Von Willebrand Factor, Soluble P-Selectin, and Target Organ Damage in Hypertension

A Substudy of the Anglo-Scandinavian Cardiac Outcomes Trial (ASCOT)

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Abstract—To investigate the relationship between soluble markers of platelet, endothelial and rheological function, and target organ damage and their response to intensified management in a population of middle-age hypertensive patients at high risk of cardiovascular complications, we studied 382 consecutive patients (308 men; mean age, 63 years, SD 8) along with 60 normotensive controls free of cardiovascular disease. Patients were divided into those with target organ damage (TOD; n = 107) and those free of end-organ damage. Plasma levels of soluble P-selectin (sP-sel), a marker of platelet activation, and von Willebrand factor (vWF), an index of endothelial damage/dysfunction (both enzyme-linked immunosorbent assay), and the rheological indices fibrinogen, plasma viscosity, hematocrit, platelet, and white cell count were measured. In 53 patients, variables were further measured after 6 months of intensified cardiovascular risk management. Patients with TOD had significantly higher vWF, 137 (SD 33) versus 125 (SD 33) IU/dL (P = 0.002,) and a greater proportion of smokers, 31% versus 16% (P = 0.002). There were no statistically significant differences in plasma viscosity, fibrinogen, hematocrit, white blood cell count, platelet count, or sP-sel between the 2 subgroups. In multivariate analysis, vWF was a significant independent predictor for TOD. After 6 months of intensified management in 53 patients who entered the trial, there were significant reductions in systolic blood pressure, total cholesterol, hematocrit, plasma viscosity, sP-sel, and vWF (all P < 0.01) but no significant change in fibrinogen. In conclusion, there is a relationship between TOD and endothelial damage/dysfunction in hypertension. Intensified management results in improvements in hemorheology, endothelial and platelet function. (Hypertension. 2002;40:61-66.)

Key Words: target organ damage ■ endothelium ■ von Willebrand factor ■ fibrinogen ■ soluble P-selectin ■ rheology

Hypertensive patients with target organ damage (TOD) are at high risk of adverse cardiovascular events, particularly myocardial infarction and stroke. For example, in the Framingham study, increasing left ventricular mass was associated with an increased incidence of cardiovascular events, including cardiovascular death. Similarly, patients with a history of stroke or transient ischemic attack (common complications of hypertension) are at increased risk of not only another stroke but also coronary artery disease. Increased cardiovascular mortality and coronary heart disease have also been noted in hypertensive subjects with severe symptomatic and asymptomatic peripheral arterial disease. Many of these complications (stroke, coronary disease) are thrombosis related.

A number of hemorheological and thrombotic markers have been shown to be elevated in hypertensive subjects that are significantly related to, and predictive of, thrombotic cardiovascular events. For example, von Willebrand factor is widely regarded as a marker of endothelial cell damage/dysfunction, and elevated plasma levels are related to adverse cardiovascular outcomes. Platelets are important in the process of both atherosclerosis and thrombosis, and soluble P-selectin is a plasma marker of platelet activation that has been related to adverse cardiovascular prognosis.

Blood rheology is also important, as abnormalities of flow constitute 1 component of Virchow’s triad of thrombogenesis. Plasma viscosity, an index of blood rheology, is positively correlated with blood pressure (BP) and has been related to future cardiovascular events in a number of prospective studies. Likewise, plasma fibrinogen, which is a clotting factor and an important determinant of plasma viscosity, has been found to be related to BP, although this has not been consistent across all studies. An extensive body of evidence also indicates a relationship between fibrinogen and incident cardiovascular disease. Another index of blood rheology, the hematocrit, has been related to adverse cardiac events.
In view of the relationship between TOD and thrombosis-related adverse cardiovascular outcomes in hypertension, we hypothesized that there would be a relationship between indices of endothelial damage/dysfunction (von Willebrand factor), platelet activation (soluble P-selectin), hemorheology (fibrinogen, plasma viscosity, hematocrit and white cell count), and TOD in hypertensive subjects. To test this hypothesis, we measured these indices in hypertensives with numerous risk factors, and provide data from healthy controls to provide a perspective.

Methods

Patients

We recruited from hypertensive patients age 40 to 79 years, both treated and untreated, who were identified from general practitioner records or a hospital hypertension clinic and were invited for screening for the Anglo-Scandinavian Cardiac Outcomes Trial (ASCOT) trial. The hypertensive patients were assessed for their future cardiovascular risk, requiring ≥3 risk factors to be included into ASCOT. Risk factors included (1) left ventricular hypertrophy (LVH) according to Cornell voltage duration product (>2440) or Sokolow Lyon criteria (>38 mV), (2) other ECG abnormalities (left ventricle strain pattern, abnormal Q waves, left bundle branch block, ST-T changes compatible with ischemic heart disease), (3) history of diabetes mellitus according to World Health Organization criteria, (4) past medical history of cerebrovascular event, including transient ischemic attack, (5) male sex, (6) age ≥55 years, (7) microalbuminuria/proteinuria, (8) smoking, (9) plasma total cholesterol/HDL cholesterol, (10) family history of first degree relative before the age of 55 (men) or 60 (women), and (11) peripheral vascular disease according to Edinburgh Claudication questionnaire. Volunteers were interviewed by a specialist nurse, who took a detailed medical history, and an ECG was performed. BP was measured after the patient was seated for 10 minutes in a quiet room, using the OMROM 705CP, as per the ASCOT protocol; a minimum of 3 readings were performed, and the average of the last 2 readings were used. Patients were excluded from the substudy if they had a history of coronary artery disease, treated anagia, or major concomitant noncardiovascular disease or were taking warfarin.

All patients were given lifestyle advice regarding diet, smoking, alcohol, and exercise in both verbal and written forms. Smoking cessation was strongly encouraged. Patients with ≥3 cardiac risk factors and untreated hypertension with systolic BP >160 mm Hg and/or diastolic BP >100 mm Hg were subjected to treatment phase of the trial; they were allocated on a randomized single-blind basis to antihypertensive therapy (with amlodipine±perindopril or atenolol± bendroflumethiazide), and previous antihypertensive medication was withdrawn. If total cholesterol was <6.5 mmol/L (250 mg/mL), patients were further randomized into the lipid arm in a double-blind manner to receive atorvastatin 10 mg once daily or placebo. Patients with total cholesterol >6.5 mmol/L (250 mg/mL) were referred back to their general practitioner for management of their hypercholesterolemia. The antihypertensive treatment was adjusted accordingly by us to aim for target blood pressure for nondiabetic patients of <140 mm Hg systolic and <90 mm Hg diastolic. In patients with diabetes mellitus, the goal was <130 mm Hg systolic and <80 mm Hg diastolic.

The ‘healthy control’ group consisted of 60 healthy normotensive controls (43 men, 17 women; mean age, 63 years, SD 8) recruited from well patients in the community, healthy hospital staff, relatives of the patients, and those attending the hospital for routine cataract surgery. The subjects were without clinical evidence of vascular, metabolic, neoplastic, or inflammatory disease by careful history, examination, and routine laboratory tests. These subjects were normotensive and in sinus rhythm.

On the day of randomization and after a median of 6 months of treatment, blood was drawn after an 8-hour fasting period with minimal trauma from the antecubital vein. Samples were centrifuged at 3000 rpm for 20 minutes within 30 minutes of collection, and the citrated plasma stored at −80°C until analysis.

Laboratory

Von Willebrand factor was measured by an established enzyme-linked immunosorbent assay using commercial antisera from Dako (Ely) and reference von Willebrand factor from the National Institute for Biological Standards and Control (Potters Bar). Soluble P-selectin was measured in citrated plasma by enzyme-linked immunosorbent assay using commercial reagents (R&D Systems). The intraassay coefficient of both assays was <5%; interassay variation was <10%. Fibrinogen was measured by a modified Clauss technique using a coagulometer and thrombin from Pacific Hemostasis. Hematocrit and white blood cells were measured using an automated blood count machine (Advia 120, Bayer Diagnostics). Plasma viscosity was measured using a Coulter viscometer II (Coulter Electronics Ltd).

Power Calculations and Statistical Analyses

We based our power calculation on levels of von Willebrand factor, a molecule known to be increased in cardiovascular disease and also to be predictive of poor prognosis. We hypothesized that patients with TOD would have levels of von Willebrand factor ~0.25 of a SD higher than patients free of TOD. To achieve this with a 1-β power of 0.80 and P<0.05, 100 subjects per group are demanded. However, to improve our power, we aimed to recruit approximately twice as many subjects free of TOD. To test the hypothesis that a package of cardiovascular risk factor treatments will reduce levels of von Willebrand factor by one third of a SD, good paired data from 50 subjects are required.

BP, cholesterol glucose, von Willebrand factor, and hematocrit were normally distributed and are presented as mean (SD). Body mass index, plasma viscosity, white blood cells, soluble P-selectin, and fibrinogen were nonnormally distributed and are thus presented as median with interquartile range. Data between the 2 groups were compared using unpaired t tests or the Mann-Whitney U test as appropriate for continuous variables and the χ² test for categorical variables. Correlations between the measured indices and BP were performed using Spearman’s rank correlation method. A stepwise multiple regression analysis was undertaken with the research indices (von Willebrand factor, soluble P-selectin, etc) as dependent variables, and clinical factors (eg, age, sex, presence of TOD, diabetes, smoking status, etc) as predictors. A value of P<0.05 was considered statistically significant. All analyses were performed using SPSS version 10 software (SPSS Inc).

Results

Cross-Sectional Data

Clinical, demographic, and laboratory data are presented in Table 1. Of the 382 patients, 341 (89%) were taking antihypertensive medication at enrollment. Of these, 138 (41%) were taking an ACE inhibitor, 23 (7%) an α-adrenoceptor blocker, 111 (32%) a β-blocker, 12 (4%) an angiotensin II receptor blocker, 124 (6%) a calcium channel blocker, and 118 (35%) a diuretic. As expected, these patients had various abnormalities in risk factors and laboratory indices compared with those of the controls. In particular, reanalysis of the data comparing research indices in diabetics versus nondiabetics in the hypertensive cohort did not show any significant differences (data not shown).

Target Organ Damage Versus No Target Organ Damage

The 108 patients with TOD were compared with 274 patients without TOD (Table 2). The only significant differences were
the proportion of smokers and levels of von Willebrand factor. As smoking is a known influence on various laboratory indices, including von Willebrand factor, soluble P selectin, and fibrinogen, we performed a subanalysis on 300 nonsmokers, which provides sufficient power to detect a difference of 0.28 of a SD. This analysis (Table 3) showed that von Willebrand factor was 0.41 of a SD higher than in those with TOD (P = 0.002). The smaller number of 77 smokers (33 with TOD) does not provide sufficient power for such an analysis. In 5 patients, smoking status was not defined.

**Correlations and Stepwise Multiple Regression Analysis**

There were significant correlations between hematocrit (HCT) and diastolic BP (R = 0.139, P = 0.01) and between von Willebrand factor and pulse pressure (ie, the difference between systolic and diastolic blood pressures) (R = 0.133, P = 0.01).

Stepwise multiple regression analysis demonstrated that the presence of TOD was a significant predictor for von Willebrand factor (P < 0.05) but not any other marker. Age was a predictor for von Willebrand factor, HCT, and fibrinogen. Male sex was a predictor for hematocrit, whereas current smoking was a predictor for soluble P-selectin, white blood cells, HCT, and fibrinogen. Finally, cholesterol/HDL cholesterol ratio was a predictor for von Willebrand factor, soluble P-selectin, white blood cells, and HCT (all, P ≤ 0.05).

**Effect of Treatment**

The results of BP and, when indicated, cholesterol treatment in 53 patients with TOD is presented in Table 4. After 6 months of treatment the mean systolic BP, total cholesterol, HCT, plasma viscosity, soluble P selectin, and von Willebrand factor all fell. However, despite this intensified management, systolic BP, glucose, fibrinogen, von Willebrand factor, and soluble P-selectin all remained significantly higher after 6 months than levels in the healthy control group (Table 4).

**Discussion**

As well as confirming the presence of endothelial, platelet, and hemorheological abnormalities in hypertension,\(^5\text{-}^5\text{,}^{19}\) the present study shows a relationship between TOD and the endothelial marker von Willebrand factor, but not soluble P-selectin and conventional hemorheological markers, in hypertensive patients. The exact mechanisms by which this occurs or, indeed, whether TOD promotes endothelial damage or vice versa is unclear. It is of note that there were no significant differences in blood pressure between the 2 groups, but as the majority of patients were treated, it may be the case that those with TOD had been treated more aggressively to achieve similar blood pressures than those without. This is probably unlikely as further analysis of our data found no significant difference in the number of drugs patients were taking between the 2 groups. Furthermore, previous work in our department has demonstrated no difference in plasma prothrombotic markers between uncontrolled hypertensives receiving medication and untreated patients.\(^19\)

When dividing our patients into those with and without TOD, we chose simply to divide a group of patients who are already at

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**TABLE 1. Von Willebrand Factor, Soluble P-Selectin, and Hemorheology in Hypertensive Subjects and Healthy Controls**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Controls (n = 60)</th>
<th>Hypertensives (n = 382)</th>
<th>P vs Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>62 (11)</td>
<td>63 (8)</td>
<td>0.735</td>
</tr>
<tr>
<td>White:black:Asian</td>
<td>53:4:3</td>
<td>313:44:25</td>
<td>0.451</td>
</tr>
<tr>
<td>Gender, M:F</td>
<td>43:17</td>
<td>308:74</td>
<td>0.110</td>
</tr>
<tr>
<td>Systolic BP, mm Hg</td>
<td>135 (11)</td>
<td>165 (17)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Diastolic BP, mm Hg</td>
<td>82 (8)</td>
<td>90 (10)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>25.6 (24.4–29.3)</td>
<td>28.4 (26.3–32.0)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Diabetes, n (%)</td>
<td>1 (1.7)</td>
<td>92 (24)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Dipstick proteinuria, ≥ +1</td>
<td>...</td>
<td>316 (83)</td>
<td>...</td>
</tr>
<tr>
<td>Smokers, n (%)</td>
<td>8 (13)</td>
<td>77 (20)</td>
<td>0.212</td>
</tr>
<tr>
<td>Cholesterol, mmol/L</td>
<td>5.6 (0.9)</td>
<td>6.1 (1.1)</td>
<td>0.008</td>
</tr>
<tr>
<td>HDL cholesterol, mmol/L</td>
<td>1.3 (0.3)</td>
<td>1.3 (0.4)</td>
<td>0.476</td>
</tr>
<tr>
<td>Fasting glucose, mmol/L</td>
<td>5.5 (0.9)</td>
<td>6.6 (2.2)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Number of drugs</td>
<td>0</td>
<td>1.4 (0.8)</td>
<td>...</td>
</tr>
<tr>
<td>Soluble P-selectin, ng/mL</td>
<td>37 (31–51)</td>
<td>62 (49–78)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Von Willebrand factor, IU/dL</td>
<td>111 (27)</td>
<td>129 (34)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Plasma viscosity, mpa</td>
<td>1.69 (1.64–1.79)</td>
<td>1.80 (1.74–1.89)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Fibrinogen, g/L</td>
<td>2.45 (2.20–2.80)</td>
<td>3.06 (2.63–3.52)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>HCT, %</td>
<td>43.6 (3.7)</td>
<td>44.2 (3.9)</td>
<td>0.327</td>
</tr>
<tr>
<td>White blood count, ×10⁹/L</td>
<td>6.9 (5.4–8.4)</td>
<td>6.3 (5.3–7.5)</td>
<td>0.309</td>
</tr>
<tr>
<td>Platelets</td>
<td>252 (51)</td>
<td>244 (61)</td>
<td>0.577</td>
</tr>
</tbody>
</table>

Values are n (%), mean (SD), or median (interquartile range), and compared by unpaired t test or Mann-Whitney test, as appropriate.
TABLE 2. Von Willebrand Factor, Soluble P-Selectin, and Haemorheology in Relation to Target Organ Damage in Hypertensive Subjects and Healthy Controls

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Hypertensives</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TOD (n=108)</td>
<td>No TOD (n=274)</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td>64 (8)</td>
<td>63 (8)</td>
<td>0.388</td>
<td></td>
</tr>
<tr>
<td>Gender, M:F</td>
<td>83:24</td>
<td>224:50</td>
<td>0.860 (χ²)</td>
<td></td>
</tr>
<tr>
<td>Systolic BP</td>
<td>166 (18)</td>
<td>164 (17)</td>
<td>0.560</td>
<td></td>
</tr>
<tr>
<td>Diastolic BP</td>
<td>88 (11)</td>
<td>90 (10)</td>
<td>0.060</td>
<td></td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>27.7 (25.4–31.5)</td>
<td>28.7 (26.5–32.2)</td>
<td>0.071</td>
<td></td>
</tr>
<tr>
<td>Diabetes, n (%)</td>
<td>24 (22)</td>
<td>67 (24)</td>
<td>0.645 (χ²)</td>
<td></td>
</tr>
<tr>
<td>Smokers, n (%)</td>
<td>33 (31)</td>
<td>44 (16)</td>
<td>0.002 (χ²)</td>
<td></td>
</tr>
<tr>
<td>Cholesterol, mmol/L</td>
<td>6.1 (1.1)</td>
<td>6.1 (1.1)</td>
<td>0.691</td>
<td></td>
</tr>
<tr>
<td>HDL cholesterol, mol/L</td>
<td>1.3 (0.4)</td>
<td>1.3 (0.4)</td>
<td>0.966</td>
<td></td>
</tr>
<tr>
<td>Glucose, mmol/L</td>
<td>6.8 (2.9)</td>
<td>6.5 (1.9)</td>
<td>0.392</td>
<td></td>
</tr>
<tr>
<td>Number of drugs, n</td>
<td>1 (1–2)</td>
<td>1 (1–2)</td>
<td>0.217</td>
<td></td>
</tr>
<tr>
<td>Soluble P-selectin, ng/mL</td>
<td>66 (49–87)</td>
<td>60 (49–75)</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>Von Willebrand factor, U/dL</td>
<td>137 (33)</td>
<td>125 (33)</td>
<td>&lt;0.002</td>
<td></td>
</tr>
<tr>
<td>Plasma viscosity, mpa</td>
<td>1.80 (1.72–1.89)</td>
<td>1.80 (1.74–1.88)</td>
<td>0.897</td>
<td></td>
</tr>
<tr>
<td>Fibrinogen, g/L</td>
<td>3.12 (2.67–3.77)</td>
<td>3.02 (2.62–3.47)</td>
<td>0.134</td>
<td></td>
</tr>
<tr>
<td>Hematocrit, %</td>
<td>44.1 (4.1)</td>
<td>44.2 (3.7)</td>
<td>0.847</td>
<td></td>
</tr>
<tr>
<td>White blood count, ×10⁹/L</td>
<td>6.4 (5.5–7.9)</td>
<td>6.6 (5.3–7.4)</td>
<td>0.292</td>
<td></td>
</tr>
<tr>
<td>Platelets</td>
<td>245 (69)</td>
<td>243 (57)</td>
<td>0.801</td>
<td></td>
</tr>
</tbody>
</table>

Values are n (%), mean (SD), or median (interquartile range), and compared by unpaired t test or Mann-Whitney test, as appropriate.

TABLE 3. Von Willebrand Factor, Soluble P-Selectin, and Hemorheology in Relation to Target Organ Damage in Hypertensive Subjects Who Do Not Smoke

<table>
<thead>
<tr>
<th>Parameters</th>
<th>TOD (n=75)</th>
<th>No TOD (n=225)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soluble P-selectin, ng/mL</td>
<td>61 (48–57)</td>
<td>61 (49–74)</td>
<td>0.741</td>
</tr>
<tr>
<td>Von Willebrand factor, U/dL</td>
<td>140 (36)</td>
<td>126 (32)</td>
<td>0.002</td>
</tr>
<tr>
<td>Plasma viscosity, mpa</td>
<td>1.81 (1.72–1.89)</td>
<td>1.80 (1.74–1.87)</td>
<td>0.978</td>
</tr>
<tr>
<td>Fibrinogen, g/L</td>
<td>3.03 (2.64–3.60)</td>
<td>2.98 (2.58–3.47)</td>
<td>0.293</td>
</tr>
<tr>
<td>Haematocrit, %</td>
<td>43.8 (3.9)</td>
<td>43.8 (3.6)</td>
<td>0.984</td>
</tr>
<tr>
<td>White cell count, ×10⁹/L</td>
<td>1.81 (0.26)</td>
<td>1.80 (0.25)</td>
<td>0.886</td>
</tr>
<tr>
<td>Platelets, ×10⁹/L</td>
<td>243 (69)</td>
<td>241 (54)</td>
<td>0.802</td>
</tr>
</tbody>
</table>

Values are n (%), mean (SD), or median (interquartile range), and compared by unpaired t test or Mann-Whitney test, as appropriate.

relatively high risk into those with and without TOD using our definition. It is also possible that those with TOD may also have had a longer history of hypertension. As our definition of TOD included those with overt peripheral, arterial, or cerebrovascular disease, it may be the case that they have more extensive atheroma, leading to endothelial damage/dysfunction; however, the vast majority of patients with TOD had LVH, which is more likely to be caused by the pressure effect of hypertension rather than by atherosclerotic vascular disease. However, we do accept the limitations of diagnosing LVH using the ECG, which is a relatively insensitive test, and several other techniques such as ultrasound examination of major arteries have been used. The net result of this would be to reduce any differences between the 2 groups in our study.

The significance of elevated von Willebrand factor in these patients is likely to be considerable. Von Willebrand factor is elevated in a variety of conditions characterized by endothelial damage or activation, such as acute coronary syndromes and hyperinsulinaemia. Von Willebrand factor plays a vital role in mediating platelet adhesion to damaged arterial walls, particularly at the high shear rates found in stenosed arteries, forming a bridge between exposed subendothelial structures and the glycoprotein IIb/IIIa receptor on platelets. Elevated levels of von Willebrand factor are also related to the incidence of ischemic heart disease. For example, the Caerphilly Heart Study found a significant association between von Willebrand factor levels and incident ischemic heart disease, whereas the Hoorn Study found a 3-fold increased incidence of cardiovascular mortality in those in the highest tertile of von Willebrand factor after adjustment for confounders. Furthermore, raised von Willebrand factor is an indicator of poor prognosis in patients who have suffered a myocardial infarction, being predictive of reinfarction. As well as being a risk factor for coronary artery disease, von Willebrand factor is also a risk factor for stroke, which is a particular concern in hypertensive patients. For example, in the Atherosclerosis Risk in Communities Study, the risk of stroke rose significantly for each standard deviation increase in von Willebrand factor.

In the present study, we found no differences in levels of white blood cells, platelet count, or soluble P-selectin be-
between those with and without TOD. This concurs with earlier
work in our department which found no difference in these
variables between patients with echocardiographic LVH. 19
Both soluble P-selectin and white blood cells have previously
been found to be elevated in hypertensives compared with
controls, 19 and it may be that there is a plateau effect with no
further increase in those with TOD above levels found in our
relatively high risk comparator group.

Our finding of no difference in fibrinogen or plasma viscosity
between the 2 groups contrasts with our earlier work, which
found higher fibrinogen and plasma viscosity in hypertensive
controls, 19 and it may be that there is a plateau effect with no
further increase in those with TOD above levels found in our
relatively high risk comparator group.

Our finding of no difference in fibrinogen or plasma viscosity
between the 2 groups contrasts with our earlier work, which
found higher fibrinogen and plasma viscosity in hypertensive
patients with LVH, although in that study, LVH was diagnosed
by echocardiography. 19 The difference may be owing to the
different populations studied, as the earlier study is likely to have
included patients at a lower overall cardiovascular risk reflected
in lower plasma fibrinogen levels in the group free of LVH. It is
also possible that plasma fibrinogen is raised in patients with
multiple cardiovascular risk factors, but not further elevated if
they develop TOD. Secondly, patients with LVH by echocardi-
ography may be a very different group from the patients with
TOD in the present study.

Our findings that management of hypertension produces a
significant reduction in several of our markers including von
Willebrand factor, soluble P-selectin, plasma viscosity, and
HCT, and a near significant reduction in white blood cells is
important. Despite effective control of blood pressure, many 27
but not all 28 reports have found antihypertensive medication
does not reduce cardiovascular risk back to the levels found in
the normotensive population. Failure to improve hemorheologi-
cal abnormalities may be one reason for this difference, and our
findings in the present study add to a number of previous (small)
studies conducted in this area. Many of these found no change in
hemorheological markers but used patients at low cardiovascular
risk followed up for short periods of time. For example, in
hypertensives with no abnormalities of coagulation or endothe-
lial function compared with controls, treatment with either
quinapril or nifedipine produced no change in fibrinogen or
von Willebrand factor. 29 Similarly, in low-risk, previously un-
treated patients, losartan or enalapril had no significant impact
on hemorheological parameters, von Willebrand factor, or sol-
uble P-selectin. 30 However, a number of studies mainly involv-
ing subjects at somewhat higher cardiovascular risk have found
reductions in plasma viscosity with a variety of agents, including
ACE inhibitors, 31 calcium antagonists, 32 and -adrenoreceptor
blockers. 33 One study also found a reduction in HCT. 31 Reduc-
tions in fibrinogen have also been demonstrated with doxazo-
sin, 34 urapidil, 34 and perindopril but not with losartan. 35 A small
number of studies have investigated the effect of blood pressure
reduction on von Willebrand factor. Blann and Waite 36 found a
significant reduction in 15 patients treated with a variety of
drugs, and another study has demonstrated reductions with
doxazosin. 37 One study has found a nonsignificant reduction in
soluble P-selectin with quinalapril and nifedipine. 38 The impor-
tance of our study is that we have demonstrated that in subjects
at particularly high cardiovascular risk by virtue of having TOD,
significant reductions in hemorheological, platelet, and endothe-
lial markers (with the exception of fibrinogen) may be achieved
by intensified BP control and risk factor management.

The present analysis primarily assesses the relation of our
research indices to TOD, but is limited by its cross-sectional
comparison. Furthermore, as this substudy is part of the main
ASCOT clinical trial, the investigations and treatment regimes
allowed are very much protocol-driven, and the substudy was
secondary to the main ASCOT trial. The patients in the present
analysis were consecutive patients over the initial period of the
trial recruitment at the Birmingham study site, and we accept
that men were overrepresented (as with many clinical trials). The
paired data on 53 patients are also presented as a whole, in
fulfillment of our power calculation, after completing a “package
of care” of general cardiovascular risk management, which
includes education, lifestyle advice, dietary advice, antihyper-
tensive treatment, and statin use. Further planned analyses from
this substudy would occur at the end of 5 years (on completion
of the main ASCOT study), at which we would hope to present
complete data from the Birmingham center on these research
indices in relation to the full duration of followup, study

**TABLE 4. Effect of Treatment in Patients With Target Organ Damage**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>At Baseline (n=53)</th>
<th>After 6 Months of Treatment (n=53)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>64 (7)</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Total cholesterol, mmol/L</td>
<td>6.1 (1.2)</td>
<td>5.4 (1.4)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>HDL cholesterol, mmol/L</td>
<td>1.3 (0.45)</td>
<td>1.4 (0.45)</td>
<td>0.778</td>
</tr>
<tr>
<td>Glucose, mmol/L</td>
<td>6.9 (3.0)</td>
<td>6.6 (1.9)</td>
<td>0.189</td>
</tr>
<tr>
<td>Systolic BP, mm Hg</td>
<td>167 (15)</td>
<td>156 (22)†</td>
<td>0.001</td>
</tr>
<tr>
<td>Diastolic BP, mm Hg</td>
<td>89 (11)</td>
<td>86 (16)</td>
<td>0.172</td>
</tr>
<tr>
<td>Hematocrit, %</td>
<td>44.4 (4.3)</td>
<td>42.5 (7.1)</td>
<td>0.007</td>
</tr>
<tr>
<td>White blood count, ×10⁹/L</td>
<td>6.6 (5.3–8.2)</td>
<td>6.3 (4.9–7.4)</td>
<td>0.19</td>
</tr>
<tr>
<td>Platelet count, ×10⁹/L</td>
<td>245 (67)</td>
<td>242 (62)</td>
<td>0.574</td>
</tr>
<tr>
<td>Plasma viscosity, mpa</td>
<td>1.81 (1.74–1.89)</td>
<td>1.76 (1.67–1.84)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Fibrogen, g/L</td>
<td>2.74 (3.25–3.87)</td>
<td>2.65 (3.20–3.66)†</td>
<td>0.45</td>
</tr>
<tr>
<td>Soluble P-selectin, ng/mL</td>
<td>67.0 (49.0–86.5)</td>
<td>53.0 (40.5–61.0)*</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Von Willebrand factor, U/dL</td>
<td>143 (35)</td>
<td>131 (32)*</td>
<td>0.003</td>
</tr>
</tbody>
</table>

*p=0.001 vs control; †p=<0.0001 vs healthy controls.
endpoints, grades of blood pressure reduction, effects of different drug regimes (including statins), etc.

Perspectives

Our study suggests that there is a relationship between TOD and endothelial activation in hypertension. Given the critical role of the endothelium in arterial thrombosis, this is likely to be of significance in the pathogenesis of hypertensive complications and raises the possibility that von Willebrand factor may be of use in identifying a "high-risk" group of hypertensives. Furthermore, intensified management results in significant improvements in hemorheological, platelet, and endothelial parameters.

Acknowledgments

We acknowledge the support of the City Hospital Research and Development program for the Hemostasis Thrombosis and Vascular Biology Unit. Other ASCOT Investigators are listed in reference 16.

References

Von Willebrand Factor, Soluble P-Selectin, and Target Organ Damage in Hypertension: A Substudy of the Anglo-Scandinavian Cardiac Outcomes Trial (ASCOT)
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