate School of Medicine, Chiba, Japan

[14]Clinical Research Unit, Italian Institute of Telemedicine, Varese, Italy

[15]Scientific Research Department of Cardiology, Science and Technology Park for Biomedicine, Sechenov First Moscow State Medical University, Moscow, Russian Federation

[16]Department of Nephrology and Hypertension, University Hospital Erlangen, Friedrich-Alexander University Erlangen-Nürnberg, Erlangen, Germany

[17]Polytechnic Institute of Coimbra, ESTES, Department of Physiology, General Humberto Delgado Street 102, Lousã, Portugal

[18]Unit of Internal Medicine at Terni University Hospital, Department of Medicine, University of Perugia, Perugia, Italy

[19]Department of Clinical Pharmacology and Department of Paediatric Nephrology, Kings College London, Evelina London Children’s Hospital, Guy’s and St. Thomas’ NHS Foundation Trust, London, United Kingdom

[20]Division of Cardiology, University of North Carolina at Chapel Hill, Chapel Hill,

North Carolina

[21]Center for Health Surveillance and Preventive Medicine, Tokyo Medical University Hospital, Tokyo, Japan

[22]Centre for Epidemiological Studies and Clinical Trials, Shanghai Key Laboratory of Hypertension, The Shanghai Institute of Hypertension, Department of Hypertension, Ruijin Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai, China

[23]Cardiology Department, Klinikum Wels-Grieskirchen, Wels, Austria

[24]Cardiovascular and Respiratory Physiology, Faculty of Science and Technology, Technical Medical Centre, University of Twente, Enschede, The Netherlands

Running title: Measuring ISH from cuff and invasive BP

Word count: 5619

Address for correspondence:
Professor James E. Sharman
Menzies Institute for Medical Research
University of Tasmania
Private Bag 23
Hobart, 7000 Australia
Telephone: +61 3 6226 4709
Fax: +61 3 6226 7704
Email: James.Sharman@utas.edu.au

Abstract

Isolated systolic hypertension (ISH) is the most common form of hypertension and is highly prevalent in older people. We recently showed differences between upper-arm cuff and invasive blood pressure (BP) become greater with increasing age, which could influence correct identification of ISH. This study sought to determine the difference between identification of ISH by cuff BP compared with invasive BP. Cuff BP and invasive aortic BP were measured in 1695 subjects (median 64 years, interquartile range [55 to 72], 68% male) from the INvaSive blood PressurE ConsorTium (INSPECT). Data was recorded during coronary angiography among 29 studies, using 21 different cuff BP devices. ISH was defined as ≥130/<80 mmHg using cuff BP compared with invasive aortic BP as the reference. The prevalence of ISH was 24% (n=407) according to cuff BP, but 38% (n=642) according to invasive aortic BP. There was fair agreement (Cohen's Kappa 0.36) and 72% concordance between cuff and invasive aortic BP for identifying ISH. Among the 28% of subjects (n=471) with misclassification of ISH status by cuff BP, 20% (n=96) of the difference was due to lower cuff SBP compared with invasive aortic SBP (mean -16.4 mmHg 95%CI -18.7 to -14.1), whereas 49% (n=231) was from higher cuff DBP compared with invasive aortic DBP (+14.2 mmHg 95%CI 11.5 to 16.9). In conclusion, compared with invasive BP, cuff BP fails to identify ISH in a sizeable portion of older people, and demonstrates the need to improve cuff BP measurements.

Keywords: catheterization; pulse wave analysis; blood pressure measurement/monitoring; artery

Introduction

Isolated systolic hypertension (ISH) is the most common form of hypertension[1] and is strongly associated with increased cardiovascular disease morbidity and mortality.[2, 3] In clinical practice, hypertension is invariably diagnosed and managed based on blood pressure (BP) readings taken from an upper-arm cuff BP method.[4, 5] However, recent evidence showed that cuff BP was not the same as invasive (intra-arterial) BP, either at the aortic or brachial artery level.[6, 7] Specifically, cuff systolic BP (SBP) was variably higher or lower than invasive aortic SBP, whereas cuff SBP was systematically lower than invasive brachial SBP. On the other hand, cuff diastolic BP (DBP) was systematically higher than both invasive brachial and aortic DBP.

The above cuff measurement differences from invasive BP were of such a magnitude to significantly influence the hypothetical classification of hypertension.[6] Of note, increasing age was related to progressively greater underestimation of cuff SBP and pulse pressure (PP) compared with invasive aortic BP values.[7] On the other hand, as age increased, cuff DBP was progressively overestimated compared with invasive aortic DBP. These observations suggest that cuff BP may particularly lack precision for identifying ISH among older people. This has never been examined but is an important consideration for correct identification and best-practice management of ISH.[3] The aim of this study was to determine the difference between identification of ISH by cuff BP compared with a reference invasive BP.

Methods

The data, analytical methods, and study materials will be made available on request to other researchers for purposes of reproducing the results or replicating the procedure. Requests for data should be made to the corresponding author.

Overview and study design. Data used in the analysis was derived from the international INvaSive blood PressurE ConsorTium (INSPECT), which includes studies with cuff BP (automated methods; Online-only Table 1) and invasive BP (fluid-filled or solid-state micromanometer catheters).[6, 7] INSPECT was developed to improve the understanding of cuff BP as an estimate of invasive BP. Comparisons between cuff and invasive aortic BP were made because cuff BP was designed to measure aortic BP[8] (that which the organs are exposed to),[6, 9-11] as others have suggested.[12, 13] However, for completeness, sensitivity analysis for the comparison of cuff BP and invasive brachial BP for identification of ISH was also conducted (more details below). The Health and Medical Human Research Ethics Committee of Tasmania approved this analysis (reference: H0015048).

Data handling. The consortium database was developed from separate studies with quality control measures in place, as previously described.[6, 7] Briefly, studies were included where the cuff and invasive BPs were measured at rest (i.e. not during any hemodynamic shifts), either simultaneously, or within an immediate period of each other. A quality score relating to the rigour of methods used was applied to each study.[6] The present analysis was conducted on subjects ≥13 years because adult hypertension cut points apply beyond this age.[5, 14] ISH was defined as SBP ≥130 mmHg and DBP <80 mmHg for both cuff and invasive BP.[5, 15] PP was calculated as SBP minus DBP and any measures less than 20 mmHg were excluded (n=12). The database for cuff BP compared with invasive aortic BP included 25 subjects with manual cuff BP measurements, but these were excluded because there was insufficient data for a separate comparison with the automated BP methods. The database for cuff BP and invasive brachial BP contained sufficient data for separate analyses for automated (n=381) and manual (n=219) cuff BP methods.

Different cut points for defining isolated systolic hypertension. In addition to the ≥130/<80 mmHg ISH threshold, the following cut points were also assessed for concordance of cuff BP and invasive BP: 1) ≥160/<95 mmHg, as used in early trials targeted at reducing

SBP[16, 17]; 2) ≥140/<90 mmHg, according to the 2018 European Society of Cardiology/European Society of Hypertension guidelines[4]; 3) a PP of ≥60 mmHg.[4]

Sensitivity analyses. Several sensitivity analyses were also conducted for completeness and included: 1) a comparison of cuff BP and invasive brachial BP, in which data were stratified according to the type of cuff device (automated methods (n=381) versus manual cuff BP (n=219)); 2) the type of catheter used for invasive BP measurement (fluid-filled versus solid-state); 3) the study quality score (maximum versus non-maximum rated).

Statistical analysis. Clinical characteristics and BP for the sample are presented as mean± standard deviation, or if non-normally distributed, median [interquartile range (IQR)] for continuous variables and number (%) for categorical variables. To determine the concordance between cuff and invasive aortic or brachial BP for classification of ISH, the proportion of data in each of the following categories was reported: no ISH from both cuff and invasive BP; ISH from both cuff and invasive BP; ISH only from invasive BP; ISH only from cuff BP.

The cause of ISH misclassification for subjects with invasive ISH only or cuff ISH only was determined by stratifying the cuff and invasive BP data at the ISH threshold using every possible permutation of cuff and invasive SBP and DBP. For example, for subjects with ISH only from invasive BP, there were three possible cuff BP categories: 1) ≥130/≥80 mmHg; 2) <130/<80 mmHg; or 3) <130/≥80 mmHg. The proportion of subjects within each category and the difference between cuff and invasive aortic BP was also analysed. The same analysis was also conducted in reverse (i.e. for subjects with ISH only from cuff BP).

Differences in BP were assessed using linear mixed models with a random effect term to account for within study clustering of subjects. Data were analysed using R version 3.5.1 (R: A language and environment for statistical computing. R Foundation for Statistical

Computing, Vienna, Austria. URL https://www.R-project.org/.) The linear mixed models were generated using the lme4 package.[18]

Results

Clinical characteristics. Overall, subjects were typical of patients undergoing coronary angiography, with a median age of 64 years IQR [55 to 72], 68% were male and body mass index was on average in the overweight range (26.1 kg/m^2 IQR [23.4 to 29.1]). Seven hundred and ninety-seven (47%) of the cuff BP measurements were the average of at least two readings and 1111 (66%) cuff BP and invasive BP readings were taken simultaneously, whereas the remaining readings were sequential, with either cuff BP just prior to invasive aortic BP or invasive aortic BP taken just prior to cuff BP.

Cuff and invasive aortic BP defined isolated systolic hypertension. According to cuff BP, 407 subjects (24%) had ISH, whilst 642 subjects (38%) were identified with ISH from invasive aortic BP. The agreement between ISH from cuff versus invasive aortic BP according to Cohen's kappa was 0.36, which is classified as 'fair' agreement.[19] Overall, there was 72% concordance between cuff BP and invasive aortic BP for classification of patients with or without ISH (≥130/<80 mmHg; Figure 1). The clinical characteristics of subjects with or without ISH were not different when ISH was defined by cuff or invasive aortic BP (Table 1). In 353 subjects (21%), ISH was only identified from invasive BP (Figure 1 and Table 2). In 118 subjects (7%), ISH was misidentified by cuff BP. Thus, ISH was misclassified by cuff BP compared to the invasive reference aortic BP in 471 subjects (28%).

Blood pressure variables causing misclassification of isolated systolic hypertension

The potential BP related causes of misclassification of ISH are shown in Figure 1. The principal BP parameters driving misclassification were lower cuff SBP and higher cuff DBP compared with invasive aortic SBP and DBP. Specifically, 96 subjects (20% of the 471 subjects misclassified) with ISH based on invasive aortic BP had cuff SBP readings that were substantially lower than invasive aortic SBP (Online-only results). Conversely, 231 subjects (49%) with ISH based on invasive aortic BP had cuff DBP readings that were substantially higher than invasive aortic DBP. Lower cuff SBP and higher cuff DBP accounted for the misclassification of ISH in 69% of subjects. Full detail of the remaining causes of misclassification are detailed in Figure 1 and the online-only supplement.

Examination of different cut points for defining isolated systolic hypertension.

ISH cut points of ≥160/<95 mmHg and ≥140/<90 mmHg. According to the ISH cut point of ≥160/<95 mmHg, 147 subjects (9%) had ISH from cuff BP, whilst 276 subjects (16%) were identified with ISH from invasive aortic BP. Using the ≥140/<90 mmHg cut point, 422 subjects (25%) had ISH from cuff BP, whilst 638 subjects (38%) had ISH based on invasive aortic BP. The clinical characteristics of subjects with or without ISH were not different when defined by cuff or invasive aortic BP using either cut point (Online-only Tables 2-3). Concordance between cuff and invasive aortic BP classification of ISH was 88% when the ≥160/<95 mmHg cut point was used (Figure 2 and Online-only Table 4). Concordance based on the ≥140/<90 mmHg ISH cut point was 76%, similar to the primary analysis (Figure 2 and Online-only Table 5).

PP cut point of ≥60 mmHg. According to cuff BP, high PP was identified in 680 subjects (40%) while, 965 subjects (57%) were identified with high PP from invasive aortic BP. The clinical characteristics of subjects with or without high PP from the ≥60 mmHg cut point were not significantly different when defined by cuff or invasive aortic PP (Online-only Table 6). Concordance between cuff and invasive aortic PP for identifying high PP was 75% (Figure 2 and Online-only Table 7).

Sensitivity analyses.

Comparisons with invasive brachial BP. According to the data for automated cuff BP, 115 subjects (30%) had ISH, whilst 212 subjects (56%) were identified with ISH from invasive brachial BP. From the data with manual cuff BP, 35 subjects (16%) had ISH, whilst 44 subjects (20%) were identified with ISH from invasive brachial BP. The clinical characteristics of subjects with or without ISH were not different when defined by automated cuff or invasive brachial BP (Online-only Table 8) or from manual cuff BP or invasive brachial BP (Online-only Table 9). Concordance between automated cuff BP and invasive brachial BP for identifying ISH was 66%, whilst concordance between manual cuff BP and invasive brachial BP was 86% (Figure 2).

Fluid-filled versus solid-state catheter. Concordance of the ISH classification was similar for fluid-filled or solid-state catheters used for the measurement of invasive aortic or brachial BP (Online-only Table 10).

Maximum versus non-maximum rated studies. Concordance of the ISH classification was similar for maximum versus non-maximum rated study methods (Online-only Table 10).

Discussion

The key new findings from this study were that there was a greater prevalence of ISH classified from invasive aortic BP than from upper-arm cuff measured BP (38% versus 24%). As expected, differences between cuff BP and invasive aortic BP classification of ISH were mostly related to lower cuff SBP and higher cuff DBP. Together, these two differences accounted for 69% of the potential BP related causes of misclassification of ISH by cuff BP compared with invasive aortic BP. Altogether, these findings show that although ISH is appropriately detected by cuff BP in many people, there is a sizeable element of potential error in identifying the true risk related to ISH - in this study, just over one quarter of the study population. Since ISH is the most common form of hypertension further improvements to non-invasive cuff BP measurement could help to achieve greater clinical precision.

It is commonly believed that SBP rises with ageing in most humans.[20] On the other hand, DBP generally increases up to midlife before a plateau and eventual drop in later life. The higher SBP and lower DBP (thus widened PP) characterises the ISH phenotype and explains why it is the most common form of hypertension, particularly in older age.[1] A widened PP is a hallmark of vascular ageing, in which stiffening of the aorta is associated with increased SBP.[21] In the current study, those classified with ISH (from either cuff BP or invasive aortic BP) were older and had higher SBP, but similar DBP compared to those not classified with ISH. Our previous work has illustrated that in older age cuff SBP underestimated invasive aortic SBP,[7] thus leading us to hypothesise that a diagnosis of ISH may be significantly underappreciated by cuff BP. Of equal importance to correctly identifying ISH is the age-related drop in aortic DBP (according to invasive BP) that is not fully detected by cuff BP methods due to systematic overestimation of cuff DBP across all ages.[7]

It was reassuring that 72% of the study population were appropriately classified with respect to ISH based on cuff BP compared with invasive aortic BP because it suggests that a majority of people will have the opportunity to receive appropriate clinical care based on correct diagnosis using standard cuff BP.[4] Nonetheless, there was only fair agreement between cuff and invasive BP methods for identifying ISH, with almost one quarter of the subjects being misclassified with or without ISH. As indicated in Figure 1, the ISH misclassification was attributable to several differences between cuff BP and invasive aortic SBP and DBP. Firstly, when cuff SBP was lower than invasive aortic SBP (in the ISH range), the correct classification of ISH was missed. A practical outcome of this ‘false negative’ ISH classification may be that appropriate treatment would not be initiated, and a heightened level of cardiovascular risk related to ISH would remain. Secondly, when cuff DBP was higher than invasive aortic DBP, a correct classification of ISH was not made. This ‘false negative’ ISH classification may have less clinical ramifications, since individuals would still be classified with hypertension and possibly receive the same medical care as if identified with ISH. Nonetheless, due to systematically higher cuff DBP compared with invasive aortic DBP, some individuals with DBP <70 mmHg could be at risk of overtreatment. This is of particular relevance to those with established coronary artery disease, where there is the potential of conferring harm.[4, 22]

Historically, hypertension treatment thresholds were focused on raised DBP,[23] but as evidence evolved the focus shifted towards raised SBP as being more clinically important.[4, 5] Today, most older people are likely to have treatment decisions made on the basis of raised SBP, irrespective of DBP. In the present study we examined other definitions of ISH beyond the 130/80 mmHg threshold (e.g. ≥160/<95 mmHg,[16, 17] ≥140/<90 mmHg).[4] Irrespective of the ISH definition, findings were similar, with the exception of ISH defined as ≥160/≥95 mmHg, in which only 12% of subjects were misclassified. However, this threshold has since been shown to be too high because increased risk related to ISH is conferred at lower levels of BP.[4] Indeed, there is a continuous association between higher SBP and/or DBP and increased cardiovascular risk[24] and this again demonstrates the importance of high-quality, BP measurement precision irrespective of hypertension thresholds. The differences between cuff BP and invasive aortic BP which become more substantial with increasing age[7] may adversely impact the optimal management of patients with high cardiovascular risk. This is perhaps of most importance in the context of absolute cardiovascular risk assessment, which is the suggested basis for hypertension management decisions outlined in current clinical guidelines.[4, 5]

Limitations. Data from INSPECT was compiled from populations undergoing coronary angiography, and so the results may not be generalisable to other populations, such as those having BP assessed in general practice. Moreover, whether these results would remain consistent in younger people is unclear. The invasive data consisted of BP measured by both micro-manometer tipped and fluid-filled catheters, as well as various cuff BP devices. Whilst these methods of BP assessment may not be considered the same, we have previously shown major cuff BP differences from invasive BP, independent of the type of invasive reference measurement and cuff type.[6] In the present study, manual cuff BP performed better than automated cuff BP for detection of ISH compared with invasive brachial BP (86% versus 66% concordance). Whilst this result suggests manual BP may be superior, there were distinct differences in the clinical characteristics of the subjects in the automated and manual cuff BP datasets which may also have contributed to the differences in ISH concordance (Online Tables 8 and 9). This study was based solely on classification of ISH from BP measures and guideline thresholds. Clinical decisions are generally recommended to be made based on absolute cardiovascular risk assessment,[4, 5, 25] but we were unable to assess this in the current analysis. Moreover, whether the theoretical misclassification of ISH described in this paper leads to adverse cardiovascular disease outcomes in clinical practice remains unknown.

Perspectives. Slightly over one quarter of this sample of older people had ISH misclassified by cuff BP compared with invasive aortic BP. This demonstrates a need to improve cuff BP methods for greater precision in identifying ISH. This study expands on previous findings which have shown greater inaccuracy of cuff BP associated with older age[7] and with heightened vascular stiffness,[26] which are characteristics that increase the likelihood of ISH. At least one study has attempted to improve the precision and accuracy of cuff measured BP among older people with stiffer vasculature, by deeper analysis of patient-specific components of the oscillometric BP waveform.[27] These investigators established proof-of-concept that such an approach was feasible, and the results of the present study provide further justification for improving the quality of cuff BP measurement to ultimately drive better patient outcomes related to ISH and other forms of hypertension.

Acknowledgements

Additional members of the Invasive Blood Pressure Consortium are:

Ahmed M. Al-Jumaily: Institute of Biomedical Technologies, Auckland University of Technology, Auckland, New Zealand

Sandy Muecke: Department of Critical Care Medicine, Flinders University, Adelaide, Australia

Niklas B. Rossen: Department of Endocrinology and Internal Medicine, Aarhus University Hospital, Aarhus, Denmark

Ralph Stewart: Green Lane Cardiovascular Service, Auckland City Hospital,

University of Auckland, Auckland, New Zealand

Funding

This work was supported by a Vanguard Grant from the National Heart Foundation of Australia (reference 101836) and Royal Hobart Hospital Research Foundation project grant (reference 19-202).

Disclosures

James E Sharman: His university has received equipment and research funding from manufacturers of BP devices including AtCor Medical, IEM and Pulsecor (Uscom). He has no personal commercial interests related to BP companies. No disclosures from other authors.

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Novelty and significance

What Is New?

- ISH was misclassified by cuff BP measurements in about one quarter of the study sample when compared to invasive BP.

What Is Relevant?

- ISH is the most prevalent form of hypertension. Irrespective of the ISH threshold, these findings may have implications for the appropriate identification of ISH.

Summary

This study extends on previous findings which have shown greater inaccuracy of cuff BP in older age and with vascular stiffness. Taken altogether, the data support the need to improve cuff BP methods for better identification of ISH in older people.

Figure legends.

Figure 1. Classification of isolated systolic hypertension (ISH) from cuff and invasive aortic blood pressure (BP n=1695). Details from the misclassified data are presented in the first branches of the flow chart to show which cuff BP variable caused ISH misclassification. For each cause of misclassification, further mechanisms and potential clinical ramifications are detailed in the lower two rows of boxes. ISH was defined as systolic BP (SBP) ≥130/diastolic BP (DBP) <80 mmHg for both cuff and invasive aortic measurements. Cuff SBP/DBP 'lower' indicates that cuff BP was lower than invasive aortic BP, whilst cuff SBP/DBP 'higher' indicates that cuff BP was higher than invasive aortic BP.

Figure 2. Classification of isolated systolic hypertension (ISH) based on cuff and invasive blood pressure according to various definitions of ISH. The comparisons of cuff and invasive aortic BP are in 1695 subjects. The comparison for automated cuff BP and invasive brachial BP is in 381 subjects. The comparison for manual cuff BP and invasive brachial BP is in 219 subjects. Some column percentages may not add to 100 due to rounding.

Table 1. Clinical characteristics and haemodynamics stratified by the presence or absence of isolated systolic hypertension defined by cuff or invasive aortic blood pressure measurements at a cut point of ≥130/<80 mmHg (n=1695).

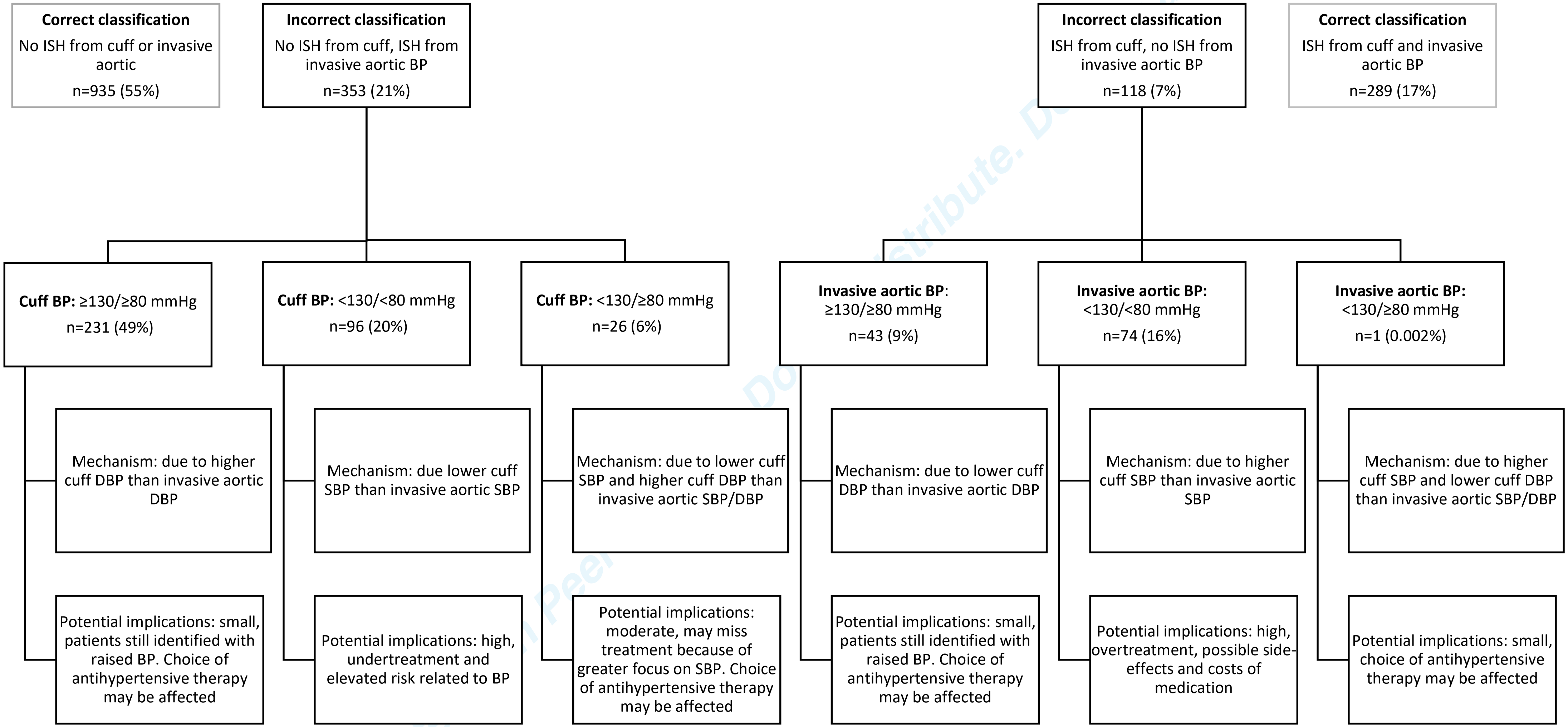
	No isolated systolic hypertension (cuff)	Isolated systolic hypertension (cuff)	No isolated systolic hypertension (invasive)	Isolated systolic hypertension (invasive)
N	1288	407	1053	642
Clinical characteristics				
Age, years	62 [54 to 70]	69 [62 to 76]	60 [52 to 68]	69 [62 to 76]
Male sex %	912 (72; n=1264)	226 (56; n=403)	747 (72; n=1032)	391 (62; n=635)
Body mass index, kg/m^2	26.1 [23.4 to 29.2; n=1178]	26.6±5 (n=360)	26.3 [23.5 to 29.8; n=959]	26.2±5 (n=579)
Height, cm	167±10 (n=1179)	163±10 (n=361)	167±10 (n=960)	163±10 (n=580)
Weight, kg	72.0 [62.0 to 85.0; n=1186]	69.0 [58.6 to 80.0; n=363]	73.7 [63.1 to 86.4; n=967]	67.5 [58.0 to 79.9; n=5821]
Heart rate, beats/min	67 [60 to 76; n=1165]	65 [58 to 73; n=322]	68 [61 to 77; n=957]	64 [58 to 72; n=530]
Coronary artery disease (%)	610 (67; n=906)	178 (71; n=252)	483 (66; n=734)	305 (72; n=424)
Blood pressure				
Cuff systolic BP, mmHg	133±23	141 [134 to 151]	126 [115 to 142]	144±18
Invasive aortic systolic BP, mmHg	133±26	146 [133 to 159]	122 [112 to 141]	147 [138 to 160]
Cuff – invasive systolic BP, mmHg	-0.8±14	-2.9±14	1.8±13	-6.3±13
Cuff diastolic BP, mmHg	80±13	73 [68 to 76]	78±14	77±11
Invasive aortic diastolic BP, mmHg	71±13	68±10	72±14	70 [63 to 75]
Cuff – invasive diastolic BP, mmHg	8.5±11	3.6±9	6.0±10	9.5±12
Cuff pulse pressure, mmHg	51 [43 to 60]	70 [63 to 82]	50 [41 to 60]	67±17
Invasive aortic pulse pressure, mmHg	59 [47 to 74]	78 [66 to 92]	53 [45 to 65]	80 [69 to 93]
Cuff – invasive pulse pressure, mmHg	-9.3±15	-6.4±15	-4.2±13	-15.8±15

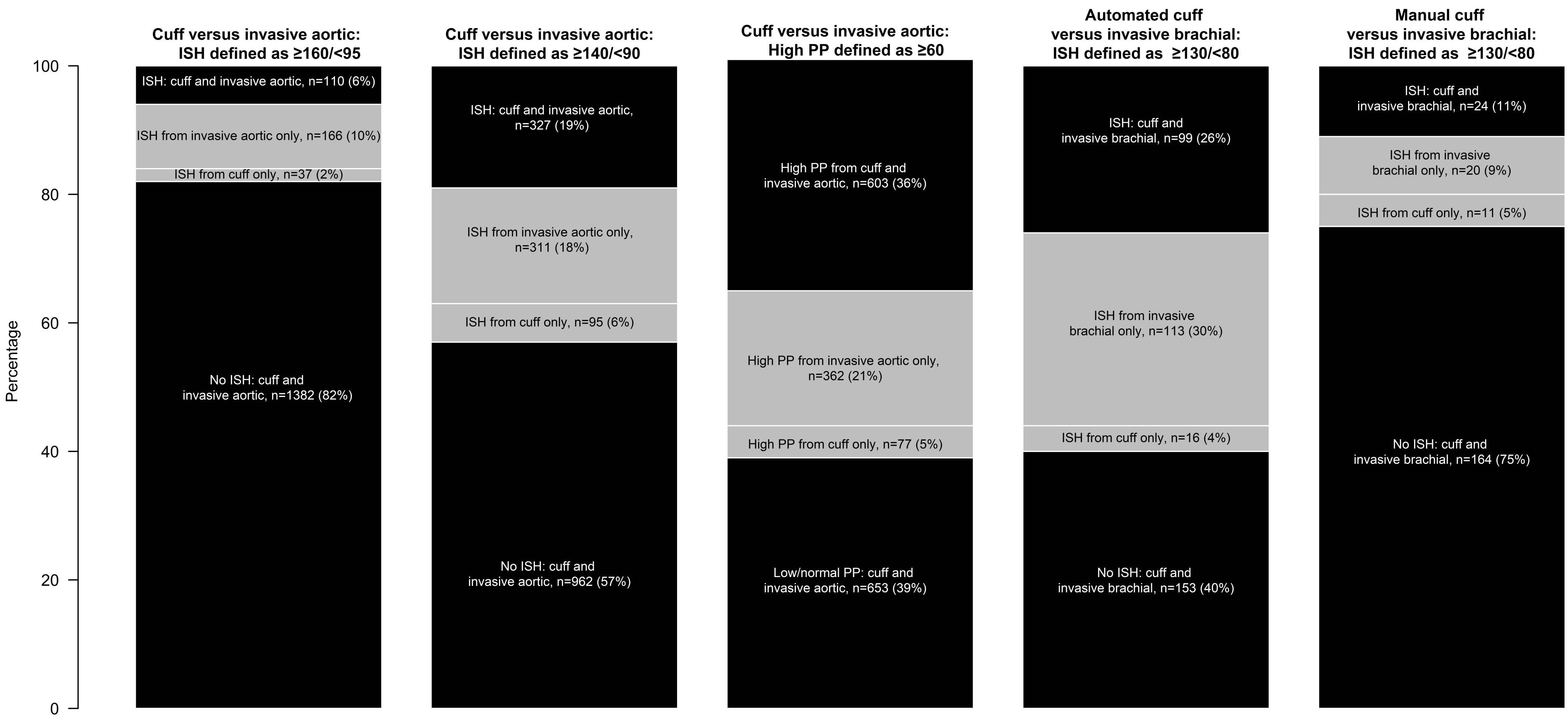
Data are mean±standard deviation, median [interquartile range] or n (%). Isolated systolic hypertension was defined as systolic blood pressure (BP)≥130/diastolic BP <80 mmHg for both cuff and invasive aortic measurements.

Table 2. Clinical characteristics and pressure parameters stratified by the isolated systolic hypertension classification based on cuff and aortic blood pressure at a cut point of ≥130/<80 mmHg (n=1695).

	No ISH (cuff and invasive)	ISH (cuff and invasive)	ISH (invasive only)	ISH (cuff only)
N	935	289	353	118
Clinical characteristics				
Age, years	60 [52 to 68]	71 [65 to 77]	67 [60 to 74]	64 [56 to 70]
Male sex (%)	679 (74; n=916)	158 (55; n=287)	233 (67; n=348)	68 (59; n=116)
Body mass index, kg/m^2	26.3 [23.5 to 29.7; n=855]	26.2±5 (n=256)	25.6 [23.0 to 27.9; n=323]	27.6±5 (n=104)
Height, cm	167±10 (n=856)	161±10 (n=257)	164±11 (n=323)	166±9 (n=104)
Weight, kg	73.4 [63.2 to 86.4; n=861]	68 [57 to 78; n=257]	67.5 [59.6 to 81.0; n=325]	74.4 [62.0 to 86.8; n=106]
Heart rate, beats/min	68 [61 to 77; n=857)	63 [57 to 72; n=222]	65 [59 to 72; n=308)	69 [62 to 75; n=100]
Coronary artery disease (%)	431 (65; n=659)	126 (71; n=177)	179 (72; n=247)	52 (69; n=75)
Blood pressure				
Cuff systolic BP, mmHg	124 [113 to 141]	142 [136 to 154]	142±20	136 [131 to 142]
Invasive aortic systolic BP, mmHg	121 [110 to 141]	149 [140 to 162]	145 [136 to 158]	126 [122 to 146]
Cuff – invasive systolic BP, mmHg	1.4±13	-6.0±12	-6.5±14	-4.9±14
Cuff diastolic BP, mmHg	79±14	72 [67 to 76]	83±10	74 [70 to 76]
Invasive aortic diastolic BP, mmHg	72±14	67 [61 to 73]	71 [66 to 76]	73 [63 to 81]
Cuff – invasive diastolic BP, mmHg	6.6±10	4.7±8	13.5±13	0.9±12
Cuff pulse pressure, mmHg	48 [40 to 57]	73 [65 to 84]	60±15	65 [59 to 71]
Invasive aortic pulse pressure, mmHg	52 [44 to 64]	85 [73 to 97]	77 [67 to 88]	61 [53 to 73]
Cuff – invasive pulse pressure, mmHg	-5.2±13	-10.7±13	-18.0 [-26.7 to -11.0]	4.0±13

Data are mean±standard deviation, median [interquartile range] or n (%). Isolated systolic hypertension (ISH) was defined as systolic blood pressure (BP)≥130/diastolic BP <80 mmHg for both cuff and invasive aortic measurements.


Correct classification
No ISH from cuff or invasive aortic
n=935 (55%)
Incorrect classification
No ISH from cuff, ISH from invasive aortic BP
n=353 (21%)
Incorrect classification
ISH from cuff, no ISH from invasive aortic BP
n=118 (7%)
Correct classification
ISH from cuff and invasive aortic BP
n=289 (17%)
Cuff BP: ≥130/≥80 mmHg
n=231 (49%)
Cuff BP: <130/<80 mmHg
n=96 (20%)
Cuff BP: <130/≥80 mmHg
n=26 (6%)
Invasive aortic BP: ≥130/≥80 mmHg
n=43 (9%)
Invasive aortic BP: <130/<80 mmHg
n=74 (16%)
Invasive aortic BP: <130/≥80 mmHg
n=1 (0.002%)
Mechanism: due to higher cuff DBP than invasive aortic DBP
Mechanism: due lower cuff SBP than invasive aortic SBP
Mechanism: due to lower cuff SBP and higher cuff DBP than invasive aortic SBP/DBP
Mechanism: due to lower cuff DBP than invasive aortic DBP
Mechanism: due to higher cuff SBP than invasive aortic SBP
Mechanism: due to higher cuff SBP and lower cuff DBP than invasive aortic SBP/DBP
Potential implications: small, patients still identified with raised BP. Choice of antihypertensive therapy may be affected
Potential implications: high, undertreatment and elevated risk related to BP
Potential implications: moderate, may miss treatment because of greater focus on SBP. Choice of antihypertensive therapy may be affected
Potential implications: small, patients still identified with raised BP. Choice of antihypertensive therapy may be affected
Potential implications: high, overtreatment, possible side-effects and costs of medication
Potential implications: small, choice of antihypertensive therapy may be affected


Cuff versus invasive aortic: ISH defined as ≥160/<95
ISH: cuff and invasive aortic, n=110 (6%)
ISH from invasive aortic only, n=166 (10%)
ISH from cuff only, n=37 (2%)
No ISH: cuff and invasive aortic, n=1382 (82%)
Cuff versus invasive aortic: ISH defined as ≥140/<90
ISH: cuff and invasive aortic, n=327 (19%)
ISH from invasive aortic only, n=311 (18%)
ISH from cuff only, n=95 (6%)
No ISH: cuff and invasive aortic, n=962 (57%)
Cuff versus invasive aortic: High PP defined as ≥60
High PP from cuff and invasive aortic, n=603 (36%)
High PP from invasive aortic only, n=362 (21%)
High PP from cuff only, n=77 (5%)
Low/normal PP: cuff and invasive aortic, n=653 (39%)
Automated cuff versus invasive brachial: ISH defined as ≥130/<80
ISH: cuff and invasive brachial, n=99 (26%)
ISH from invasive brachial only, n=113 (30%)
ISH from cuff only, n=16 (4%)
No ISH: cuff and invasive brachial, n=153 (40%)
Manual cuff versus invasive brachial: ISH defined as ≥130/<80
ISH: cuff and invasive brachial, n=24 (11%)
ISH from invasive brachial only, n=20 (9%)
ISH from cuff only, n=11 (5%)
No ISH: cuff and invasive brachial, n=164 (75%)
Percentage
0
20
40
60
80
100