Association of the CYP17 Gene Polymorphism with the Risk of Prostate Cancer: A Meta-Analysis

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Abstract

A T-to-C polymorphism in the 5′ promoter region of the CYP17 gene that encodes the cytochrome P450c17α has been implicated as a risk factor for prostate cancer, but individual studies have been inconclusive or controversial. Therefore we performed a meta-analysis of 10 studies (12 individual studies have been inconclusive or controversial. The costs of publication of this article were defrayed in part by the payment of advertisement.

Received 6/27/02; revised 11/8/02; accepted 11/16/02.
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pedigrees with several affected cases per family because their analysis is based on linkage considerations.

**Data Extraction.** Two investigators independently extracted the data and reached consensus on all items. The following information was sought from each study: authors; journal and year of publication; country of origin; selection and characteristics of prostate cancer cases and controls; demographics; racial descent of the study population (categorized as European, African, and Asian descent); eligible and genotyped cases and controls; and number of cases and controls for each CYP17 genotype. For studies where subjects of different racial descent were included, data were extracted separately for each race. Furthermore, we examined whether matching had been used, whether there was specific mention of blinding of the personnel who performed the genotyping to the clinical status of the subjects, and whether the genotyping method had been validated. Whenever complete information on distribution of genotypes in cases and controls was missing in a published report, we obtained the pertinent data directly from primary study investigators.

**Meta-Analysis.** The primary analysis compared prostate cancer patients against controls for the contrast of A2 versus A1 alleles. This analysis aims to detect overall differences. We also examined the contrast of extremes (homozygotes) A2/A2 versus A1/A1. Finally, we examined the contrast of A2/A2 versus (A1/A2 + A1/A1) and (A1/A2 + A2/A2) versus A1/A1. These contrasts correspond to recessive and dominant effects, respectively, of the A2 allele.

Because case-control studies were involved, the OR was used as the metric of choice. Studies with subjects of different races were split into separate race-specific comparisons. For each genetic contrast, we estimated the between-study heterogeneity across all eligible comparisons using the χ²-based Q statistic (16). Heterogeneity was considered significant for P < 0.10. Data were combined using both fixed effects (Mantel-Haenszel) and random effects (DerSimonian and Laird) models (17). Random effects incorporate an estimate of the between-study variance and tend to provide wider CIs when the results of the constituent studies differ among themselves. In the absence of between-study heterogeneity, the two methods provide identical results. Random effects are more appropriate when heterogeneity is present (17).

Subgroup analyses estimated race-specific ORs for the A2 versus A1 contrast. Beyond race, studies were not consistent about adjusting for other parameters such as age, smoking, or family history and presented different genetic contrasts for the adjusted analyses. Therefore, we examined whether the unadjusted analyses yielded similar OR estimates as the adjusted/stratified analyses whenever reported.

We also performed cumulative meta-analysis (18) and recursive cumulative meta-analysis (19, 20) to evaluate whether the summary OR for the A2 versus A1 contrast changed over time as more data accumulated. Inverted funnel plots and the Begg-Mazumdar publication bias diagnostic (nonparametric τ correlation coefficient; Ref. 21) evaluated whether the magnitude of the observed association was related to the variance of each study.

Analyses were conducted in SPSS 10.0 (SPSS, Inc., Chicago, IL), StatXact (Cytel, Inc., Boston, MA), and Meta-Analyst (Joseph Lau, Boston, MA). All P values are two-tailed.

**Results**

**Eligible Studies.** Ten studies probing the relationship between the CYP17 polymorphism and prostate cancer susceptibility were identified (6–15). One of the two comparisons in one report pertained to a family-based linkage study, so this comparison was excluded (12). Two of the eligible studies (6, 11) contained subjects of two different racial descents, thus a total of 12 separate comparisons were considered (Table 1). There was a considerable diversity of ethnic groups. Six studies (6–8, 11, 13, 15) selected prostate cancer patients based on a histological diagnosis from biopsy and/or prostatectomy, whereas the other four (9, 10, 12, 14) did not clarify the exact criteria used for the diagnosis of prostate cancer. Two studies (11, 14) mentioned that they included a small proportion of patients with a first-degree relative with prostate cancer, one study (13) specifically excluded such patients, whereas the remaining did not clarify the background of family history. Controls did not have a clinical diagnosis of prostate cancer, but the amount of additional screening [with digital rectal examination, prostate-specific antigen (<4 ng/ml), needle biopsy or prostate resection] to exclude prostate cancer differed substantially across studies (Table 1).

With one exception (10) where the mean age of controls and cases differed by 9 years, the mean or median age of cases and controls was very similar (difference < 2 years), and specific matching for age was described in five studies (7–9, 11, 14). One study also matched for smoking status (9). Three studies (9, 11, 15) mentioned specifically blinding of the personnel who performed the genotyping. Appropriate molecular methods for genotyping were used. All studies used PCR, and three studies used also sequencing (9–11).

**Meta-Analysis Database.** The eligible studies included a total of 2442 patients with prostate cancer and 2816 controls of whom 2404 and 2755, respectively, had genotype data. Allele and genotype frequencies per group are shown in Table 2. The A2 allele was more highly represented among controls of Asian descent [44% (95% CI, 41–47)] than in controls of European descent [39% (95% CI, 37–40)] or African descent [31% (95% CI, 25–37)]. Overall, the prevalence of A2/A2 homozygosity was 18, 15, and 10% in control subjects of Asian, European, and African descent, respectively. The respective prevalence rates of A1/A2 heterozygosity were 52, 48, and 42%, and the respective rates for A1/A1 homozygosity were 30, 37, and 48%.

The distribution of genotypes in control groups was consistent with Hardy-Weinberg equilibrium in all studies, with the exception of Yamada et al. (8), where there was a significant deficit of both homozygote genotypes (P = 0.01). A sensitivity analysis was thus performed excluding this study.

**Overall Effects for Alleles.** There was no strong evidence that the A2 allele conferred increased susceptibility to prostate cancer (Fig. 1). The summary OR was 1.08 by random effects (P = 0.24) and 1.04 by fixed effects (P = 0.29). However, there was significant heterogeneity between the 12 study comparisons (P = 0.04). Excluding the one study where Hardy-Weinberg equilibrium was violated in the controls (8) brought the results even closer to the null (OR, 1.05; 95% CI, 0.93–1.19; P = 0.43 by random effects and OR, 1.03; 95% CI, 0.95–1.11; P = 0.53 by fixed effects), but there was still some between-study heterogeneity (P = 0.053).

In subgroup analyses, we documented a significant association of the A2 allele with the risk of prostate cancer (P = 0.022) in subjects of African descent without any between-study heterogeneity, although data were limited (Table 3). On the contrary, no differences were observed in allele distribution between prostate cancer patients and controls in European and Asian descent subgroups (Table 3). There was no significant between-study heterogeneity in comparisons of subjects of Eu-
European descent (P = 0.15), whereas there was significant heterogeneity (P = 0.02) between the two studies performed in subjects of Asian descent, with a trend for an association of the A2/A2 genotype with the risk of prostate cancer seen only in the study without Hardy-Weinberg equilibrium in the control group.

Other Contrasts. We found no evidence of an association of the A2/A2 genotype with the risk of prostate cancer relative to the A1/A1 genotype. There was no significant between-study heterogeneity (P = 0.11 for heterogeneity), and the 95% CI excluded a large effect (Table 3). No evidence for an association with prostate cancer was discerned also when recessive and dominant models were examined for the effect of A2. There was no between-study heterogeneity in the recessive model contrast, whereas significant heterogeneity (P = 0.003) was seen for the dominant model contrast (Table 3).

Adjusted/stratified Analyses for Age and Other Factors. Three studies (10, 13, 14) provided only unadjusted analyses. The other studies provided some estimates taking also age into account [either by stratification (6–8) or as a continuous adjusting variable (9, 11, 12, 15)]. Smoking status was also considered in one study (9) and having a relative with prostate cancer in another (11). In four studies (8, 9, 11, 12), the adjusted and unadjusted estimates practically coincided (difference in ORs < 0.03). In the other three studies (6, 7, 15), the adjusted OR was slightly smaller than the unadjusted OR for the effects of either A2/A2 or A1/A1 + A2/A2 versus A1/A1. In Gsur et al.
phism is unlikely to be a major risk factor for susceptibility to prostate cancer. Each comparison is presented by the name of the first author, the year of publication, and the number of alleles. A1 signifies subjects of African descent, A2 signifies subjects of Asian descent; all other comparisons are in subjects of European descent. For each comparison, the point estimate of the OR and the accompanying 95% CI are shown. Also shown is the summary random effects estimate for the comparison along with the respective 95% CI as well as final z-statistic for the summary OR. The studies are ordered according to year of publication. Values >1 denote an increased risk for prostate cancer with A2.

Fig. 1. Meta-analysis for the effect of A2 versus A1 allele on the risk of prostate cancer. Each comparison is presented by the name of the first author, the year of publication, and the number of alleles. A1 signifies subjects of African descent, A2 signifies subjects of Asian descent, and A1/A2 signifies heterozygotes have intermediate risk.

In two stratified analyses (6, 8), A2/A2 and A1/A1 seemed to confer a significant susceptibility to prostate cancer in younger subjects (subgroups ≤64 and <72 years old, respectively). Conversely, in another stratified analysis (7), A2/A2 and A1/A2 conferred susceptibility to prostate cancer in older patients (subgroup >66 years old), whereas a protective trend was seen in the younger group. Thus, there was no consistent evidence for a greater susceptibility in younger or older patients.

Other Bias Diagnostics. In cumulative meta-analysis and recursive cumulative meta-analysis, the magnitude of the summary OR had been stable and not changing in the same direction over time (by random effects, summary OR for A2 versus A1: 1.10 at the end of 1999, 1.07 at the end of 2000, 1.12 at the end of 2001, and 1.08 in 2002). However, the inverted funnel plot was potentially asymmetric. There was a significant correlation between the variance of each study and the magnitude of the OR ($\tau = 0.52, P = 0.038$ considering the 10 studies; $\tau = 0.44, P = 0.046$ considering the 12 comparisons with racial subgroups considered separately), suggesting that a relationship between A2 and prostate cancer was seen unilaterally in the smaller studies.

Discussion

This meta-analysis includes data from 12 case-control comparisons with >5000 genotyped prostate cancer patients and controls. The overall data demonstrate that the CYP17 polymorphism is unlikely to be a major risk factor for susceptibility to prostate cancer on a wide population basis. There has been some heterogeneity between the results of various studies. Heterogeneity may be because of bias, in particular publication bias (22, 23), because the published smaller studies suggest increased susceptibility to prostate cancer with the A2 allele, whereas this has not been documented in studies with larger sample sizes. Genuine heterogeneity may also be present and it may relate to racial differences, with a genetic effect limited to subjects of African descent.

For subjects of European descent, the meta-analysis excludes any clinically meaningful overall effect of this polymorphism on prostate cancer risk. No overall effect is seen among Asian descent subjects, but data seem heterogeneous and one study lacks Hardy-Weinberg equilibrium in the control group. Conversely, the polymorphism may play a role in susceptibility to prostate cancer among subjects of African descent. If the association between this polymorphism and prostate cancer holds true, especially in subjects of African descent, this may be because of gene by gene or gene by environment interactions or may be a reflection of a pattern of linkage disequilibrium with other more important polymorphisms, which is unique to men of African descent. However, the currently available data on men of African descent are still very limited and thus should be interpreted with caution. A few more studies may be required in African Americans or other African-derived groups. African Americans have a higher incidence of prostate cancer, present with more advanced disease and at younger ages, and have a worse prognosis than subjects of other ethnicities (24–27).

This differential profile is not entirely explained by lifestyle, dietary, socioeconomic, or clinical factors (25–27), thus genetic parameters may be important. In the meta-analysis database, the A2 allele was slightly less frequent in African versus European descent, whereas an opposite trend has been observed in a different study (28). Overall, these two racial groups may exhibit little difference in A2 frequency.

The meta-analysis findings may be interpreted against the postulated biological context of the CYP17 polymorphism. One study has shown that white men with the A2/A2 genotype have 0.5 SDs higher bioavailable testosterone than men with the A1/A1 genotype, and A1/A2 heterozygotes have intermediate...
values (29). However, other studies have found no differences in the levels of testosterone or other androgens and metabolites thereof (dehydrotestosterone, androstenediol glucuronide) according to CYP17 genotypes in men (9, 30). Most studies in women also do not suggest major influences on hormonal levels (31–33). An early study suggested that the A2 allele creates an additional Sp1-binding site in the CYP17 promoter region (4). Subsequently, Nedelecheva Kristensen et al. (5) did not document Sp1 binding at this polymorphic site or within the promoter region of CYP17 in general, whereas Lin et al. (34) found that Sp1 is an essential factor for CYP17 transcription in human adrenal NCI-H295A cells. Overall, evidence that the A2 allele increases androgen levels is weak and inconsistent. The exact role of androgens in prostate cancer is a contentious issue (1, 35, 36). If androgens participate in the causal pathway of prostate cancer (1, 35, 36), a null effect of the CYP17 polymorphism on androgen levels would be consistent with the results of the meta-analysis.

The CYP17 polymorphism may not be an important population-wide risk factor for prostate cancer. Genome scans have typically not identified significant linkage in the 10q24.32 chromosomal region where the CYP17 gene is located (37, 38). A recent meta-analysis of 15 comparisons (39) also concluded that this polymorphism does not seem to play a significant role in susceptibility to breast cancer in women, another type of cancer where hormonal influences are considered to be important. Data on other conditions potentially affected by endogenous sex hormone levels such as endometrial cancer (32, 40), ovarian cancer (41, 42), hepatocellular carcinoma (43), and polycystic ovaries (44) are more limited and don’t always show consistent associations. A larger number of studies and many more genotyped subjects are required to clarify these postulated associations.

The meta-analysis was consistently based on unadjusted estimates, but we took care to account for racial effects. Moreover, the reported adjusted estimates taking age into consideration suggest that the overall results would probably shift closer to the null, even if age-adjusted analyses were consistently available. We should acknowledge that the meta-analysis could not address conclusively familial prostate cancer. One study with pedigrees of ≥3 prostate cancer cases/family (mean, 5.08; Ref. 12) has suggested a possible link of prostate cancer with the CYP17 gene region, but the LOD score was only 1.3. However, hereditary forms of prostate cancer with many members affected per family are not very common (38). Associations limited to strictly hereditary forms are unlikely to have a substantial population-attributable fraction for prostate cancer. Conversely, it is common to encounter families where two first-degree relatives or one first-degree relative and at least two second-degree relatives are affected. This pattern may account for 10–20% of all cases of the disease (38). Future studies should explore specifically whether the CYP17 polymorphism may have any effect on the risk of prostate cancer specifically in this setting.

Attention should also be given to the design of individual studies. The results of meta-analyses may be affected by methodological problems and potential biases in the designs of the constituent studies. Quality deficiencies may sometimes affect the magnitude of the observed association. Nondifferential misclassification errors may dilute the strength of an observed association. In the CYP17 studies, genotyping was performed with appropriate methods, thus genotype errors are unlikely to have influenced the results substantially. However, controls were not screened consistently across studies to exclude subclinical, latent prostate cancer. Control groups of the different studies were also not equally well characterized as to the extent of inclusion of subjects with BPH. The inclusion or not of subjects with BPH in the control group may affect the results if the CYP17 polymorphism affects BPH. One study found a difference between controls with versus without BPH in the frequency of the A2 allele (15), but another study has shown no effect of this polymorphism on prostate volume (45). Moreover, some young control subjects may have developed prostate cancer at older ages. The lifetime risk of prostate cancer in American men is estimated at 16% (46), therefore the dilution of the OR would not be very large. The choice of an appropriate age-window for assessing a postulated genetic risk factor for prostate cancer is difficult. Studies of younger subjects may be more suitable for identifying risk factors that result in early carcinogenesis. Conversely, selection of younger subjects may be less appropriate, if hormonal or other influences regulated by the postulated risk factor are more important in later ages (35).

Cases of prostate cancer included in most of these studies are those brought to therapeutic attention, and this may differ from cases diagnosed from population screening. However, there is no reason why the CYP17 genotype distribution would be affected by this selection. Moreover, cases and controls may have been recruited through different sources, but they were ethnically matched and with one exception, they were also well matched for age. Finally, even among cases with prostate cancer, some misclassification might be unavoidable, if cases were unconfirmed by histology. However, this potential misclassification should not have affected a considerable proportion of the cancer cases.

Notwithstanding these considerations, one should not overemphasize subgroup analyses of age or other factors. For CYP17, age subgroup analyses in different studies have reached opposite conclusions, perhaps as a result of chance and multiple comparisons. The summary results do not support a strong overall effect. A very large number of subjects are needed to

### Table 3: Summary ORs for various contrasts

<table>
<thead>
<tr>
<th>Contrast</th>
<th>Comparisons (n)</th>
<th>Random effects OR (95% CI)</th>
<th>Fixed effects OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2 versus A1 alleles</td>
<td>12 (10,318)</td>
<td>1.08 (0.95–1.22)^a</td>
<td>1.04 (0.96–1.13)</td>
</tr>
<tr>
<td>European</td>
<td>7 (8,052)</td>
<td>1.04 (0.92–1.18)</td>
<td>1.03 (0.94–1.13)</td>
</tr>
<tr>
<td>Asian</td>
<td>2 (1,772)</td>
<td>1.06 (0.66–1.71)^a</td>
<td>0.99 (0.82–1.20)</td>
</tr>
<tr>
<td>African</td>
<td>3 (494)</td>
<td>1.56 (1.07–2.28)</td>
<td>1.56 (1.07–2.28)</td>
</tr>
<tr>
<td>A2/A2 versus A1/A1</td>
<td>12 (2,673)</td>
<td>1.15 (0.91–1.46)</td>
<td>1.09 (0.92–1.29)</td>
</tr>
<tr>
<td>A2/A2 versus (A1/A2 + A1/A1)</td>
<td>12 (5,159)</td>
<td>1.08 (0.92–1.24)</td>
<td>1.07 (0.92–1.24)</td>
</tr>
<tr>
<td>(A1/A2 + A2/A2) versus A1/A1</td>
<td>12 (5,159)</td>
<td>1.11 (0.90–1.35)^a</td>
<td>1.05 (0.93–1.18)</td>
</tr>
</tbody>
</table>

^a Heterogeneity, 0.01 < P < 0.10.
^b Heterogeneity, P < 0.01.
establish or refute a genetic association of modest magnitude (47) and even larger numbers are needed to validate subgroup differences, let alone more subtle associations such as gene-gene and gene-environment interactions. Given the large number of potential genetic risk factors that may be probed, several initial observations may not be validated by subsequent evidence (47).

Acknowledgments

We thank Dr. Alain Latil for providing additional data and clarifications on his study.

References

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