Blood Pressure Measurement in Atrial Fibrillation: Is there a Niche for Novel Brachial Cuff and Suprasystolic Waveform Algorithms?

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Abstract
Atrial fibrillation (AF) is the most common sustained arrhythmia, with a prevalence of approximately 1.60% in the United Kingdom [1]. AF is associated with increased rates of death, stroke and other thromboembolic events, heart failure and hospitalisations, degraded quality of life, reduced exercise capacity, and left ventricular dysfunction [1-3]. Hypertension occurs in 65-70% of AF patients, making this the most common co-morbidity found in AF registries in Europe [4]. Early detection and treatment of hypertension is a crucial component of the management of AF. However, non-invasive assessment of blood pressure (BP) in AF has traditionally proven challenging and inaccurate. Novel brachial cuffs utilising suprasystolic waveform algorithms allow accurate assessment of central BP and augmentation index, a measure of arterial stiffness. It remains to be determined whether these devices have a niche in determining authentic assessment of BP in AF.

INTRODUCTION

Population-based studies that assess risk related to hypertension demonstrate strong associations between brachial BP (measured by cuff at the upper-arm) and cardiovascular morbidity and mortality [5]. It is well recognised that systolic BP is higher in the more muscular peripheral arteries (e.g., brachial artery) than in the elastic central arteries (e.g., aortic, carotid) [6-13]. The magnitude of this pressure amplification varies between individuals and can result in markedly different aortic (central) systolic BP between individuals despite sharing similar peripheral (brachial) systolic BP. This is relevant because central BP may be an even stronger predictor of cardiovascular risk and mortality than brachial blood pressure [8,9].

AF is the most common sustained cardiac arrhythmia (estimated lifetime risk, 22%-26%) [1,2]. AF is associated with substantial morbidity, reductions in functional status and quality of life (QOL), and increased mortality because of a combination of altered haemodynamics, atrioventricular dyssynchrony, progressive atrial and ventricular mechanical dysfunction, and thromboembolic complications [1,2].

Hypertension is the most significant population-attributable risk factor for AF [14]. Recent studies suggest that systolic BP in the pre-hypertensive range (130-139 mm Hg) and widened pulse pressure are also associated with increased risk [14]. Accurate assessment of BP in subjects with AF is therefore crucial. The reliability of the now widely available automated oscillometric BP monitors is well established in sinus rhythm but is not well investigated when assessing BP in patients with paroxysmal or persistent AF. In AF there is beat-to-beat variability of stroke volumes and hence, significant BP fluctuation. With the disappearance of mercury sphygmomanometers from clinical use, automated oscillometric BP-measuring devices are now widespread. Automated oscillometric BP monitors produce flawed blood pressure measurements in patients with AF due to inability to recognise Korotkoff sounds, erroneously relying on the oscillations transmitted from the brachial artery to the cuff [15-17].

We reviewed the current options for assessing BP in AF and considered whether novel brachial cuff and suprasystolic waveform algorithms to noninvasively derive central BP could result in improved monitoring and assessment of patients with AF.

The Mercury Sphygmomanometer

Traditionally, BP has been measured using a mercury...
sphygmomanometer reading to the nearest 2 mmHg at the onset of the first and fifth Korotkoff sounds audible over the antecubital fossa for systolic and diastolic blood pressure, respectively [15-17]. BP remains dynamic, varying from beat to beat. This method relies on taking multiple readings and having a relaxed patient. The operator needs to select an appropriate-sized cuff (90% of the upper arm circumference), as well as being able to deflate the cuff at a relatively slow but continuous rate (2-3 mmHg/s) and accurately discriminate between the Korotkoff sounds to provide a reproducible reading [15-17]. Despite this, the mercury sphygmomanometer is regarded as the most accurate device for BP measurement when used by a trained observer.

Limitations of the mercury sphygmomanometer include that the equipment is delicate and easily damaged from rough handling, potentially resulting in hazardous mercury spillage [15-17]. It is also operator dependent often resulting in inaccurate readings. These drawbacks have resulted in a significant decline in the availability of these devices [16,17].

**Automated Blood Pressure Monitors**

The use of automated BP machines has been increasing in most hospitals. Several studies have shown that they perform well compared to manual devices. They are simple to use and remove the operator dependency which adversely affects mercury sphygmomanometers [15-17].

As automated machines are unable to recognise Korotkoff sounds, relying instead on the oscillation transmitted from the brachial artery to the cuff they detect both systolic and mean BP by use of an algorithm to calculate diastolic BP [18]. However, this mechanism is flawed in two specific circumstances:

i) Irregular heart rhythms – in particular atrial fibrillation (AF) – where there is beat-to-beat variability of stroke volumes and hence, significant BP fluctuation [15-17].

ii) In severe peripheral vascular disease when atherosclerosis results in arterial calcification and hence poor oscillation transmission [15-17].

In view of these limitations, and the inability of the monitors to measure central blood pressure and arterial stiffness, novel devices have been developed.

**Central and Peripheral Blood Pressure**

BP determined at different sites can have considerably different values [7-11]. Generally, from the central aorta to the bifurcation of the peripheral arteries, such as the brachial and radial arteries, the lack of significant resistance of large conduit arteries renders mean and diastolic pressures at nearly the same values [7-11]. In contrast, peripheral systolic BP and pulse pressure are usually higher than their corresponding values in central arteries. This "pressure amplification" phenomenon of systolic BP and pulse pressure from the central arteries to the peripheral brachial arteries results from decreased vascular compliance of peripheral arteries as well as distal wave reflections, which distort the propagating arterial pressure wave [6]. The aorta-brachial pulse pressure amplification becomes less obvious with advancing age and the disproportional stiffening of the central elastic versus peripheral muscular arteries, which leads to early return of the prominent reflected waves from the lower body, causing augmentation of the aortic systolic BP and pulse pressure. However, large inter- and intra-individual disparities between the peripheral and central aortic BPs is important because the latter may be more relevant than the former in predicting cardiovascular risk. Moreover, recent studies suggest that the pulse pressure amplification may offer additional prognostic value beyond that of central and peripheral pulse pressure alone [9,10].

**Non-Invasive Central Blood Pressure Measurement and Pulse Pressure Amplification**

The American Heart Association state in their Recommendations for Blood Pressure Measurements that intra-arterial BP is the most accurate method of ascertaining true blood pressure [18]. However, invasive assessment of central BP is impractical for widespread use, and this has led to development of various non-invasive methods. The reference standard is generally accepted to be radial applanation tonometry [19], and several of these devices are available on the market for estimating central BP indices. However, this method has not been used clinically for several reasons including the need for specialised equipment and training and the time involved in capturing waveforms of appropriate quality.

**Brachial Cuff and Suprasystolic Waveform Algorithm Methods to Noninvasively Derive Central Blood Pressure**

A number of upper-arm cuff-based methods to estimate central BP have been developed. One of the earliest examples is the Pulsecor R6.5 (Pulsecor Ltd, Auckland, New Zealand) which estimates the central blood pressure from the brachial systolic and diastolic pressures during deflation of the cuff [21]. The device then inflates again and holds cuff pressure approximately 30 mmHg above the brachial systolic pressure (i.e. suprasystolic measurement) for approximately 10s. Intra-arterial pressure waves impinging on artery occlusion, caused by the suprasystolic cuff pressure fluctuation recorded during this period can then be directly related to the intra-arterial pressure oscillations. The intra-arterial pressures in the brachial artery at the cuff measurement site are then used to estimate the pressures in the aorta by applying a physics-based model of the left subclavian-to-brachial branch.

This system also allows measurement of augmentation index. The augmentation index is a ratio calculated from the blood pressure waveform. It is a measure of wave reflection and arterial stiffness. Augmentation index is commonly accepted as a measure of the enhancement (augmentation) of central aortic pressure by a reflected pulse wave. Augmentation index is a sensitive marker of adverse cardiovascular events in a variety of patient populations, and higher augmentation index is associated with target organ damage.

It has recently been shown that left atrial diameter is significantly increased and independently associated with large arterial stiffness in patients with obstructive sleep apnoea [13]. Since large left atrial dimensions predispose to a greater risk of development of AF, this may help to explain the increased risk of AF in these patients.
DISCUSSION

Accurate non-invasive measurement of BP in AF is essential. However, this is still not currently achievable. Beat-to-beat variability in stroke volume and the branching structure and mechanical properties of the arterial system cause BP in peripheral arteries to be amplified and therefore peripheral pressure does not necessarily accurately reflect the central pressure. A number of novel upper-arm cuff-based methods to estimate BP have been developed and show good agreement with arterial tonometry-derived central BP and invasive aortic BP. Some of these devices allow measurement of augmentation index, a reflection of arterial stiffness, which is a strong predictor of future AF in hypertensive patients. There is a need for further studies to confirm the need for novel brachial cuff and suprasystolic waveform algorithms in determining central and peripheral BP in AF.

CONCLUSIONS

It is hopeful but not proven that novel brachial cuff and suprasystolic waveform algorithms to noninvasively derive central blood pressure will allow more accurate non-invasive assessment of BP in patients with AF, and hopefully improve the management and prognosis of both these common conditions.

REFERENCES


Cite this article