Coagulation factor XIII gene variation, oral contraceptives, and risk of ischemic stroke

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Prothrombotic conditions are associated with ischemic stroke in young women. In particular, the combination of oral contraceptive use and prothrombotic genetic variants appears to increase the risk of ischemic stroke. We performed a population-based case-control study in 190 women aged 20 to 49 years with ischemic stroke and 767 women without cardiovascular disease stratified for age, calendar year of the index event, and residence. A total of 4 variants of coagulation factor XIII subunit A and B genes (F13A1 and F13B) were investigated. The Phe allele of the F13A1 Tyr204Phe variant was present in 59 (31%) patients and 43 (6%) controls; the odds ratio for ischemic stroke was 9.1 for Phe/Phe and Phe/Tyr versus Tyr/Tyr genotype; the 95% confidence interval was 5.5 to 15. Homozygous genotypes (Phe/Phe) conferred a higher risk (odds ratio, 77; 95% confidence interval, 7.0-848) than heterozygous (Tyr/Phe) genotypes (odds ratio, 8.2; 95% confidence interval, 4.9-14). The risk of ischemic stroke was further increased in carriers of the 204Phe allele using oral contraceptives (odds ratio, 20; 95% confidence interval, 9-46) compared with non-users with Tyr/Tyr genotype. In conclusion, the F13A1 Tyr204Phe allele was strongly associated with ischemic stroke in young women. Oral contraceptive use further increased the risk of ischemic stroke.

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Methods

Study design

The Risk of Arterial Thrombosis in relation to Oral Contraceptives (RATIO) study is a multicenter, population-based case-control study. The study consists of 3 substudies on ischemic stroke, myocardial infarction, and peripheral arterial disease. The first phase evaluated the risk of arterial
thrombosis related to the use of oral contraceptives (1990-1995). In the second phase, blood samples were drawn or buccal swabs collected to study prothrombotic conditions (1998-2002). The study was approved by the medical ethics committees of the participating hospitals.

Patients

Eligible patients were women aged 18 to 50 years who were hospitalized for a first ischemic stroke in 1 of 9 participating Dutch hospitals between 1990 and 1995. Stroke was diagnosed in all patients based on the medical history and neurologic examination as well as computed tomography (CT) or magnetic resonance imaging (MRI) scan by experienced neurologists in the participating centers. Exclusion criteria were transient ischemic attack (an event lasting less than 24 hours), hemorrhagic stroke, cerebral venous sinus thrombosis, carotid artery dissection, history of cardiovascular or cerebrovascular disease, terminal illness, aphasia or cognitive impairment interfering with the questionnaire, or not speaking Dutch. Of the 295 eligible patients admitted during the study period, 203 patients agreed to participate in the first phase of the study. A population-based control group was identified by random-digit dialing between 1990 and 1995. This group was frequency-matched to the patients for age, residence, and year of the stroke. Eligible controls were women aged 18 to 50 years without a history of coronary heart disease, cerebrovascular event, or peripheral vascular disease. A total of 925 of 1039 eligible women were included as controls in the RATIO study for the 3 patient groups combined. DNA was obtained from 767 women. Of the 203 patients from the first phase, 140 patients also participated in the second phase: 6 had died, 10 refused to participate, 44 did not respond, and 3 had insufficient availability of DNA. To compensate for the loss of patients, we approached 59 additional patients with ischemic stroke who presented in the University Medical Center Utrecht between 1996 and 2001 using the same inclusion and exclusion criteria. Of these 59 patients, 50 were included (9 refused to participate). Therefore, 190 patients participated in the present study. Informed consent was obtained in accordance with the Declaration of Helsinki.

Data collection and definitions

Patients and controls received a standardized mail questionnaire between 1997 and 2001 on use of oral contraceptives, smoking status, alcohol use, weight, height, physician’s diagnosis, and medication use for hypertension, diabetes mellitus, and hyperlipidemia. Color photos of boxes of all oral contraceptives marketed in the Netherlands were used to help women recall the specific type of oral contraceptives they had used. All questions referred to the time period preceding the index date (ie, the date of stroke in patients and the mid-year of the same year in controls). Current use of oral contraceptives was defined as use of a contraceptive pill within 1 month before the index date. Nonuse was defined as previous use or never having used. Smoking was categorized into current, former, and never having smoked. Current smoking was defined as having smoked at least 1 cigarette a day in the year before the index date. Alcohol use before the index date was categorized into never, 1 to 15 drinks a week, and more than 15 drinks a week, in the year before the index date. At the time of blood collection, we were able to confirm the data on hypertension, diabetes, and hyperlipidemia. Blood pressure was measured twice in a supine position after 5 minutes of rest and averaged. A woman was classified as hypertensive when using antihypertensive medication, having a systolic blood pressure of 160 mmHg or higher, or having a diastolic blood pressure of 95 mmHg or higher at the time of blood collection.

DNA was isolated from 10-mL EDTA-augmented blood or buccal swabs and amplified by polymerase chain reaction technique. Blood samples were available for 175 patients and 638 controls. Buccal swabs were collected in 15 patients and 129 controls. A total of 4 genetic variants were genotyped with the 5’ nuclease/TaqMan assay: Val34Leu (rs5985), Tyr204Phe (rs3024477), and Pro564Leu (rs5982) variants in the FXIII subunit A gene and the His95Arg variant (rs6003) in the FXIII subunit B gene. No other variants were genotyped. Polymerase chain reactions with fluorescent allele-specific oligonucleotide probes (Assay-by-Design/Assay-on-Demand; Applied Biosystems, Foster City, CA) were performed on a PTC-225 thermal cycler (Biozym, Hessisch Oldendorf, Germany), and fluorescence end-point reading for allelic discrimination was performed on an ABI 7900 HT (Applied Biosystems). Primer sequences, probe sequences, and restriction enzymes used are available on request. The reference cluster ID (rs) numbers for genetic variants (also included in Table 2) enable retrieval through the dbSNP website. The laboratory technicians were unaware of case-control status and other patient characteristics.

Statistical analysis

The relative risk of ischemic stroke associated with genetic variation in FXIII was assessed as an odds ratio with a 95% confidence interval using unconditional logistic regression. A dominant model of inheritance was used: variant allele heterozygotes and homozygotes were compared with wild-type homozygotes. Adjustments were made for the stratification variables: age, calendar year of the index event, and residence. The additional patients were assigned the highest index year of patients from the first study phase with whom the controls were matched. Odds ratios adjusted for cardiovascular risk factors were not computed because environmental factors are unlikely to affect genotype frequencies and to confound genetic associations. The combined effect of oral contraceptive use and genetic variation in FXIII on ischemic stroke was analyzed by computing odds ratios in patients with either one or both of these risk factors, as compared with those with neither risk factor, in a model adjusting for the stratification variables. The combined effect of smoking and genetic variation in FXIII on ischemic stroke was analyzed similarly. Odds ratios involving oral contraceptive use were adjusted for stratification variables and vascular risk factors. The genotype distribution in the control group was in Hardy-Weinberg equilibrium and similar to the genotype distribution for Europeans in the HapMap project for all tested genetic variants.

Results

Table 1 provides baseline characteristics of 190 women with ischemic stroke and 767 control women. The age of the patients ranged from 20 to 50 years, and the age of the control women varied from 18 to 53 years. Risk factors for ischemic stroke

| Table 1. Baseline characteristics of young women with ischemic stroke and control women |
|-----------------|-----------------|
| **No.** | **Patients** | **Controls** |
| Age, y* | 39.8 | 38.6 |
| European ethnicity, no. (%) | 182 (96) | 723 (94) |
| Hypertension, no. (%) | 62 (33) | 47 (6) |
| Diabetes mellitus, no. (%) | 8 (4) | 10 (1) |
| Hyperlipidemia, no. (%) | 15 (8) | 22 (3) |
| Oral contraceptive use, no. (%) | 98 (52) | 272 (36) |
| Smoking, no. (%) | | |
| Current | 66 (35) | 247 (32) |
| Former | 85 (45) | 272 (36) |
| Never | 39 (21) | 248 (32) |
| Alcohol use, no. (%) | | |
| Never | 89 (47) | 227 (30) |
| 0-15 drinks a week | 84 (44) | 500 (65) |
| > 15 drinks a week | 2 (1) | 32 (4) |

Data were missing on ethnicity in 1 patient and in 4 controls, on diabetes mellitus in 3 controls, on hyperlipid in 5 controls, on oral contraceptive use in 6 controls, and on alcohol use in 15 patients and 8 controls.

*Mean age at index date.
(hypertension, diabetes mellitus, hyperlipidemia, oral contraceptive use, and smoking) were more common in patients than in controls. Patients reported less alcohol use than controls. After adjustment for stratification variables and vascular risk factors, oral contraceptive use increased the risk of ischemic stroke (odds ratio, 2.7; 95% confidence interval, 1.7-4.1). All oral contraceptives were combinations of an estrogen (ethinyl estradiol) and a progestin. The estrogen dose ranged between 20 and 50 μg. Most oral contraceptives contained 30 μg estrogen (n = 192; 52%). The most common types of progestin used were levonorgestrel (n = 177; 48%), desogestrel (n = 83; 22%), lynestrenol (n = 22; 6%), and cyproterone acetate (n = 20; 5%). The estrogen dose and the type of progestin were evenly distributed in patients and controls.

The overall call rate for all 4 genetic variants was 96.5% (range, 94.8%-97.8%). Genotype distribution in patients and controls and odds ratios for ischemic stroke are shown in Table 2. Carriers of at least 1 Phe allele of the F13A1 Tyr204Phe variant had a 9-fold increased risk of ischemic stroke. Subjects with a homozygous genotype (Phe/Phe) had a much higher risk of ischemic stroke (odds ratio, 77; 95% confidence interval, 7.0-848) than subjects with wild-type (Tyr/Tyr). Subjects with a heterozygous genotype (Phe/Tyr) also had a higher risk than subjects with wild-type (odds ratio, 8.2; 95% confidence interval, 4.9-14). The F13B His95Arg variant conferred a 1.7-fold increased risk of ischemic stroke. The Phe allele of the Tyr204Phe variant of the coagulation FXIII subunit A gene was associated with a 9-fold increased risk of ischemic stroke in this population-based case-control study among young women. The heterozygous and homozygous genotype increasingly affected stroke risk (8-fold and 77-fold, respectively), indicating a gene-dose effect compatible with an additive mode of inheritance. Oral contraceptive use combined with carriership of the 204Phe allele led to a 20-fold increased risk of ischemic stroke. The Arg allele of the F13B His95Arg variant was slightly associated with ischemic stroke but showed no combined effect with oral contraceptive use. A gene-dose effect was also observed for the 95Arg allele. The F13A1 Val34Leu and Pro564Leu variants did not show an association with ischemic stroke or combined effect with oral contraceptive use or smoking. We could not replicate (1) a previously reported increased risk of ischemic stroke by the Leu allele of the Val34Leu variant in young women and (2) a combined effect of the 95Arg allele and the Leu allele of the Val34Leu variant.

The strong association we found between the 204Phe allele and ischemic stroke is biologically plausible because this allele has been shown to lower both the FXIII plasma level and FXIII activity. A lower FXIII plasma level and activity can theoretically lead to both an increased or decreased thrombotic risk depending on several other factors, including the concentrations of thrombin, prothrombin, fibrinogen, and fibrinectin.

Since familial aggregation of ischemic stroke is higher in young women, stronger genetic effects on stroke can be expected than in an elderly population. The 204Phe allele was associated with a slightly increased risk of ischemic stroke in young women.

### Table 2. Genotype distribution in patients and controls and odds ratios for ischemic stroke under a dominant genetic model

<table>
<thead>
<tr>
<th>Gene name (HUGO abbreviation)</th>
<th>Variant</th>
<th>RefSNP ID no.</th>
<th>Distribution in patients (%) (n = 190)</th>
<th>Odds ratio (95% CI)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor XIII subunit A (F13A1)</td>
<td>Val34Leu</td>
<td>rs5985</td>
<td>AA 121 (64) AB 60 (32) BB 8 (4)</td>
<td>419 (56) AB 283 (38) BB 45 (6) 0.77 (0.53-1.11)</td>
</tr>
<tr>
<td>Factor XIII subunit A (F13A1)</td>
<td>Tyr204Phe</td>
<td>rs3024477</td>
<td>AA 116 (66) AB 54 (31) BB 5 (3)</td>
<td>711 (94) AB 42 (6) BB 1 (0) 9.1 (5.5-15)</td>
</tr>
<tr>
<td>Factor XIII subunit A (F13A1)</td>
<td>Pro564Leu</td>
<td>rs5982</td>
<td>AA 107 (62) AB 57 (33) BB 8 (5)</td>
<td>466 (62) AB 251 (33) BB 34 (5) 0.89 (0.61-1.29)</td>
</tr>
<tr>
<td>Factor XIII subunit B (F13B)</td>
<td>His95Arg</td>
<td>rs6003</td>
<td>AA 134 (76) AB 33 (19) BB 10 (6)</td>
<td>609 (83) AB 112 (15) BB 9 (1) 1.7 (1.1-2.7)</td>
</tr>
</tbody>
</table>

HUGO indicates Human Genome Organization; RefSNP ID no., reference single nucleotide polymorphism identification number; 95% CI, 95% confidence interval; AA, wild-type homozygote; AB, variant heterozygote; and BB, variant homozygote. Percentages do not always add up to 100% due to rounding.

* Odds ratio with 95% confidence interval assuming dominant inheritance: heterozygous (AB) and homozygous (BB) variant genotypes versus wild-type (AA).

### Table 3. Effect of oral contraceptive use on the association of the Tyr204Phe variant of the coagulation FXIII subunit A gene and ischemic stroke

<table>
<thead>
<tr>
<th>Oral contraceptive use</th>
<th>Distribution in patients, %</th>
<th>Distribution in controls, %</th>
<th>Odds ratio (95% CI)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absent</td>
<td>204Phe allele</td>
<td>Tyr/Tyr</td>
<td>Tyr/Phe</td>
</tr>
<tr>
<td>Absent</td>
<td>Absent</td>
<td>54</td>
<td>—</td>
</tr>
<tr>
<td>Present</td>
<td>Absent</td>
<td>62</td>
<td>29</td>
</tr>
<tr>
<td>Absent</td>
<td>Present</td>
<td>—</td>
<td>29</td>
</tr>
<tr>
<td>Present</td>
<td>Present</td>
<td>—</td>
<td>25</td>
</tr>
</tbody>
</table>

†Data on oral contraceptive use was missing in 6 controls.

*Odds ratios with 95% confidence interval assuming dominant inheritance (Tyr/Phe and Phe/Phe variant genotypes versus Tyr/Tyr) adjusted for age at index date, index year, residence, hypertension, diabetes, hyperlipidemia, and smoking.
We found a 20-fold increased risk of ischemic stroke for carriership of the 204Phe allele combined with oral contraceptive use. Previous studies similarly found an increased risk of ischemic stroke for other prothrombotic gene variants combined with contraceptive use: 11-fold for factor V Leiden, and 5- to 12-fold for the MTHFR 677TT genotype. However, there is no indication for screening for prothrombotic genetic variants in current clinical practice. If these genetic associations are replicated, a cost-effectiveness analysis should be performed that takes into account the low incidence of ischemic stroke among young women. The incidence of ischemic stroke among young women is reported to be 8.5 per 100 000 per year in the Netherlands. In our study, carriers of the 204Phe allele had a 8.8-fold increased risk of ischemic stroke and a 20-fold increased risk in combination with oral contraceptive use (Table 3). Based on these data, the estimated “number needed to harm” would be 2324, meaning 1 ischemic stroke would be prevented if 2324 women carrying the 204Phe allele would refrain from using oral contraceptives for 1 year. Assuming a 6% prevalence of the 204Phe allele, more than 40 000 young women would need to be screened to prevent 1 ischemic stroke each year. Moreover, the benefits of oral contraceptive use, such as a reduction in ovarian cancer risk, endometrial cancer risk, and pregnancy-associated morbidity and mortality, must also be considered. Type of progestin and estrogen dose may also affect the risk of ischemic stroke oral contraceptive users who carry the 204Phe allele. We refrained from subgroup analyses taking these factors into account. Such subgroups would be too small to detect an association with sufficient precision. The risks of other thrombotic diseases, like deep venous thrombosis and myocardial infarction, in oral contraceptive users who carry the 204Phe allele have not yet been studied.

In conclusion, we found a strong association between the 204Phe allele of the coagulation FXIII subunit A gene and the risk of ischemic stroke in young women. Oral contraceptive use further increased the risk of ischemic stroke.

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Authorship

Contributions: A.J.C.S., F.R.R., Y.v.d.G., and A.A. designed the research; D.M.O. and A.A. analyzed the data and drafted the manuscript. All authors contributed to interpretation of the data and critical revision of the manuscript.

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