Risk Factors for Changes in Aorto-Iliac Arterial Compliance in Healthy Men

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Doppler ultrasound was used to measure pulse wave velocity down the aorta and iliac arteries. Arterial wall compliance was calculated from pulse wave velocity in 45 apparently healthy men. Their arterial compliance fell significantly with advancing age, raised blood pressure, increased sérum cholesterol and triglyceride levels, and reduced serum high density lipoprotein cholesterol levels. The correlation between compliance and age was independent of the other risk factors, and the correlation between compliance and lipid status was independent of age and blood pressure. There was no significant correlation between compliance and area under the glucose tolerance curve. (Arteriosclerosis 6:105–108, January/February 1986)

Objective studies that relate risk factors for atherosclerosis to preclinical arterial disease should be valuable in providing support for the major epidemiological studies.[1] Arteriography was used by Blankenhorn[2] to study early disease, but this is an invasive technique and introduces ethical problems particularly for larger studies. Noninvasive techniques using Doppler ultrasound have been developed by Gosling[3] to provide quantitative measurement of early disease. Using this approach researchers have shown that arterial compliance decreases with age,[3,4] in diabetes,[4–6] and with clinically evident atherosclerotic disease.[4,7] The wider range of potential determinants of compliance has not been assessed. Risk factors for atherosclerotic vascular disease require evaluation for their relative importance as determinants of arterial compliance, especially preclinically.

We have taken the opportunity to examine together age, blood pressure, blood lipids, and glucose tolerance in relation to compliance in apparently healthy men. The independence with which age determines arterial compliance has been assesssed by partial correlation analysis, thereby eliminating the effects of other risk factors that might themselves explain the effects of age. The extent to which metabolic risk factors (blood lipids and glucose tolerance) account for differences in compliance, independent of age and blood pressure, has also been evaluated by partial correlation analysis. The pulse wave velocity along the aorto-iliac arterial segment was measured by the time delay between two Doppler signals and was used to calculate arterial compliance.

Methods

Subjects

The study was approved by the ethics committee of Prince Henry's Hospital in accordance with the statement on human experimentation by the National Health and Medical Research Council of Australia. Informed consent was obtained.

A group of 45 male volunteers were studied. Their ages ranged from 22 to 78 years (mean, 46 years). No subject had any past history of ischemic heart disease, cerebrovascular disease, or peripheral arterial disease. None had known diabetes or treated hyperlipidemia. Only six subjects were cigarette smokers. In all subjects, the peripheral pulses and the ankle/arm pressure ratios were normal.

Each subject rested supine for 10 minutes to allow the blood pressure to stabilize. Two 4 MHz Sonicaid Doppler ultrasound units were used. The probes were placed, in turn, over the left subclavian artery in the supraclavicular fossa and over each common femoral artery at the inguinal ligament. The two signals obtained were passed through a Medishield Spectrum Analyzer and displayed on light sensitive paper. The time delay between the start of the proximal and the distal pulse waves was calculated from the mean of 10 pulses from each side. The pulse wave velocity (PWV) down the aorta and iliac segments was calculated from the ratio of time delay (t) and the measured distance between the probes (L). Gosling[3] has developed an expression for relative arterial compliance (C), as the percentage of lumen

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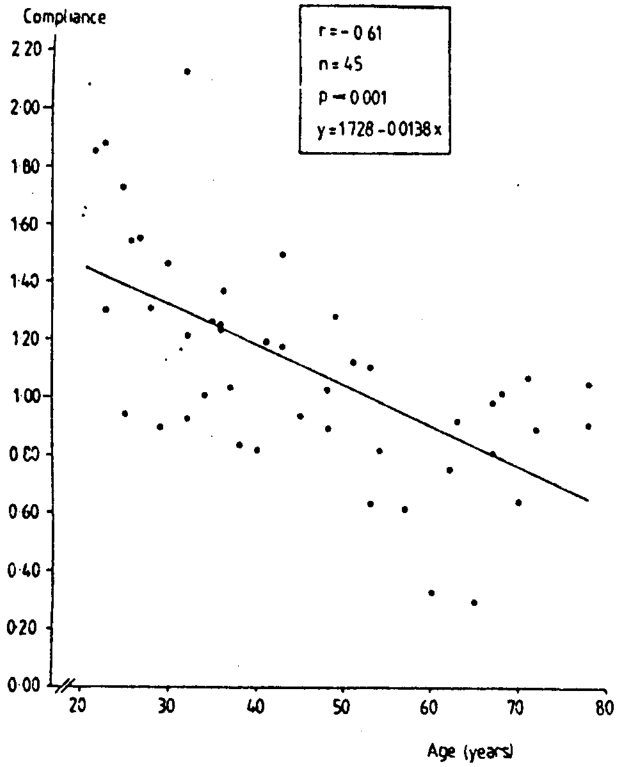


Figure 1. Correlation between aorto-iliac compliance and age.

diameter change caused by a 10 mm Hg pressure increment. C is inversely proportional with the square of PWV

$$PWV = \frac{L}{t}\ msec^{-1} \quad (1)$$

$$C = \frac{66.7}{(PWV)^2} \quad (2)$$

These equations are consistent with the well-recognized phenomenon that the less compliant or less distensible artery will transmit a pulse wave at an increased velocity. We expressed our findings in these terms for comparison with Gosling's data. Using the same instrumentation for comparable subjects, we obtained similar values for both PWC and C. In each subject, fasting serum total cholesterol, triglyceride and high density lipoprotein (HDL) cholesterol concentrations were estimated, and a 75 g oral glucose tolerance test was performed.

Individual subject values for compliance and putative risk factors for compliance have been plotted in Figures 1 and 2 showing the relevant relationships.

Correlation coefficients were then determined relating aorto-iliac compliance to the various measured risk factors. A partial correlation analysis was performed between the arterial compliance and age while eliminating the effect of the other measured risk factors. This was also performed between arterial compliance and biochemical risk factors after eliminating the effects of age and blood pressure.[8]

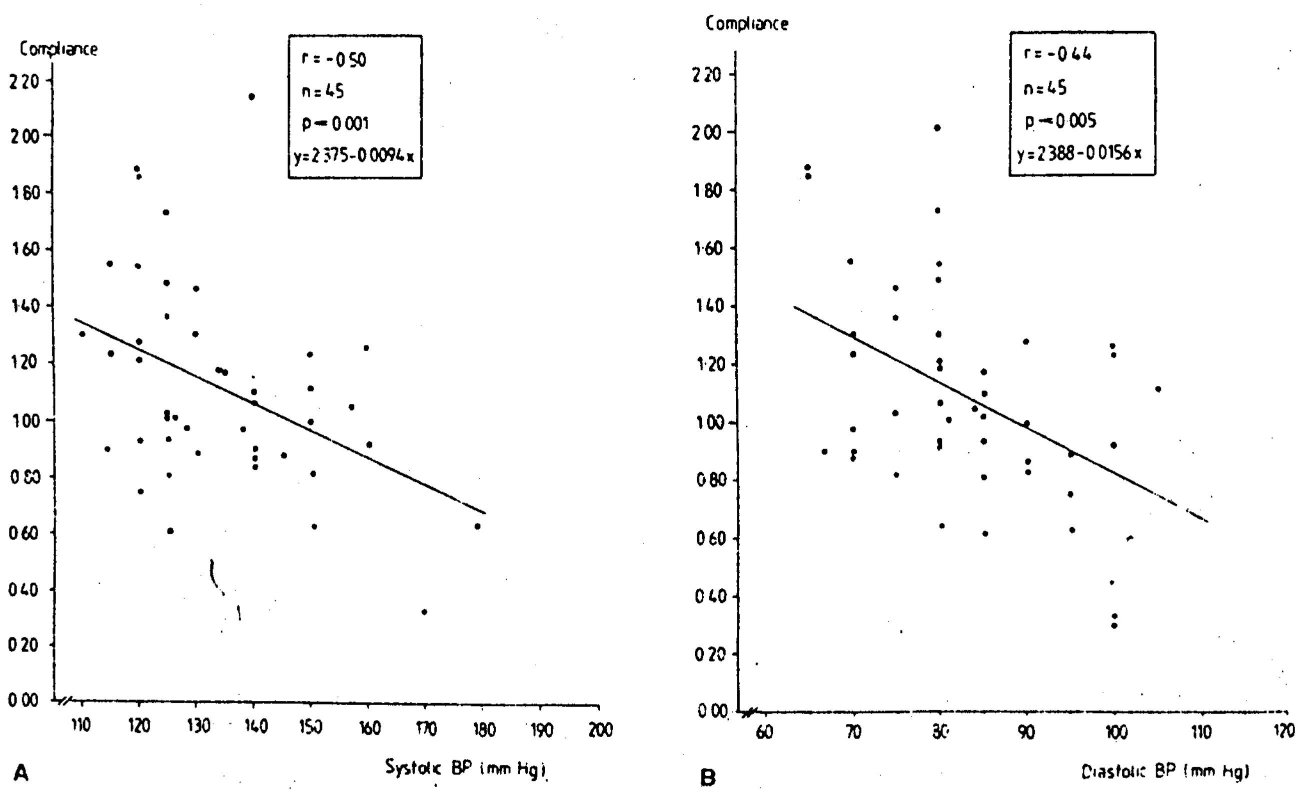
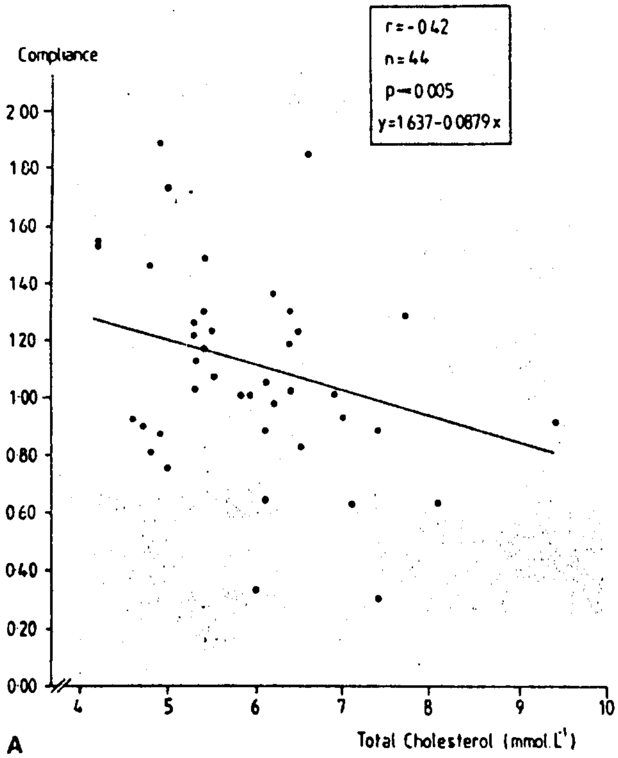


Figure 2. Correlation between aorto-iliac compliance and blood pressure.

We have used this statistical approach as an alternative to multiple regression analysis. All variables were available for partial correlation analysis in 39 subjects.



A

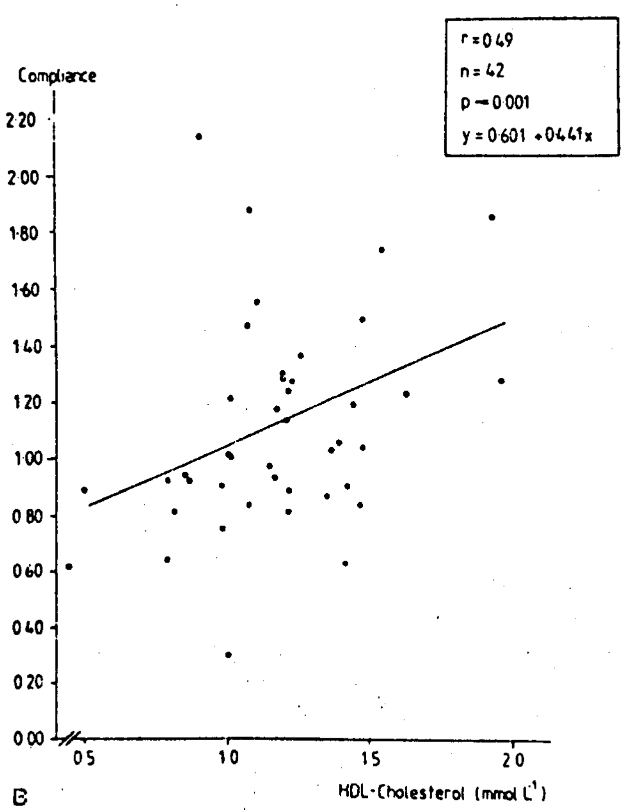
Results

There was a significant decrease in arterial compliance related to advancing age, higher blood pressure, higher total cholesterol and triglyceride levels, and lower HDL cholesterol levels (Figures 1–3). There was no significant relation between compliance and the area under a glucose tolerance curve ($r = -0.29$, n = 42, $p > 0.05$).

The partial correlation analyses showed significant correlation between arterial compliance and age independent of each of the other risk factors (Table 1). They also showed significant correlation between compliance and total cholesterol and HDL cholesterol (but not triglyceride), independent of age and blood pressure (Table 2).

Discussion

Arterial compliance measured by Doppler ultrasound is noninvasive, reproducible, and simple to perform. Animal studies[9] have shown that atherosclerosis causes reduced compliance in large elastic arteries. Farrar et al.[10] also showed that producing regression of atherosclerosis in monkeys causes an increase in arterial compliance. Reduced arterial compliance in nonoccluded arteries has been demonstrated in patients with peripheral arterial disease[4] and in patients with coronary artery disease.[7] However, it cannot be stated whether reduced compliance in humans results from atherosclerosis, medial sclerosis,[11] or even from changes such as glycosylation of proteins in the arterial wall.[12]



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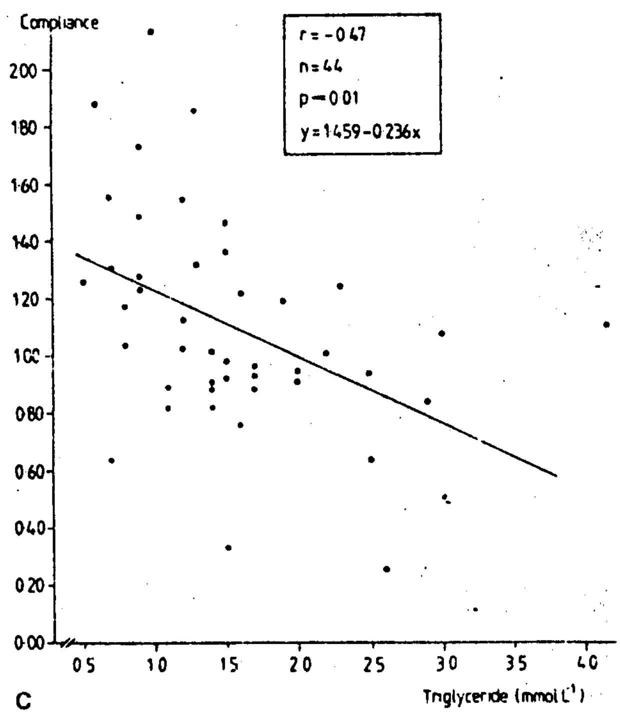

C

Figure 3. Correlation between aorto-iliac compliance and lipids.

Table 1. Relationships between Arterial Compliance and Age after Eliminating the Effect of Other Risk Factors by Partial Correlation Analysis

Variable eliminated	Correlation between compliance and age ($r_{12.3}$)†‡	*p*
Total cholesterol	−0.58	<0.001
HDL cholesterol	−0.56	<0.001
Triglyceride	−0.53	<0.001
G-TT area	−0.56	<0.001
Systolic BP	−0.53	<0.001
Diastolic BP	−0.64	<0.001

There were 39 subjects, but not all 39 had all observations; thus partial correlation analysis calculations were based on correlations among the same number of variables.

†r_{12}, the correlation between compliance and age is $r = -0.61$, $n = 45$, $p < 0.001$ (see Figure 1).

‡$r_{12.3}$ is the partial correlation coefficient where 1 is compliance, 2 is age, and 3 is the variable eliminated.

Table 2. Relationship between Arterial Compliance and Various Risk Factors after Eliminating the Effect of Age and Blood Pressure by Partial Correlation Analysis

Variable with which compliance correlated	Correlation eliminating age and blood pressure ($r_{12.34}$)	*p*
Total cholesterol	−0.44	<0.01
HDL cholesterol	0.57	<0.001
Triglyceride	−0.18	NS
G-TT area	−0.02	NS

There were 39 subjects. $r_{12.34}$ is the partial correlation coefficient where 1 is compliance, 2 is the risk factor, 3 is age, and 4 is blood pressure.

In this study, a significant decrease in arterial compliance was observed with advancing age, higher blood pressure, and changing lipid status. Gosling[3] used pulse wave velocity to show reduced compliance with advancing age. Others have showed this relationship using techniques that measure arterial wall movement[9] or aortic distension.[13] The present study suggests that this relationship is a reflection of aging rather than of concomitant changes of blood pressure or lipid status.

An important finding of this study is that higher cholesterol and lower HDL cholesterol concentrations are associated with reduced arterial compliance in healthy men. This is independent of age and blood pressure and is consistent with epidemiological evidence linking these lipid variables to the complications of macrovascular disease.[14]

We found no correlation between arterial compliance and the area under the glucose tolerance curve in these nondiabetic subjects. Perhaps a more sensitive index of abnormal glucose metabolism might show a correlation with compliance, because a significant decrease in compliance has been reported[4-6] in diabetics.

We consider that measurement of peripheral arterial compliance by Doppler ultrasound is a useful technique to assess the presence and severity of changes in the arterial wall. Evidence from surgical arterial grafts indicates that graft compliance is a predictor of subsequent patency.[15] This would suggest that compliance and its determinants may be worth evaluating in their own right.

Acknowledgments

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