Relationship of age and blood pressure to baroreflex sensitivity and arterial compliance in man

Hypertension and Cardiology Sections, Department of Internal Medicine, University of Michigan Medical Center, Ann Arbor, Michigan, U.S.A.

Summary
1. The relationship between baroreflex sensitivity (BRS) and arterial compliance index (ACI) has been investigated (a) in paired subjects matched in one instance for systolic blood pressure with differing ages, and (b) in another instance matched for age with differing systolic blood pressures.
2. There was a significant negative correlation between BRS and age and between ACI and age in the twelve systolic blood pressure-matched subjects.
3. A significant negative correlation of systolic blood pressure with both BRS and ACI was observed in the fourteen age-matched subjects.
4. Both BRS and ACI appear to decrease with increasing age and systolic blood pressure. This decrease in BRS is probably due at least in part to the observed reduction in arterial distensibility.

Key words: arterial distensibility, arterial stiffness, hypertension, systolic blood pressure.

Introduction
Smyth, Sleight & Pickering (1969) developed a method for quantifying the sensitivity of the baroreflex arc in man. Several subsequent reports have documented a decrease in BRS with ageing and in hypertension (Bristow, Honour, Pickering, Sleight & Smyth, 1969; Gribbin, Pickering, Sleight & Petro, 1971; Takeshita, Tanaka, Kuroiwa & Nakamura, 1975). Such a diminution in BRS could be due to a reduction in arterial distensibility, at the site of the high-pressure arterial baroreceptors of the carotid sinus and aortic arch. We have investigated this possibility by studying the relationship of arterial compliance to age, blood pressure and baroreflex sensitivity in man.

Methods
Baroreflex sensitivity was determined by the ramp method of Smyth et al. (1969). This technique requires continuous simultaneous monitoring of intra-arterial blood pressure and heart rate. Multiple graded doses of angiotensin (commencing with 0.25 µg) were injected intravenously as a bolus until a dose was reached which produced a rise in systolic blood pressure of 25-35 mmHg. Each peak systolic blood pressure, when plotted against the second succeeding cardiac cycle length, produced a linear distribution. The slope of the line relating systolic pressure and cardiac cycle length is a quantitative expression of BRS (ms/mmHg rise in systolic blood pressure).

Arterial compliance describes the viscoelastic properties of the walls of the large and medium arteries. It is measured as the change in volume in the arterial system that accompanies a unit change in pressure (ΔV/ΔP). In this study mean systemic arterial compliance index (ACI = ΔV/ΔP per body surface area) is determined by the method of Randall, Calfee, Esler & Bulloch (1975). The estimation of ΔV is based on the relationship between the instantaneous rate of change in arterial volume, dv/dt, during diastolic run-off, and the instantaneous arterial pressure (P). For the estimation of ΔV, an assumption is made of zero flow from the arterial
reservoir at pressures under 20 mmHg (Whittaker & Winton, 1933). This is an approximate figure based on experimental results, and is the value most often used (Hamilton & Remington, 1947; Warner, Swan, Connolly, Tompkins & Wood, 1953; Guyton, 1971). Change in volume is calculated by integrating to find the area under a designated portion of the pressure pulse contour (above 20 mmHg) in diastole and dividing by the vasomotor resistance to flow (Hamilton & Remington, 1948). The corresponding change in pressure is measured directly from the pressure pulse tracing. The value for compliance given represents a weighted mean of the compliance of individual arteries throughout the arterial system.

This method of evaluation of ACI relies upon the following assumptions: (1) the pressure-flow relationship is constant during diastolic run-off above 20 mmHg (Whittaker & Winton, 1933); (2) the portion of the brachial diastolic pressure pulse contour used, when compared with the aortic pulse contour, is negligibly distorted (O'Rourke, 1970); (3) the pressures used during diastolic run-off are the same throughout the central arterial system.

Use of this method differs from the Windkessel theory of Frank (1899) in that it does not assume the arterial system to be an elastic chamber with a linear pressure–volume curve between end-systole and end-diastole. Instead, the actual pressure difference is measured at 0.04 s intervals during the portion of diastole used and the change in volume for the corresponding change in pressure is determined.

The relationship of BRS and ACI to age was determined in six pairs of subjects matched for systolic blood pressure (<150 mmHg), with one member of each pair less than 35 years of age and one member older than 35 years. Similarly, the relationship of BRS and ACI to systolic blood pressure was studied in seven pairs of subjects matched for age (below 35 years of age), with the systolic blood pressure of one member of each pair below 140 mmHg and above 140 mmHg in the other member.

Blood pressure in the normotensive subjects was below 140/90 mmHg. Hypertensive subjects had either borderline (at least one diastolic pressure above and one below 90 mmHg on three separate

![Fig. 1. Effect of blood pressure and age on baroreflex sensitivity (BRS) and arterial compliance index (ACI) in (a) six blood pressure-matched and (b) seven age-matched subjects. Bars represent mean values ± sd. * P<0.05; ** P<0.01; ns = not significant.](image-url)
Determinants of baroreflex sensitivity

Essential hypertension. No subjects had received anti-hypertensive medication in the preceding month.

All studies were done in the fasting state, without sedation, in the supine position. Intra-arterial blood pressure, cardiac output and heart rate were measured as previously described by Julius, Amery, Whitlock & Conway (1967).

Results

Values for age, systolic blood pressure, BRS and ACI for the six pairs of subjects matched for systolic blood pressure and for the seven pairs of subjects matched for age are shown in Fig. 1. In the blood pressure-matched pairs, BRS and ACI were both significantly lower (P < 0.01) in the older subjects (Fig. 1). On the other hand, in age-matched pairs, both BRS and ACI were somewhat lower in the hypertensive subjects (Fig. 1), but this difference only reached significance for ACI (P < 0.05).

Significant correlations of both age and blood pressure with BRS and ACI were noted. In twelve blood pressure-matched subjects, age correlated with BRS (r = -0.90, P < 0.01) and ACI (r = -0.86, P < 0.01). In fourteen age-matched subjects, systolic blood pressure correlated significantly with both BRS (r = -0.56, P < 0.05) and ACI (r = -0.75, P < 0.01). Overall, a significant direct relationship of BRS and ACI existed (r = +0.47, P < 0.05).

Discussion

The results confirm our previous finding of a significant overall correlation of BRS with ACI (Randall, Esler, Julius & Calfee, 1975). However, the extent of the individual contributions of age and of blood pressure to this relationship needed clarification. Therefore the independent effects of age and blood pressure were studied by the technique of paired matching (in one case for age, in the other for blood pressure). A significantly lower BRS and ACI in the older subjects (matched for systolic blood pressure) was noted. An inverse relationship of age to BRS and ACI was observed. The decrease in BRS and ACI can be attributed to the ageing of the arterial system, with consequent loss of distensibility of the arterial wall. In the age-matched subjects, an elevated systolic blood pressure was associated with a somewhat lower BRS and ACI (statistically significant only for ACI). Overall a significant negative correlation of blood pressure with BRS and ACI was observed.

It is concluded that: (1) two known determinants of BRS, namely age and systolic blood pressure, showed a significant independent relationship to both BRS and ACI; (2) BRS was significantly correlated with ACI, probably through their independent correlations with age and systolic blood pressure; (3) age and systolic blood pressure influenced both BRS and ACI; however, systolic blood pressure had a greater influence on ACI, thus it appears that the reduction of BRS is largely secondary to a reduction in ACI produced by both. A poorly compliant arterial system (including sensor sites for the high-pressure baroreceptors), whatever the cause, may result in diminished stretch of the baroreceptor nerve endings and thereby a blunted baroreflex response.

Acknowledgment

The authors thank Mr Carl Smith for preparing the illustration.

References


regulation of arterial pressure during sleep in man: a quantitative method of assessing baroreflex sensitivity. 

