ORIGINAL RESEARCH

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Blood pressure measurement and the prevalence of postprandial hypotension

Abstract

Background: Postprandial hypotension (PPH) is a serious condition that has been shown to be an independent risk factor for falls, fractures and death.

Purpose: The prevalence of this problem in older adults with a past history of falls has shown a wide variability in the literature; the present study seeks to examine how the frequency with which blood pressure is measured impacts the prevalence and severity of PPH.

Methods:

Older adults were recruited sequentially from a geriatric medicine falls clinic for meal testing (n=95). All subjects (mean age 77.5 ± 0.7 years, $61 \pm 5\%$ female) were fasting prior to each 90 min standardized meal test. A Finometer (Finapres Medical Systems BV) was used to monitor blood pressure. Beat-by-beat systolic (SBP) measures were averaged for 0.5, 1, 2, 3, 5, 6, 9, 10, 15, 18, 30, 45 and 90 min respectively during the meal test.

Results: Using the original diagnostic method of checking mean blood pressure every 10 min resulted in a PPH prevalence of $42.1 \pm 5.1\%$ in our population, with an overall range from $81.1 \pm 4.0\%$ to $11.6 \pm 3.3\%$ depending on the frequency of calculating SBP. The maximal observed postprandial decrease in SBP also showed a significant difference with blood pressure measurement frequency ($p < 0.001$).

Conclusion: The frequency with which blood pressure is measured has a profound effect on the measured prevalence and severity of PPH, and is one factor in explaining the wide variability of the PPH response reported in the literature.

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Postprandial hypotension (PPH) is a common, poorly understood condition in which blood pressure (BP) decreases after eating, often resulting in falls due to fainting. In older adults, fainting after eating results in dangerous and expensive outcomes such as hip fractures, institutionalization and increased rates of hospitalization [1,2]. Previous work has demonstrated that PPH is an independent risk factor for falls and fractures [3], and has been shown to be an independent predictor of both morbidity [4,5] and mortality [6]. The often asymptomatic [7] nature of this condition can make PPH a diagnosis that is frequently overlooked.

Further complicating this issue is the fact that there is no clear agreed upon definition for PPH [8]. Postprandial hypotension is currently defined as a postprandial decrease in systolic blood pressure (SBP) of more than 20 mmHg, or a postprandial SBP of less than 90 mmHg [9], as measured for 90 min after eating. Decreases in SBP that meet these current criteria have been shown to vary between two and 90 min in length, bringing into question how often blood pressure should be checked during a meal test [10]. Given that decreases in blood pressure lasting fewer than 15 seconds can result in syncope [11], the lack of a clear criterion could mean that clinically significant PPH could remain undetected, or the severity of the problem underestimated [10].

The current study examines the impact of the frequency of blood pressure checks on both the prevalence and severity of PPH in a falls clinic population of older adults.

Materials and Methods

Subjects

All subjects had to be over 65 years of age, and were recruited sequentially from January 2014 to January 2018 for meal testing (n=95) (Table 1). All subjects were referred by their family physician to the falls clinic (Division of Geriatric Medicine) at Vancouver General Hospital located in Vancouver, British Columbia, Canada. None of the subjects had an oral or swallowing issue that prevented the ability to do a meal test. This study received approval by the Human Subjects Committee of the University of British Columbia, and all subjects gave written informed consent.

Meal testing

All subjects were fasting prior to each meal test, and the test lasted 90 min after meal administration. All study sessions were performed between 7 AM and noon to avoid bias due

to circadian rhythms and were performed with the subject supine. Each subject was supine for 30 min prior to the start of data collection in order to reach steady state. Subjects refrained from vigorous exercise and from consuming alcohol or caffeine for the 24 hours prior to each session. The morning of each meal test, all antihypertensive and diabetes medications were held. All tests occurred in a quiet room with a constant ambient temperature ($25 \pm 1^\circ\text{C}$). The meals used for the test was standardized, and consisted of a 1050 kJ standardized meal substitute (containing 7.8 g fat, 38 g carbohydrates, 9.4 g protein and 3.4 g fibre) and was served at a standardized refrigerated temperature ($3.0 \pm 0.5^\circ\text{C}$). We chose to serve the meal cold, as previous work had shown that consumption of higher temperature meals exacerbated the PPH response [12].

Data collection and processing

Continuous beat-to-beat measurements of blood pressure were collected at baseline and for a total of 90 min after ingestion of standardized meal. Each meal test was performed with the subject resting comfortably in the sitting position. All blood pressure signals were sampled at 1000 Hz (Powerlab, AD Instruments) and digitized for later analysis.

A Finometer (Finapres Medical Systems BV, The Netherlands) was used to monitor blood pressure. The Finometer uses infrared plethysmography through a finger-cuff to measure beat-to-beat blood pressure noninvasively. The infrared plethysmography technique has been well established as a noninvasive measure of beat-to-beat blood pressure [13] and has been validated against intra-arterial blood pressure monitoring in older adult subjects [14]. In addition, the Finometer performs waveform filtering, level correction and an additional return-to-flow calibration; this allows for accurate reconstruction of brachial artery pressures from finger-cuff infrared plethysmography data [15,16]. Commercially available software was used to provide beat-to-beat measures of systolic (SBP), mean (MBP) and diastolic (DBP) blood pressure (Beatscope, Finapres Medical Systems BV). The SBP, mean arterial pressure (MAP) and DBP beat-to-measures were averaged for each data window (0.5, 1, 2, 3, 5, 6, 9, 10, 15, 18, 30, 45 and 90 min, respectively) during the meal test.

The presence of PPH was defined as a decrease in SBP of 20 mmHg during one of the data windows within 90 min of ingesting the standardized meal [17]. The number of times each subject met PPH criteria (PPHnum) was determined for each data window. The maximum blood

pressure drop (PPHmax) was calculated for each data window length and averaged. The analysis of the data and all post-collection processing was done in a blinded fashion. Each segment of blood pressure data was visually examined to exclude artifacts prior to all derived measurements. Given the fact that oscillometric methods of measuring SBP have shown absolute deviations of approximately 4 mmHg when compared with traditional auscultatory methods [18], all blood pressure measures (both baseline and during the meal test) were performed using the same methods. Baseline blood pressure was calculated by averaging 20 min of resting data taken prior to the meal test.

As described previously in the literature, fall risk was determined in the falls clinic using the Physiological Profile Assessment, which assigns a Z-score for each patient after a quantitative assessment of edge contrast sensitivity, postural sway, leg strength, reaction time and reaction time [19].

Statistical methods

All results are expressed as the mean $\pm$ standard error. Normality was ensured by examining the density plots prior to statistical analysis. If normality assumptions were not met, measures of spread were calculated using a 999-repetition bootstrap analysis [20]. A one-way analysis of variance (ANOVA) with repeated measures was used with data window length as the predictor and PPHnum and PPHmax [21] as dependent variables. The change in heart rate during the meal test was also determined using a one-way analysis of variance with repeated measures, with time as the predictor and heart rate as the dependent variable. Prior to each ANOVA a Mauchly's test of sphericity was performed and followed by a Greenhouse-Geisser correction if necessary [21]. A value of p of 0.05 was considered significant. The R core software package version 3.0.1 was used for all statistical analyses [22].

Results

Subject characteristics

Subject characteristics are summarized in Table 1. None of the subjects experienced any syncopal or presyncopal symptoms. During the 90 min meal test, all subjects experienced an average maximal increase in heart rate 4.3 ± 0.9 beats per minute (5 min time windows, $p < 0.001$).

TABLE 1. Subject clinical characteristics

Clinical characteristic	
Age (years)	77.5 $\pm$ 0.7
Percentage female (%)	61 $\pm$ 5
Body mass index (kg/m ²)	28.9 $\pm$ 1.2
Waist circumference (cm)	101 $\pm$ 2
Systolic blood pressure (mmHg)	145 $\pm$ 2
Diastolic blood pressure (mmHg)	76 $\pm$ 1
Mean arterial pressure (mmHg)	99 $\pm$ 1
Standing systolic blood pressure (1 min) (mmHg)	144 $\pm$ 7
Standing diastolic blood pressure (1 min) (mmHg)	79 $\pm$ 7
Standing mean arterial pressure (1 min) (mmHg)	101 $\pm$ 7
Heart rate (beats per minute)	69 $\pm$ 6
Percent diagnosis of diabetes (Type 2, %)	47 $\pm$ 5
Percent diagnosis of hypertension	57 $\pm$ 5
Number of smokers	0
Physiological Fall Profile Risk Score (Z score)	1.34 $\pm$ 0.31
Medications (number of subjects)	
Metformin	36
Sulfonylureas	15
Glitazones	0
Statin	32
ACE inhibitors/ARB	36
Betablockers	12
Calcium channel blocker	21
Hydrochlorothiazide	4
Other diuretics	28

Time window and PPH prevalence

The choice of time window in the definition of PPH had a large effect on the reported prevalence of PPH. Using the method found in the original paper (checking mean blood pressure every 10 min) [23] produced a PPH prevalence of 42.1 $\pm$ 5.1% in our population (Figure 1). The proportion of

subjects meeting the criteria for PPH ranged from $81.1 \pm 4.0\%$ to $11.6 \pm 3.3\%$, depending on the frequency of calculating mean blood pressure. Using a time window of 1 min instead of 15 min resulted in an approximate doubling of the measured prevalence of PPH. As shown in Figure 1, the prevalence of PPH was relatively constant between 5 min ($50.5 \pm 5.1\%$) and 15 min ($37.9 \pm 5.0\%$) defined time windows.

Time window and PPHnum

One-way repeated measures ANOVA indicated a significant effect of time window length on PPHnum ($F=47.26$, $p<0.001$) (Figure 1). The average number of times subjects met PPH criteria varied from a mean of 32.1 ± 4.7 to 0.1 ± 0.0 over a 90 min period as the time window varied from 0.5 to 90 min.

Time window and maximal change in SBP (PPHmax)

The maximal observed decrease in SBP also showed a significant difference with one-way repeated measures ANOVA ($F = 22.01$, $p<0.001$). As shown in Figure 2, different time windows showed quite a large variability in the PPH response: a 5 min window resulted in a mean PPHmax of 14.5 ± 4.1 mmHg while a 15 min window resulted in a mean PPHmax of 7.0 ± 3.3 mmHg; a decrease of approximately 50%.

Discussion

The frequency of checking mean blood pressure had a large impact on the prevalence of PPH, the number of times subjects met PPH criteria and the magnitude of the detected decrease in SBP detected in a population of community-dwelling older adults referred to a falls clinic.

There have been numerous small studies examining the prevalence of PPH in varied populations (residential care patients [23–25], healthy normal patients [26], older adults with a history of falls [27,28] and inpatients [29]) and using varied techniques (automated sphygmomanometer [23–26], continuous infrared plethysmography [27,30] and ambulatory blood pressure monitoring [28,31]). Perhaps due to wide subject heterogeneity (ranging from acutely ill inpatients to healthy volunteers) and the widely different measurement frequencies (every 30 s to every hour) observed prevalence ranged from 18% [28] to 67% [27]. In the literature solely examining the outpatient older adult population with a falls history (the population sampled in the current study), PPH

prevalence has been shown to vary from between 18% (blood pressure measured every 30 min) [28] to 67% (blood pressure measured every 1–2 min) [27]. Interestingly, these prevalences were similar to the range noted in the current investigation, suggesting that the seeming contradiction between these past findings are an artifact of the techniques used to measure blood pressure and not due to any property of the subjects being investigated.

Similarly, the magnitude of the PPH response has shown wide variation in the literature, ranging from 15 to 34 mmHg in various populations [23–30]. The only study that provided a magnitude for the postprandial response in older adults with a past history of falls demonstrated a decrease of 12 mmHg; this study measured blood pressure every 15 min [28], which was similar to the magnitude observed in the current study using a 15 min data window.

Clinical implications

Although PPH has been long established as risk factor for increased mortality [23], falls [23] and fractures [25], the prevalence of the problem has shown wide variability in the literature [23–30]. The results of our study indicate that this variability may be due, in large part, to how often the blood pressure is measured. Changes in the frequency of measuring blood pressure showed a large impact on the measured prevalence, magnitude of the blood pressure decrease and the number of times subjects met PPH criteria. Future clinical guidelines and research studies should formally standardize blood pressure measurement methods in order to avoid over/underestimating the prevalence of this serious condition, which might respond to eating smaller meals [32], ingesting coffee [33] and rapidly consuming a large quantity of water [34].

Limitations and future research

Given that our study did not measure syncope rates, there is no method to determine which frequency of blood pressure measurement is the most appropriate to detect the presence of clinically significant PPH. Future research should follow subjects longitudinally, allowing us to separate out those subjects with clinically significant PPH from those that can successfully compensate for postprandial declines in blood pressure. Also, since our population was recruited from an ambulatory clinic, our patients were younger, less frail and more cognitively intact than the average patient population that has had a fracture.

FIGURE 1.

Effects of time window length on PPH prevalence and number of times subjects met PPH criteria. The effect of time window length on both the prevalence of postprandial hypotension (PPH) and the number of times subjects met PPH criteria are shown.

FIGURE 2.

Effects of time window length on maximal decrease in systolic blood pressure. Time window length showed a highly significant impact on the mean maximal observed decrease in systolic blood pressure with one-way repeated measures ANOVA ($F = 22.01$, $p < 0.001$).

Previous work has demonstrated that caution must be exerted in interpreting absolute blood pressure values using Finometer methods, since it has shown significant differences when compared with auscultatory methods [18,35], and with other noninvasive methods [36].

Oscillometric methods of measuring SBP have shown to be approximately 4 mmHg lower than more gold standard auscultatory methods [18]. Although this is an important limitation, both baseline and meal test measurements were done using the same method (that is, Finometer readings) and our analysis only relied on changes in blood pressures using the same technique.

The frequency with which blood pressure is measured has a profound effect on the measured prevalence and severity of PPH.

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