Atrial Fibrillation and the Prothrombotic State in the Elderly
The Rotterdam Study

Dwayne S.G. Conway, MRCP; Jan Heeringa, MD; Deirdre A.M. Van Der Kuip, MD, PhD;
Bernard S.P. Chin, MRCP; Albert Hofman, MD, PhD;
Jacqueline C.M. Witteman, PhD; Gregory Y.H. Lip, MD, FRCP

Background and Purpose—Atrial fibrillation (AF) is a major cause of stroke among the elderly. Evidence for a prothrombotic state in AF is controversial, and there is a lack of studies among the elderly. We studied the relationships between AF and 3 prothrombotic plasma markers—von Willebrand factor (vWf; a marker of endothelial damage/dysfunction), soluble P-selectin (sP-sel; a marker of platelet activation), and fibrinogen—in a matched case-control study nested within a large community-based study of an elderly population.

Methods—We identified 162 elderly participants (mean ± SD age, 78 ± 8 years; 51% male) in the Rotterdam Study with documented AF and matched each case by age and sex to 2 population controls. vWf and sP-sel were measured by enzyme-linked immunosorbent assay; fibrinogen was measured with the Clauss method. We used conditional logistic regression analysis to assess the relationships between the markers and AF, adjusting for potential confounders.

Results—There were no significant relationships between either fibrinogen (P=0.8) or sP-sel (P=0.6) and AF. However, a positive linear relationship between vWf level and presence of AF remained significant after adjustment for potential confounders among women (odds ratio [OR], 1.17; 95% CI, 1.02 to 1.34) per 10-IU/dL increase in vWf but not among men (OR, 1.06; 95% CI, 0.96 to 1.17).

Conclusions—We observed a positive relationship between AF and plasma vWf (or endothelial damage/dysfunction) in our elderly population, which was most apparent among women. Fibrinogen and sP-sel levels were unrelated to AF. The prothrombotic state of AF may be subject to sex differences, but longitudinal studies are needed to determine the relationship between these plasma markers and stroke risk. (Stroke. 2003;34:413-417.)

Key Words: atrial fibrillation • fibrinogen • selectins • von Willebrand factor
hundred four cases of AF were identified among 6808 participants for whom an ECG was available for analysis; ECGs were missing for 1175 subjects usually because of technical or logistical problems. Stored plasma samples were available for analysis for 162 of the AF cases. Each case was matched on the basis of sex and age within 5 years with 2 controls without AF from the cohort for whom plasma was available for analysis.

Baseline Examination
Information on current health status, medical history, and smoking behavior was obtained from a computerized questionnaire. Participants were classified as current or nonsmokers. Blood pressure was measured twice on the right upper arm with a random-zero mercury sphygmomanometer in patients in the sitting position. Systolic and diastolic blood pressures were calculated as the average of 2 consecutive measurements. Hypertension was defined from the World Health Organization criteria of the time as systolic blood pressure of ≥160 mm Hg, diastolic blood pressure of ≥90 mm Hg, or the use of blood pressure–lowering drugs prescribed for hypertension. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters. Serum total cholesterol was measured with an automated enzymatic method. Diabetes was defined as the use of antidiabetic medication or a preload or postload serum glucose level of ≥11.1 mmol/L.

Ten-second 12-lead ECGs were recorded at the research center with an ACTA Gnosis IV ECG recorder (ESAOte), stored digitally, and analyzed with the Modular ECG Analysis System (MEANS). This computer program has been shown to be highly reliable at ECG diagnosis. ECIs that the MEANS program was not able to interpret because of poor ECG quality or pacemaker activity on the ECG were evaluated separately. Visual coding of these ECGs to determine the presence of a rhythm disorder was possible in 52 poor-quality ECGs. Because pacemaker implantation is often necessary in AF, information on the underlying rhythm disorder was obtained from general practitioner files for 25 subjects with pacemaker activity on the ECG. Of these participants, 12 had AF as the underlying rhythm disorder. Left ventricular hypertrophy (LVH) was diagnosed by the MEANS program with an algorithm taking into account QRS voltages with an age-dependent correction and regularization. A history of myocardial infarction (MI) was defined as a self-reported MI with hospital admission or the presence of MI on the ECG. A positive report of MI was confirmed by a review of the medical records of general practitioners and specialists for the ECG. A positive report of MI with hospital admission or the presence of MI on the ECG was considered a positive index of blood pressure was significant, we entered all other blood pressure indexes into the final model because these markers represented potential confounding factors. These findings suggest that control for the blood pressure indexes in the final model was appropriate.

Statistical Analysis
Patient characteristics were compared between cases and matched controls by use of a χ² test for categorical variables and Student’s t test for continuous variables. Because fibrinogen and sP-sel were not normally distributed, we undertook analyses using the natural log transformation of these variables because this technique would result in a more normal distribution. The associations between AF and the 3 prothrombotic plasma markers were examined by calculating crude odds ratios (ORs) with their 95% confidence intervals (CIs) through conditional logistic regression. Stratified analyses were performed according to sex.

We undertook 2 separate approaches to examine the true relationships between AF and our 3 markers by removing the effects of possible confounding factors. First, indexes of blood pressure (systolic blood pressure, diastolic blood pressure, history of hypertension, LVH), history of MI, smoking status, serum cholesterol, diabetes, and BMI were considered potential confounding factors if a univariate value of P<0.25 was found for the association with any prothrombotic marker and for AF. These potential confounding factors were tested in the conditional logistic regression model for AF with the relevant prothrombotic markers and were kept in the final conditional logistic regression model if P<0.05 was met. If any index of blood pressure was significant, we entered all other blood pressure indexes into the final model because these markers represented different characteristics of hypertension, although diastolic and systolic blood pressures were never together in the models.

Second, we restricted our investigation to those free of cardiovascular disease (other than AF). Participants were considered free of cardiovascular disease if they had no previous history of MI, no hypertension, no LVH on the ECG, and no diabetes. Cases of AF without these additional features were considered “lone” AF cases. Because the absence or presence of cardiovascular disease was not a matching variable, we performed an unmatched logistic regression analysis in this group. An additional justification for this procedure was that the estimates of both the matched and unmatched analysis did not differ substantially. The estimates of the unmatched analysis were generally closer to unity.

Results

Whole Group

The clinical features of the AF cases and non-AF controls are outlined in Table 1. Compared with the control group, the AF group had a lower mean systolic blood pressure and a lower mean serum cholesterol level. There were no significant differences with regard to mean age and sex (as expected.

<table>
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<td>Characteristic</td>
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<tr>
<td>Percentages</td>
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<tr>
<td>Male</td>
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<tr>
<td>Current smoker</td>
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<tr>
<td>Diabetes</td>
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<td>Hypertension</td>
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<td>LVH</td>
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<td>Myocardial infarction</td>
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<td>Mean (SD)</td>
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<tr>
<td>Age (yr)</td>
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<tr>
<td>Systolic blood pressure, mm Hg</td>
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<tr>
<td>Diastolic blood pressure, mm Hg</td>
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<tr>
<td>Cholesterol, mmol/L</td>
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<tr>
<td>BMI, kg/m²</td>
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<tr>
<td>LN fibrinogen, g/L</td>
</tr>
<tr>
<td>vWF, IU/dL</td>
</tr>
<tr>
<td>LN sP-sel, ng/mL</td>
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P values obtained by chi-square test for categorical variables and Student’s t test for continuous variables. LN indicates natural log transformation.
After adjustment for potential confounding factors (Table 2), no significant associations were found between natural log–transformed fibrinogen or natural log–transformed sP-sel levels and AF among individual sexes. The proportion of men in the study >75 years of age was 54%, whereas 72% of women were >75 years of age. However, secondary analysis of the data by age stratification did not reveal any effect of age on the relationships between vWf, natural log–transformed sP-sel, or natural log–transformed fibrinogen and AF (data not shown).

### Discussion

Among an elderly community-based population, the presence of AF was significantly associated with increased vWf levels in women but not men. Indeed, after adjustment for potential confounding variables, the association between vWf and AF in women was more pronounced, becoming significant for the whole group despite the lack of a significant relationship in men alone. However, AF was not associated with increased fibrinogen or sP-sel levels among the whole group or among individual sexes, and the presence of lone AF was not associated with significantly altered vWf, sP-sel, or fibrinogen levels compared with controls free of cardiovascular disease.

Several previous studies, including those from our group, have described associations between AF and abnormal prothrombotic plasma markers, including fibrinogen, vWf, and
TABLE 4. ORs With Their 95% CI Calculated by Logistic Regression Describing the Relationship Between Prothrombotic Plasma Factors and Lone AF: The Rotterdam Study 1990–1993

<table>
<thead>
<tr>
<th></th>
<th>All</th>
<th>Men</th>
<th>Women</th>
</tr>
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<tbody>
<tr>
<td>vWF†</td>
<td>1.02 (0.93–1.12)</td>
<td>0.96 (0.86–1.07)</td>
<td>1.19 (1.00–1.43)</td>
</tr>
<tr>
<td></td>
<td>1.02 (0.93–1.13)**</td>
<td>1.00 (0.87–1.12)**</td>
<td>1.13 (0.94–1.35)**</td>
</tr>
<tr>
<td>LN fibrinogen</td>
<td>0.7 (0.3–1.9)†</td>
<td>1.3 (0.4–4.6)†</td>
<td>0.2 (0.02–1.2)†</td>
</tr>
<tr>
<td></td>
<td>0.7 (0.3–2.0)***</td>
<td>1.4 (0.4–4.8)***</td>
<td>0.2 (0.02–1.1)***</td>
</tr>
<tr>
<td>LN sP-sel</td>
<td>0.9 (0.4–2.2)†</td>
<td>0.8 (0.3–2.6)†</td>
<td>1.0 (0.2–4.2)†</td>
</tr>
<tr>
<td></td>
<td>0.8 (0.3–2.1)***</td>
<td>0.7 (0.2–2.2)***</td>
<td>0.9 (0.2–4.2)***</td>
</tr>
</tbody>
</table>

*For vWF, ORs are presented per 10 IU/L increase.
†Adjusted for age and sex, if applicable.
**Additionally adjusted for serum cholesterol level, systolic blood pressure, and BMI.
 ***Additionally adjusted for systolic blood pressure.
 ****Additionally adjusted for serum cholesterol level and diastolic blood pressure.

Lone atrial fibrillation cases are defined as cases with AF in the absence of other cardiac arrhythmias (including paroxysmal AF because the diagnosis of AF was made on the basis of a single ECG) or noncardiovascular disease. Thus, it is possible that estimated associations between AF and fibrinogen, sP-sel, and vWF in both sexes might have been confounded by the unknown prevalence of these disorders in both groups. In addition to possible confounding by unmeasured disease states among the control group, the lack of any significant association between lone AF and our markers might also be due to reduced statistical power. Furthermore, we constructed our conditional logistic regression model using statistical methods to identify possible confounding factors within our population rather than identifying confounding factors using the available literature. In view of the high prevalence of cardiovascular disease among the control group, including higher systolic blood pressure and serum cholesterol than in AF cases, the control group may well have been far from healthy, which may have lead to underestimation of the relationship between AF and our markers.

We also considered that the age and condition of the plasma samples, some of which had been in storage for up to 10 years and thus were at risk of deterioration, might have affected the relationships between AF and our prothrombotic factors. Indeed, because 10 samples produced unreliable fibrinogen values, the remaining samples used may also have deteriorated from their original state, which may explain why we found no significant relationship between this marker and any clinical feature on univariate analysis (data not shown), despite the known association between fibrinogen and cardiovascular disease. However, we did observe the expected strong association between sP-sel and smoking (P<0.001; data not shown) and between vWF and MI, diabetes mellitus, current smoking, LVH, and peripheral vascular disease (data not shown), suggesting that sample deterioration is unlikely to have significantly affected these 2 markers and is thus unlikely to have altered the relationship between either sP-sel or vWF and AF.
With the above caveats in mind, we must consider that raised vWF in AF, especially among women, might have implications for the pathogenesis of thromboembolic disease in this group. Raised plasma vWF levels have previously been found to independently predict presence of left atrial appendage thrombus in patients with AF and correlate with severity of ultrastructural changes to the left atrial appendage endocardium in mitral stenosis. Furthermore, increased left atrial appendage endocardial expression of vWF has been described in AF and appears to correlate with the presence of adherent platelet thrombus in the overloaded left atrial appendage. If the relationship between AF and raised vWF is indeed stronger among women, it may represent, in part, a potential mechanism of the apparent excess stroke risk conferred by AF among women compared with men and thus warrants further investigation. Indeed, even though we found no relationships between sP-sel or fibrinogen and AF, the cross-sectional nature of our analysis does not allow us to examine whether plasma fibrinogen, sP-sel, or vWF levels might relate to risk of subsequent stroke and thromboembolism in AF, a question that we intend to address in a future longitudinal study among the same cohort.

Acknowledgments
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References
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