IMPORTANT  Secondhand smoking is a risk to adult ocular health, but its effect on children’s ocular development is not known.

OBJECTIVE  To assess the association between choroidal thickness and secondhand smoking exposure in children.

DESIGN, SETTING, AND PARTICIPANTS  Children aged 6 to 8 years were consecutively recruited from January 2016 to July 2017 from the population-based Hong Kong Children Eye Study at the Chinese University of Hong Kong Eye Centre. All participants underwent detailed ophthalmic investigations. Choroidal thickness was measured by swept-source optical coherence tomography, with built-in software that automatically segmented the choroid layer to analyze its terrain imagery. History of secondhand smoking was obtained from a questionnaire. Multiple linear regression analyses were performed to assess the correlation between choroidal thickness and secondhand exposure when controlling for confounding factors. Analysis began July 2018 and ended in April 2019.

MAIN OUTCOMES AND MEASUREMENTS  The association between children’s choroidal thickness and their exposure to secondhand smoking.

RESULTS  Of 1400 children, 941 (67.2%) had no exposure to secondhand smoking, and 459 (32.8%) had exposure to secondhand smoking. The mean (SD) age was 7.65 (1.09) years for children in the nonexposure group and 7.54 (1.11) years for children in the exposure group. After adjustment for age, sex, body mass index, axial length, and birth weight, exposure to secondhand smoking was associated with a thinner choroid by 8.3 μm in the central subfield, 7.2 μm in the inner inferior, 6.4 μm in the outer inferior, 6.4 μm in the inner temporal, and 7.3 μm in the outer temporal. Choroidal thinning with also associated with increased number of family smokers and increased quantity of secondhand smoking. An increase of 1 family smoker was associated with choroidal thinning by 7.86 μm in the central subfield, 4.51 μm in the outer superior, 6.23 μm in the inner inferior, 5.59 μm in the inner inferior, 6.06 μm in the inner nasal, and 6.55 μm in the outer nasal. An increase of exposure to 1 secondhand cigarette smoke per day was associated with choroidal thinning by 0.54 μm in the central subfield, 0.42 μm in the inner temporal, and 0.47 μm in the outer temporal.

CONCLUSIONS AND RELEVANCE  This investigation showed that exposure to secondhand smoking in children was associated with choroidal thinning along with a dose-dependent effect. These results support evidence regarding the potential hazards of secondhand smoking to children.
cigarette smoking is an important risk factor of systemic and ocular vascular diseases and poses a threat to public health globally. It may impose pathologic effects by causing anatomical alterations of the arterial system in thickening the arterial wall as in atherosclerosis and affecting both the microvascular and macrovascular structures. It is a potent risk factor of cardiovascular diseases with high mortalities, such as myocardi infarction, and serious lung diseases, such as chronic obstructive pulmonary disease and lung cancer. Notably, cigarette smoking is also associated with many eye diseases, including age-related macular degeneration (AMD), cataracts, retinal ischemia, anterior ischemic optic neuropathy, Graves ophthalmopathy, tobacco-alcohol amblyopia, glaucoma, and ocular inflammation.

Secondhand smoking also imposes health hazards and has been associated with serious diseases, including lung cancer, asthma, cardiovascular diseases, and sudden infant death syndrome. Among young people in Spain, 27.8% and 33.6% were exposed to secondhand smoke at home and outside, respectively. They have 2- to 6-times higher risk of many diseases compared with people who never smoke or were not exposed to secondhand smoking.

A 2018 national survey in the United States reported that up to 25.2% of the population has been exposed to secondhand smoking and, alarmingly, 37.9% in children aged 3 to 11 years and teenagers 12 to 19 years had exposure. In 2006, there were 42,000 deaths attributed to secondhand smoking in the United States; among them, 900 were infants younger than 1 year. Combining 192 countries from all parts of the world, as high as 28% of deaths in children and morbidity of 1% of the total population are due to secondhand smoking. Therefore, secondhand smoking remains a global health threat in children.

Association of secondhand smoking has also been reported for eye diseases of variable pathology and affecting different parts of the eye, including cataracts, AMD, and Graves ophthalmopathy. There are choroidal changes in active smokers. Smoking-associated choroidal changes were linked with the development of AMD. Nearly 90% of ocular artery blood flow comes from the choroid layer. Its primary functions are to supply oxygen and nutrients to the outer retina and to regulate temperature and intraocular pressure. In Europe, maternal secondhand smoking or pregnancy smoking is linked to low birth weight, preterm birth, and hospital admissions due to asthma; the latter 2 conditions improved significantly after smoke-free legislation. So far, however, the effect of secondhand smoking on children’s ocular development is not known. We hypothesize that secondhand smoking may affect the choroid from early childhood, similar to direct smoking in adults. Long-term exposure may lead to ocular complications. In view of its potentially serious consequences in children and the vulnerability of the choroid to the development of eye diseases, we investigate the association of secondhand smoking with choroidal thickness in school-aged children in the population-based Hong Kong Children Eye Study.

Key Points

**Question** Is there an association between secondhand smoking and choroidal thickness in children?

**Findings** In this cross-sectional study of 1400 Hong Kong children, choroidal thickness was associated with the number of smokers and quantity of smoking in the family.

**Meaning** The data provide information to suggest that exposure to secondhand smoking in children is associated with choroidal thinning along a dose-dependent effect; avoidance of cigarette smoking in living environments of children should be advocated.

Methods

**Study Population**
All the school-aged children who were recruited from the Hong Kong Children Eye Study underwent comprehensive ophthalmic examination and physical examination. They were aged 6 to 8 years. Their parents or legal guardians were given a standardized questionnaire. The study procedure was performed with adherence to the Declaration of Helsinki. The protocol was approved by the Ethic Committee Board of the Chinese University of Hong Kong. Written informed consent was obtained from all children and their legal guardians. All the participants understood the study procedures. The exclusion criteria included having prior eye trauma, congenital malformations, ocular diseases (except myopia and hypermetropia), history of ocular surgery, and/or incapability to complete optical coherence tomography or other optical examination. The study individuals were recruited consecutively from January 2016 to July 2017 at the Chinese University of Hong Kong Eye Centre. Only right eyes were included for analysis in this study. Analysis began July 2018 and ended in April 2019.

**Ophthalmic and Physical Examinations**
A logMAR chart (Nidek) was used to measure visual acuity with or without spectacles. Complete ocular examinations including anterior segment, posterior segment, and ocular motility examinations for each individual were conducted by trained ophthalmologists (J.C.Y. and L.J.C.). Refraction was measured before and after cycloplegia by autorefractor (Nidek ARK-510A). Cycloplegia was performed by 2 cycles of cyclopentolate, 1% (Alcon), and tropicamide, 1% (Santen), which were applied 10 minutes apart. Axial length was evaluated by an intraocular lens master (Carl Zeiss Meditec). Blood pressure was measured with a digital automatic blood pressure monitor (Spacelabs Medical). Height and weight were measured using a professional integrated set (Seca). Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared.

**Choroidal Imaging**
Swept-source optical coherence tomography (Triton DRI OCT; Topcon) was used for choroidal imaging (Figure). A 1050-nm wavelength light source was used at a scanning speed of 100,000 A-scans per second to investigate the deep layers of...
choroid. A 12-line radial scan pattern with a resolution of 1059 × 400 was also used. Each image was an average of 32 overlapped consecutive scans focused on the fovea, covering an area of 12 × 9 mm. A built-in software was used to segment the choroid layers and to construct the topographic map. All images were inspected and manually corrected by 2 trained researchers (N.Y. and J.L.) to ensure an accurate automated segmentation. Choroidal thickness was defined as the distance between the outer border of the retinal pigment epithelium and the inner border of the sclera.30 Choroidal thickness map was presented by using the Early Treatment Diabetic Retinopathy Study grid. The mean regional thickness was calculated for each of the 9 sectors in the grid.31 The diameters for central foveal circle, parafoveal circle, and perifoveal circle were 1 mm, 3 mm, and 6 mm, respectively. Intrgrader and intergrader reliability was assessed. A subset of images was randomly selected and independently measured by 2 graders (N.Y. and F.F.L.).32 Smoking Status and Questionnaire

Questionnaires were administered to parents or legal guardians for their completion with assistance by a trained staff in presence or on the telephone.27,28 Smoking habits of parents and other family members were obtained through the following questions: (1) Is the mother smoking at home after the child is born? How long does she smoke and how many cigarettes a day? (2) Is the father smoking at home after the child is born? How long does he smoke and how many cigarettes a day? (3) Do the other members of the family smoke at home after the child is born? How long does he or she smoke and how many cigarettes a day? Number of cigarettes smoked per day was documented. Information about daily living including living environment, children's lifestyle, and children's time spent in outdoor activities and near work was also obtained. Parents' medical conditions, including mother's obstetric history, child's birth history, past and current medical history, and a thorough family history of eye disorders, were also recorded.

The association of children’s choroidal thickness with exposure of secondhand smoking was investigated by 3 approaches: (1) comparison of choroidal thickness between secondhand smoking exposure group vs nonexposure group; (2) association of choroidal thickness with number of family smokers; and (3) association of choroidal thickness with quantity of family smoking. Quantity was measured as the total number of cigarettes for all smokers in a family per day.

Statistical Analysis

Statistical analyses were performed with SPSS, version 22 (SPSS Inc). Continuous parameter was presented as mean (SD). Medians and interquartile ranges were calculated for skewed distributions. Comparisons of the parameters between smoking nonexposure and smoking exposure were performed with independent t test. χ² Test and Fisher exact test were used to test
the group difference in categorical data. Linear regression and bivariate (Pearson) correlation test were used for continuous variable and categorical data to test the association between potential confounders and central subfield choroidal thickness. Analysis of covariance was used to estimate mean choroidal thickness in associations with secondhand smoking exposure. For each choroidal thickness parameter, 2 multivariable models were constructed. In model 1, age and sex, which are known determinants of choroidal thickness, were included to serve as a basic model with minimal adjustment. In model 2, as many potential confounders as possible were included for comprehensive adjustment. First, we conducted a univariate analysis of all potential factors with choroidal thickness (eTable 1 in the Supplement). Axial length was found to be a determinant and was therefore included in model 2. Second, we included other factors that have a reported association with choroidal thickness. Therefore, birth weight and BMI were also included although they were not found significant in eTable 1 in the Supplement. Furthermore, we tested for trend by treating number of smokers (nonsmoker, 1 smoker, ≥2 smokers) as a continuous ordinal variable. We also tested for trend by treating quantity of smoking per day (nonsmoker, ≤10 cigarettes per day, >10 cigarettes per day) as a continuous ordinal variable. In all statistical analyses, the mean and sectoral choroidal thickness were compared between exposed and nonexposed secondhand smoke. Reliability was assessed using the intraclass correlation coefficient. The 2-sided P value less than .05 was considered statistically significant.

Table 1. Demographics of Study Individuals

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>No Smoking Exposure (n = 941)</th>
<th>Smoking Exposure (n = 459)</th>
<th>P Valuea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>7.65 (1.06)</td>
<td>7.54 (1.11)</td>
<td>.85</td>
</tr>
<tr>
<td>Body mass index, mean (SD)b</td>
<td>16.64 (7.20)</td>
<td>16.35 (3.27)</td>
<td>.07</td>
</tr>
<tr>
<td>Birth weight, mean (SD), kg</td>
<td>3.16 (0.78)</td>
<td>3.18 (0.54)</td>
<td>.54</td>
</tr>
<tr>
<td>Axial length, mean (SD), mm</td>
<td>23.17 (0.93)</td>
<td>23.03 (0.92)</td>
<td>.49</td>
</tr>
<tr>
<td>Spherical equivalent, mean (SD), D</td>
<td>0.18 (1.54)</td>
<td>0.24 (1.40)</td>
<td>.051</td>
</tr>
<tr>
<td>Sex, No. (%)</td>
<td></td>
<td></td>
<td>.41</td>
</tr>
<tr>
<td>Boys</td>
<td>466 (49.5)</td>
<td>238 (51.9)</td>
<td></td>
</tr>
<tr>
<td>Girls</td>
<td>475 (50.5)</td>
<td>221 (48.1)</td>
<td></td>
</tr>
<tr>
<td>Outdoor activity time, No. (%), h1</td>
<td></td>
<td></td>
<td>.83</td>
</tr>
<tr>
<td>≤2</td>
<td>245 (26.0)</td>
<td>117 (25.5)</td>
<td></td>
</tr>
<tr>
<td>&gt;2</td>
<td>696 (74.0)</td>
<td>342 (74.5)</td>
<td></td>
</tr>
<tr>
<td>Reading distance, No. (%), cm</td>
<td></td>
<td></td>
<td>.96</td>
</tr>
<tr>
<td>≤20</td>
<td>604 (64.2)</td>
<td>294 (64.1)</td>
<td></td>
</tr>
<tr>
<td>&gt;20</td>
<td>337 (35.8)</td>
<td>165 (35.9)</td>
<td></td>
</tr>
<tr>
<td>Family income per mo. No. (%), HK$</td>
<td></td>
<td></td>
<td>&lt;.001</td>
</tr>
<tr>
<td>≤20 0000c</td>
<td>277 (29.4)</td>
<td>212 (46.2)</td>
<td></td>
</tr>
<tr>
<td>&gt;20 0000d</td>
<td>664 (70.6)</td>
<td>247 (53.8)</td>
<td></td>
</tr>
<tr>
<td>Parents’ education level, No. (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Father</td>
<td></td>
<td></td>
<td>&lt;.001</td>
</tr>
<tr>
<td>High school</td>
<td>162 (17.2)</td>
<td>124 (27.0)</td>
<td></td>
</tr>
<tr>
<td>&gt;Bachelor degree</td>
<td>779 (82.8)</td>
<td>335 (73.0)</td>
<td></td>
</tr>
<tr>
<td>Mother</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High school</td>
<td>181 (19.2)</td>
<td>137 (29.9)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>&gt;Bachelor degree</td>
<td>760 (80.8)</td>
<td>322 (70.1)</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviation: D, diopter.

a Statistical significance was tested using independent t test; χ² test and Fisher exact test were used to test the group difference in categorical data.

b Calculated as weight in kilograms divided by height in meters squared.

c Outdoor activity = outdoor exercise + outdoor leisure activity.

d US $2551.10.

Results

Cohort and Ocular Demographics

Overall, 1720 Chinese children were recruited for the ophthalmic investigations, and 320 children were excluded because of poor quality of optical coherence tomography images or because they could not complete the ophthalmic examinations. Of 1400 children who completed the examinations successfully and were included for analysis, 941 (67.2%) whose parents and other family members did not smoke were categorized into the nonexposure group and 459 (32.8%) who had at least 1 family member who was a smoker were categorized into the secondhand smoking exposure group. The mean (SD) age was 7.65 (1.09) years for children without exposure and 7.54 (1.11) years for children with exposure. Demographics of the individuals were summarized and compared between the smoking nonexposure group and exposure group in Table 1. Associations of central subfield choroidal thickness and its potential determinants were summarized in eTable 1 in the Supplement. In addition, the associations of axial length and choroidal thickness in each sector were evaluated. Of note, every 1-mm increase in axial length was associated with 18.24-μm thinning in central choroidal subfield (β = −18.24; 95% CI, −21.43 to −14.96; P < .001) (eTable 2 in the Supplement). Furthermore, demographics of excluded and included individuals were similar (eTable 3 in the Supplement). Both intra- and intergrader reliability were high with intraclass cor-
relation coefficient of 0.78 or greater (eTable 4 in the Supplement).

Choroidal Thickness in Children Exposed or Not Exposed to Smoking
In the exposure group, children's choroidal thickness was 6 μm to 8 μm thinner compared with the nonexposure group at some sectors (central subfield, inner inferior, outer inferior, inner temporal, and outer temporal) after adjusting for age, BMI, axial length, birth weight, and sex (Table 2 and eFigure in the Supplement). In addition, among 1400 children in this study, 14 children (1%) had in utero exposure to maternal smoking. We conducted a sensitivity analysis to examine the association between exposure in smoking after excluding these 14 individuals with prior in utero exposure (eTable 5 in the Supplement). The results were largely similar to our primary results.

Association of Children's Choroidal Thickness With Extent of Exposure to Smoking
The study individuals were further categorized according to the number of smokers in the family. Children's choroidal thickness was negatively correlated with the number of family smokers, ie, children with more family smokers had thinner choroids (Table 3). For an increase of 1 family smoker, children's choroid was associated with a thinning by 7.86 μm in the central subfield, 4.51 μm in the outer superior, 6.23 μm in the inner inferior, 5.59 μm in the outer inferior, 6.06 μm in the inner nasal, and 6.55 μm in the outer nasal (eTable 6 in the Supplement).

Furthermore, the study individuals were also categorized according to the quantity of cigarettes smoked of all smokers in a family per day. Children's choroidal thickness was negatively associated with quantity of family smoking in most sectors, ie, the larger quantity of family smoking, the thinner of children's choroid (Table 4). An increase of exposure to 1 secondhand cigarette smoker per day was associated with a reduction of choroid by 0.54 μm in the central subfield, 0.42 μm in the inner temporal, and 0.47 μm in the outer temporal (eTable 7 in the Supplement).

Discussion
This population-based study provides evidence that secondhand smoking was associated with thinner choroid in children aged 6 to 8 years after adjustment for age, sex, BMI, axial length, and birth weight. The affected sectors were central subfield, inner inferior, outer inferior, inner temporal, and outer temporal. In addition, we observed that more family smokers and larger quantity of family members smoking were associated with thinner choroidal thickness in most choroidal regions. A dose-dependent association of children's exposure to secondhand smoking with their choroidal thinning is therefore evident. There is a tangible impact of cigarette smoking...
Table 3. Association Between Number of Smokers and Choroidal Thickness (CT) in Each Sector

<table>
<thead>
<tr>
<th>CT at Different Sectors, μm</th>
<th>Mean (95% CI)</th>
<th>P Value for Trend</th>
<th>Adjusted R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Smoker (n = 941)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central subfield</td>
<td>273.4 (269.9-277.1)</td>
<td>0.17</td>
<td>0.06</td>
</tr>
<tr>
<td>Inner superior</td>
<td>278.6 (275.3-282.2)</td>
<td>0.70</td>
<td>0.06</td>
</tr>
<tr>
<td>Outer superior</td>
<td>267.7 (264.6-271.0)</td>
<td>0.70</td>
<td>0.06</td>
</tr>
<tr>
<td>Inner inferior</td>
<td>276.2 (272.9-280.0)</td>
<td>0.52</td>
<td>0.06</td>
</tr>
<tr>
<td>Outer inferior</td>
<td>259.7 (256.6-263.0)</td>
<td>0.42</td>
<td>0.03</td>
</tr>
<tr>
<td>Inner temporal</td>
<td>291.1 (287.6-294.5)</td>
<td>0.31</td>
<td>0.03</td>
</tr>
<tr>
<td>Outer temporal</td>
<td>288.3 (285.1-291.5)</td>
<td>0.18</td>
<td>0.03</td>
</tr>
<tr>
<td>Inner nasal</td>
<td>248.4 (245.9-252.3)</td>
<td>0.75</td>
<td>0.06</td>
</tr>
<tr>
<td>Outer nasal</td>
<td>198.2 (194.7-202.1)</td>
<td>0.47</td>
<td>0.06</td>
</tr>
<tr>
<td>Central subfield</td>
<td>264.6 (261.7-267.8)</td>
<td>0.62</td>
<td>0.03</td>
</tr>
<tr>
<td>Inner superior</td>
<td>278.6 (275.3-282.2)</td>
<td>0.75</td>
<td>0.06</td>
</tr>
<tr>
<td>Outer superior</td>
<td>267.7 (264.6-271.0)</td>
<td>0.75</td>
<td>0.06</td>
</tr>
<tr>
<td>Inner inferior</td>
<td>276.2 (272.9-280.0)</td>
<td>0.52</td>
<td>0.03</td>
</tr>
<tr>
<td>Outer inferior</td>
<td>259.7 (256.6-263.0)</td>
<td>0.42</td>
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</tr>
<tr>
<td>Inner temporal</td>
<td>291.1 (287.6-294.5)</td>
<td>0.31</td>
<td>0.03</td>
</tr>
<tr>
<td>Outer temporal</td>
<td>288.3 (285.1-291.5)</td>
<td>0.18</td>
<td>0.03</td>
</tr>
<tr>
<td>Inner nasal</td>
<td>248.4 (245.9-252.3)</td>
<td>0.75</td>
<td>0.06</td>
</tr>
<tr>
<td>Outer nasal</td>
<td>198.2 (194.7-202.1)</td>
<td>0.47</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Model 1a is adjusted for age and sex. Mean value: adjusted mean value.
Model 2b is adjusted for age, sex, body mass index, axial length, and birth weight. Mean value: adjusted mean value.

Table 4. Association Between Quantity of Family Smoking and Choroidal Thickness (CT) in Each Sector

<table>
<thead>
<tr>
<th>CT at Different Sectors, μm</th>
<th>No. of Cigarettes Smoked by All Smokers in the Family per Day, Mean (95% CI)</th>
<th>P Value for Trend</th>
<th>Adjusted R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Cigarettes (n = 941)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central subfield</td>
<td>274.4 (270.9-277.9)</td>
<td>0.01</td>
<td>0.30</td>
</tr>
<tr>
<td>Inner superior</td>
<td>279.6 (276.2-282.9)</td>
<td>0.48</td>
<td>0.29</td>
</tr>
<tr>
<td>Outer superior</td>
<td>268.6 (265.5-271.7)</td>
<td>0.16</td>
<td>0.27</td>
</tr>
<tr>
<td>Inner inferior</td>
<td>277.3 (273.9-280.7)</td>
<td>0.16</td>
<td>0.27</td>
</tr>
<tr>
<td>Outer inferior</td>
<td>260.5 (257.4-263.6)</td>
<td>0.09</td>
<td>0.29</td>
</tr>
<tr>
<td>Inner nasal</td>
<td>292.1 (288.8-295.4)</td>
<td>0.03</td>
<td>0.27</td>
</tr>
<tr>
<td>Outer nasal</td>
<td>289.3 (286.2-292.4)</td>
<td>0.02</td>
<td>0.25</td>
</tr>
<tr>
<td>Central subfield</td>
<td>265.4 (262.6-268.5)</td>
<td>0.11</td>
<td>0.31</td>
</tr>
<tr>
<td>Inner superior</td>
<td>279.6 (276.2-282.9)</td>
<td>0.48</td>
<td>0.29</td>
</tr>
<tr>
<td>Outer superior</td>
<td>268.6 (265.5-271.7)</td>
<td>0.16</td>
<td>0.27</td>
</tr>
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<td>Inner inferior</td>
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<td>0.16</td>
<td>0.27</td>
</tr>
<tr>
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<td>0.09</td>
<td>0.29</td>
</tr>
<tr>
<td>Inner nasal</td>
<td>292.1 (288.8-295.4)</td>
<td>0.03</td>
<td>0.27</td>
</tr>
<tr>
<td>Outer nasal</td>
<td>289.3 (286.2-292.4)</td>
<td>0.02</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Model 1a is adjusted for age and sex. Mean value: adjusted mean value.
Model 2b is adjusted for age, sex, body mass index, axial length, and birth weight. Mean value: adjusted mean value.
on the ocular conditions of the next generation in a family. In
Hong Kong, smoking in public areas has been banned since
January 1, 2007. Therefore, children's exposure to smoking
is mainly from the home. The findings in this study provide
further support regarding education of the public to avoid
smoking around children.

Our study evaluated the association between children's ex-
posure to secondhand smoking and their choroidal thick-
ness. A 2013 study found that there was choroidal thinning
from 301.1 μm to 270.8 μm at 3 hours after active smoking in
34 healthy adults. Another study reported significant cho-
roidal thinning from 337 μm to 311 μm 1 hour after oral nicotine
administration in 32 healthy adults. Notably, in a study of
an adult Greek population of 31 smokers who smoked lon-
ger than 25 years and 25 nonsmokers, long-term smokers had
thinner subfoveal choroidal thickness (mean [SD], 229.1 [10.2]
μm in smokers vs 257.0 [23.4] μm in nonsmokers) and around
20 μm to 30 μm thinner in the inner, outer nasal, temporal,
superior, and inferior quadrants. Of note, choroidal thin-
ing also could be investigated.

Results in this present study suggest that exposure to sec-
condhand smoking in children can affect the choroid thick-
ness with a dose-dependent effect, but the associations did not
prove it is a causative effect. There can be other confounding
factors. Of note, the thinning effect in children is on average
6 μm to 8 μm, which is relatively small compared with those
thinning in long-term smokers in adults. First, this may be due
to the relatively smaller effect from secondhand smoking. Sec-
ond, choroidal thinning in adults may take time to develop. It
is possible that long-term exposure to secondhand smoking
will lead to progressive choroidal thinning from childhood.
Whether the choroidal thinning association no longer is ap-
parent after abstinence from exposure of secondhand smok-
ing also could be investigated.

Choroidal thinning from exposure to smoking may be as-
associated with disruptive choroidal blood flow. As a
highly vascular ocular structure, the choroid is directly af-
fected by hemodynamic changes. Harmful substances pro-
duced by cigarette smoking could impair choroidal circula-
tion and decrease perfusion. Smoking products include
nicotine, carbon monoxide, carbon dioxide, and nitric oxide.
Nicotine alters choroidal blood flow and perfusion by caus-
ing long-term and systemic vasoconstriction. Inhaled carbon monoxide caused systemic hemodynamic effect. Chronic vasoconstriction, coupled with direct oxidative
damage to the endothelium, could lead to vascular drop-
out. In long-term smokers, abnormal choroidal vascular reac-
tivity to carboxgen inhalation leads to impaired endothelium
cell function, vasoconstriction, and altered endothelial
response.

Strengths and Limitations
The strength of our study includes population-based design
with relatively large sample size. Furthermore, swept-
source optical coherence tomography, which uses a longer
beam wavelength with less signal noise and deeper sweep
depth, provides better visualization of choroidal layer.

There are a few limitations in our study. First, this is a
cross-sectional study, and our findings only suggested an
association and not a causative relationship. Our findings
have to be replicated in further studies. Longitudinal stud-
ies are also warranted. Second, smoking status in our study
was documented by questionnaires, which are prone to
call bias and inaccuracy. Urinary cotinine measurement
should provide objective and solid evidence. Third, we
had to exclude a certain number of eyes with poor image
quality and missing data (18.6%), which may have intro-
duced selection bias and limited the generalizability of
results. Nevertheless, we did not find any statistically sig-
nificant differences in demographics between included and
excluded individuals (eTable 3 in the Supplement). Fourth,
the adjusted $R^2$ in our models were weak, suggesting that
other residual confounding factors could have biased or
modified the associations observed in our sample. Of note,
the strength of association of choroidal thickness with sec-
ondhand smoking was stronger in model 2 than model 1,
suggesting the association was affected more by additional
factors including axial length, birth weight, and BMI. More-
ever, results of the study were exploratory. Confirmatory
studies are necessary to evaluate the findings that were con-
considered statistically significant.

Fifth, we found the choroidal thinning only in some sec-
tors, including central subfield, temporal, and nasal region,
but not the overall mean difference. This further suggested
the association is rather weak, and thus the mean difference
could not reach significance. On the other hand, the exact
mechanism on why only some sectors were affected needs
further investigations, while it is noted that the central sub-
field has been consistently demonstrated to be affected in
the adult direct smoking. Sixth, our measurements of cho-
roidal thickness involved manual correction, which may
introduce potential bias, although our reliability assessment
showed that both intragrader and intergrader reliability
were high with intraclass correlation coefficient of 0.78 or
more.

Conclusions
In summary, we have shown an association of secondhand
smoke to thinning of choroidal thickness by 6 μm to 8 μm among
children exposed to secondhand smoking at home in Hong
Kong. The thinning was associated with the number of smokers
in the family and the quantity of smoking, suggesting a dose-
dependent relationship. While it is unknown if there is a casual
relationship from this association or if this is due to confound-
ning factors, these findings add to the potential harmful effect
of secondhand smoking on children’s ocular health and
development.
Association of Secondhand Smoking Exposure With Choroidal Thinning in Children Aged 6 to 8 Years

ORIGINAL INVESTIGATION RESEARCH

REFERENCES


For instance, previous studies have provided evidence of an 
insight into early, subclinical vascular remodeling. 

A population-based study, even in children, and offer fasci-

tographs down to the capillaries (using optical coherence 

tomography [OCT]) and choroidal vessels (especially thanks to the latest developments of swept-source OCT). These techniques can easily be applied in large population-based studies, even in children, and offer fascinating insights into early, subclinical vascular remodeling. For instance, previous studies have provided evidence of an association of retinal vessel calibers with sedentary lifestyle or nutrition in children. However, these studies did not investigate the potential outcomes of parental smoking on retinal vascular health.

In this issue of JAMA Ophthalmology, Yuan et al6 investigated the association of exposure to secondhand smoke with choroidal thickness using swept-source OCT imaging in a framework of a population-based study performed in Hong Kong. Among 1400 children aged 6 to 8 years, 33% were exposed to secondhand smoke. After adjustment for age, sex, body mass index, axial length, and birth weight, children with secondhand smoke exposure showed significantly thinner choroids than children who were not exposed (a difference of approximately 6-8 microns, depending on the location). The association appeared to be dose dependent, with choroidal thinning increasing with number of family members who smoked and increasing frequency of smoking. While strengths of this study lie in the large sample size and use of swept-source OCT, which allowed for precise and automated segmentation of the choroid, this study suffers from several limitations. In particular, exposure to secondhand smoke was determined only from questionnaires, whereas use of biomarkers (such as urine cotinine) would have been more precise and objective. More importantly, exposure to secondhand smoke is strongly associated with sociodemographic status and thus most probably with major lifestyle differences, in particular regarding diet, physical activity, or obesity. In the absence of adjustment for these other lifestyle characteristics, any interpretation deserves caution, because the association of smoking exposure with choroidal thinning might be attributable to residual confounding.