The Prevalence of Open-angle Glaucoma Among Blacks and Whites 73 Years and Older

The Salisbury Eye Evaluation Glaucoma Study

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Objective: To determine the prevalence of glaucoma among black and white persons 73 years and older.

Design: Participants in the fourth round of a population-based study, the Salisbury Eye Evaluation, were examined. The main outcome measure was glaucoma, based on optic nerve damage and visual field loss or obvious glaucomatous optic neuropathy without an available, reliable, reproducible visual field.

Results: A total of 1250 individuals (95.9% of those eligible) participated, 1233 (98.6%) of whom agreed to screening and an eye examination. The prevalence (95% confidence interval) of open-angle glaucoma was 3.4% (0.5%-6.4%) for white individuals aged 73 and 74 years, increasing to 9.4% (7.4%-11.5%) for those 75 years and older. There was no increasing prevalence in those older than 75 years. Among black persons, the prevalence (95% confidence interval) was 5.7% (0%-11.9%) in those aged 73 and 74 years and 23.2% (17.8%-28.5%) in those 75 years and older.

Conclusions: Many older individuals have open-angle glaucoma, and black persons 75 years and older have substantially higher rates than whites. These findings have important implications for public health initiatives, in which screening programs may be of benefit.

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The demographics of the United States are changing rapidly, with projections that the number of those 85 years and older will more than quadruple in the next 50 years, from 4.3 million in 2000 to 19.3 million in 2050 (Population Projections Program, Population Division, US Census Bureau, Washington, DC). This major shift in the population pyramid of the United States will place enormous demands on the health care system. Extrapolation from a recent meta-analysis of glaucoma prevalence surveys suggests that the number of individuals with glaucoma will increase nearly 50% over the next 15 years, to 3.4 million.

Glaucoma is an expensive disease to treat. Glaucoma was the principal diagnosis listed for 3 254 000 visits (an average of 26.8 visits per 100 individuals, but some individuals had multiple visits per year) among those older than 75 years in 1991 and 1992. Furthermore, the number of office visits with a principal diagnosis of glaucoma among the most elderly persons more than doubled from 1981 to 1991, far outpacing demographic changes that could have accounted for this increased use. Assuming that these visit rates remain constant, there will be more than 16 000 000 office visits for glaucoma among individuals 75 years and older in 2050.

Population-based studies of glaucoma have found that prevalence increases with age. These estimates typically show a 5- to 10-fold increase in glaucoma prevalence from the fifth to the eighth decade. However, individuals older than 75 years, and especially those in their 80s, are poorly represented in population-based studies of glaucoma prevalence. Not only do they make up a relatively small proportion of the older than 40 years cohort typically sampled, but they also are the most difficult to bring in for screening and definitive eye examinations.

The reported prevalence among whites in their 80s varies widely across these studies, with estimates as low as 1.9% to as high as 8.8%. While some of the variation seen can be explained by different methods and definitions, most of these studies used similar approaches. More important factors are likely the small sample size in the oldest age groups and potential nonresponse bias.
The estimates are even less well supported in the literature about blacks. The Baltimore Eye Survey reported an adjusted prevalence of 11.3% among 101 blacks 80 years or older. Afro-Caribbean populations have had much higher rates of open-angle glaucoma (OAG), with the Barbados Eye Study reporting a prevalence of 23.2% for participants 80 to 86 years of age (224 participants had definitive examinations), while the St Lucia, West Indies, study reported a 21% prevalence in individuals 70 years and older using a less conservative definition. The implications for potential screening strategies depend on the estimates; for example, a strategy that might result in a high false-positive referral rate with a prevalence of 10% might have a more acceptable rate with a prevalence of 25%.

We provide our findings from a population-based study of glaucoma prevalence among black and white individuals 73 years and older living on the eastern shore of Maryland.

METHODS

SUBJECTS AND GENERAL DESIGN

From September 16, 1993, through September 25, 1995, a random sample of potential participants (aged 65-84 years) was chosen from the Health Care Financing Administration Medicare Database and recruited from Salisbury, Md (on the eastern shore), to take part in the population-based Salisbury Eye Evaluation Glaucoma Study. While participants and nonparticipants in the original study were similar in most characteristics, nonparticipants were more likely to be older and to have more difficulties with activities of daily living and instrumental activities of daily living. The cohort was invited for the fourth follow-up examination, and all examinations were completed between June 21, 2001, and July 27, 2003. Figure 1 shows the status of participation from the original cohort of 2520 individuals; high participation occurred among those surviving and not in nursing homes. Individuals examined in the first round who were not examined in the fourth round of the Salisbury Eye Evaluation were on average 2.5 years older, more likely to be males (44.2% vs 40.1%; age-adjusted P=0.002), and, at baseline, had lower Mini-Mental State Examination scores (26.4 vs 27.6; age-adjusted P<0.001). They were also more likely to report fair or poor health status (36.2% vs 21.4%; age-adjusted P<0.001) and were more likely to require help with instrumental activities of daily living (18.2% vs 6.3%; age-adjusted P=0.001). These differences were expected given that the main reasons for unavailability for follow-up were participant death in the 8-year interval (644 individuals, or 50.7% of nonresponders) and nursing home admission (235 individuals, or 18.5% of nonresponders).

Previous examinations did not include threshold testing of the central visual field (VF) and questioning regarding a family history of glaucoma. All participants underwent eye examinations during the first 2 visits, and two thirds underwent eye examinations during the third visit. Examinations were performed by ophthalmologists in the first 2 rounds; in the third round, subjects were examined by either an ophthalmologist or an optometrist. If the optometrist or ophthalmologist suspected glaucoma based on the eye examination result, he or she referred the participant to a local ophthalmologist for confirmation. The follow-up examination for this study included a glaucoma history questionnaire, VF testing, optic nerve head imaging, and intraocular pressure (IOP) measurements. All subjects with abnormal follow-up examination results were referred to a fellowship-trained glaucoma specialist (D.S.F.) for a definitive examination. Informed consent was obtained from all participants before administration of any tests. All protocols of the study adhere to the tenets of the Declaration of Helsinki and were reviewed and approved by The Johns Hopkins Medical Institutions’ review board. The study was performed in compliance with the regulations of the Health Insurance Portability and Accountability Act.

EXAMINATION TECHNIQUES AND DEFINITIONS

Screening Examinations

Interview and Vision Testing. All subjects were asked whether they had ever been told they had glaucoma and, if so, if they had been treated. They were also asked if any first-degree family members had glaucoma. Visual acuity was tested using Early Treatment Diabetic Retinopathy Study charts following a standard protocol, as described previously.
Intraocular Pressure. Screening IOP was measured by an optometrist using an electronic applanation tonometer (Mentor Tonometer–TonoPen XL; Bio-Rad Inc, Santa Ana, Calif) fitted with a disposable latex cover after the administration of approximately 20 µL of 0.5% proparacaine hydrochloride in each eye for anesthesia. Two IOP readings with a coefficient of variation of less than 5% (as estimated by the electronic applanation tonometer) were taken for each eye. If the 2 readings differed by less than 5 mm Hg, then the mean of the 2 values was calculated; if they differed by 5 mm Hg or more, a third reading (with a coefficient of variation of <3%) was taken and the median recorded. The electronic applanation tonometer was calibrated before each day of use, per the instruction manual.

VF Testing. All subjects who attended the research site clinic were tested using the Humphrey Field Analyzer II (Zeiss-Humphrey Systems, Dublin, Calif), running the Swedish Interactive Thresholding Algorithm (SITA) in the fast mode. While the fast SITA seems to have greater variability than the SITA standard, it has been shown to detect glaucoma at similar rates as the SITA standard. Those who could not attend the clinic were tested at home with the frequency-doubling technology (FDT) perimeter (Zeiss-Humphrey Systems). Seventy-one persons had FDT data. Digital Imaging Digital videoimaging device (with a coefficient of variation of 0.69 (95% confidence interval [CI], 0.49-0.89) for detecting a VCDR of 0.7 or higher.

Referral Criteria

The referral criteria were as follows. (1) The subject was previously diagnosed as having glaucoma or as having a history of glaucoma drug therapy or surgery. (2) The subject had a VCDR greater than 0.7 in each eye or differing by greater than 0.2 between eyes (based on a screening image of the optic nerve obtained with a videoimaging device). (3) No videoimage was obtainable. (4) The subject had an abnormal Humphrey Field Analyzer II result that remained abnormal on repeated testing. A VF was considered abnormal if the glaucoma hemifield test result was outside normal limits, was borderline, had an abnormally high sensitivity, there was generalized reduction of sensitivity, or if the pattern standard deviation was abnormal at P<.05 or worse. (6) The subject had a visual acuity of 20/40 or worse in the better-seeing eye.

Definitive Examination

Referred patients underwent a definitive examination by a glaucoma specialist (D.S.F.), including a second fast SITA VF test with the use of a Humphrey Field Analyzer II machine, gonioscopy, and clinical examination of the optic nerve.

The glaucoma specialist measured the IOP using Goldmann applanation tonometry, at a random-start setting with a second observer to read and reset the tonometer. The average of 2 measurements was used in more than 90% of subjects, with a third reading taken and the median recorded only if the first 2 readings differed by more than 1 mm Hg (<10% of the time). Gonioscopy was performed using a 4-mirror Placido disk and without compression and, in suspect angle-closure cases, a 2-mirror Goldmann lens was also used. The VCDR was assessed clinically using a 90-diopter lens during biomicroscopy and/or a contact lens. Stereophotographs of the optic nerve head were obtained by a trained ophthalmic photographer using a stereocameras when glaucoma was suspected (Topcon America Corporation, Paramus, NJ). Stereopsis was achieved by standard decentration of the camera angle. For individuals requiring a definitive examination who were unable to undergo VF testing at the clinic, FDT perimetry (Welch Allyn, Skaneateles Falls, NY) was performed in the screening mode and repeated if any points were abnormal. The FDT was used subjectively to assist in the final diagnosis. Frequency-doubling technology tests were performed twice and, when VF abnormalities were seen in a similar pattern on both fields, the defects were considered to be consistent with glaucoma. Frequency-doubling technology test results were reviewed by both clinicians who determined the final diagnosis of glaucoma.

Defining Glaucoma

Glaucoma was defined using a previously described consensus approach. Two glaucoma-trained ophthalmologists (D.S.F. and H.D.J.) independently reviewed all data available for each eye of a subject. The review consisted of assessment of the VF and optic nerve images (using videoimaging and stereophotographs) and review of the examination findings and old medical records. Each reviewer determined if glaucoma was definitely, probably, possibly, or not present. All disagreements were adjudicated using a masked rereview by both investigators followed by an open discussion of the case. The term definite glaucoma was reserved for eyes with glaucomatous-appearing optic nerves (including excavation and loss of neuroretinal rim tissue) along with aVF defect or total cupping. Other cases that had poorer documentation of glaucomatous VF loss but in which the optic nerve had classic features of glaucoma (excavation, thin neuroretinal rim, large VCDR, and vertical cup-disc asymmetry) were classified as probable glaucoma. A subject was classified as having glaucoma if there was a definitive or probable glaucoma diagnosis in either eye.

Glaucoma was classified as OAG if the pigmented trabecular meshwork was visible for greater than 90° without compression and there were no peripheral anterior synechiae or if peripheral anterior synechiae were present but prior surgery had been performed. Angle-closure glaucoma was present if the pigmented trabecular meshwork was visible for 90° or less or peripheral anterior synechiae were present without evidence of prior surgery or inflammatory disease. Glaucomas were classified as secondary based on the medical history.

The characteristics of the more severely affected eye with available information were used to describe the severity of glaucoma (eg, the VCDR and the mean deviation on VFs). When 2 reliable VFs were available for that eye, the second VF was used. For subjects with glaucoma who had a visual acuity of 20/200 OU or worse, the cause of blindness was determined after definitive examination and medical record review. Finally, to calculate prevalence rates, definite or probable glaucoma was considered glaucoma.

RESULTS

A total of 1250 individuals (95.9% of those eligible) participated in the fourth round of the Salisbury Eye Evaluation Glaucoma Study, 1233 (98.6%) of whom agreed to screening and an eye examination with the glaucoma specialist (Figure 1). Of these 1233 individuals, 778 (63.1%) met at least 1 referral criterion, but 54 of those with borderline VFs were found on optic nerve head review to have healthy optic nerves and were not called back for...
reexamination. A total of 680 individuals were reexamined (44 did not return for a definitive examination and had only a records review), with a total of 136 subjects found to have OAG. An additional 8 subjects with angle-closure glaucoma and 6 with secondary glaucoma were also identified.

Rates of OAG were lower among those individuals aged 73 and 74 years than among those 75 years and older. After the age of 75 years, there was less evidence of an age-related increase (Table 1 and Figure 2). The prevalence of OAG was 3.4% (95% CI, 0.5%-6.4%) for white individuals aged 73 and 74 years and 9.4% (95% CI, 7.4%-11.5%) for those 75 years and older. This was also the case among black persons, who had a prevalence of 5.7% (95% CI, 0%-11.9%) in those aged 73 and 74 years and 23.2% (95% CI, 17.8%-28.5%) in those 75 years and older. Rates of OAG were lower among white persons than among black persons (Table 1).

Among subjects with glaucoma, 14.0% of the whites and 17.6% of the blacks (P = .39) had a best-corrected acuity worse than 20/40 in the better-seeing eye. Blacks with glaucoma seemed to have more severe manifestations of disease, with a significantly higher VCDR, a higher IOP, a greater mean deviation, and more frequent occurrence of bilateral disease (Table 2). The rate of blindness in black patients with glaucoma was 5.3% vs 1.3% in whites, but was not statistically significant (P = .19, Fisher exact test).

More than 80% of those diagnosed as having glaucoma had reproducible VF defects in association with a glaucomatous optic nerve, with an additional 11.8% of subjects having 1 reliable abnormal VF and optic nerve damage (Table 3).

Among those diagnosed as having glaucoma, about one third (n = 45) reported never having been told that they had glaucoma (Table 2). Nevertheless, 15 (33.3%) of these 45 subjects had been referred to an ophthalmologist for a comprehensive examination as the result of at least 1 of 3 previous visits to the Salisbury Eye Evaluation clinic. More than half of the subjects were taking glaucoma medications, although 40.7% had never been treated.

**COMMENT**

We found high rates of OAG among white and black persons 73 years and older. Approximately 1 in 5 black individuals and 1 in 10 white individuals in this age range has glaucoma.

Obtaining population-based prevalence estimates of eye disease among elderly persons is challenging because this group of individuals is less likely to partici-

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**Table 1. Prevalence of OAG by Age and Race***

<table>
<thead>
<tr>
<th>Age, y</th>
<th>No. of Subjects</th>
<th>% With OAG (95% Confidence Interval)</th>
<th>No. of Subjects</th>
<th>% With OAG (95% Confidence Interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>73-74</td>
<td>145</td>
<td>3.4 (0.5-6.4)</td>
<td>53</td>
<td>5.7 (0-11.9)</td>
</tr>
<tr>
<td>75-79</td>
<td>397</td>
<td>9.3 (6.5-12.2)</td>
<td>120</td>
<td>21.7 (14.3-29.0)</td>
</tr>
<tr>
<td>80-84</td>
<td>234</td>
<td>7.3 (3.9-10.6)</td>
<td>80</td>
<td>26.3 (16.6-35.9)</td>
</tr>
<tr>
<td>≥85</td>
<td>153</td>
<td>13.1 (7.7-18.4)</td>
<td>32</td>
<td>21.9 (7.6-36.2)</td>
</tr>
<tr>
<td>Total</td>
<td>929</td>
<td>8.5 (6.7-10.3)</td>
<td>285</td>
<td>20.0 (15.4-24.6)</td>
</tr>
</tbody>
</table>

Abbreviation: OAG, open-angle glaucoma.

*Age, test for trend P = .001. Age-adjusted test for differences between whites and blacks, P < .001.

**Table 2. Characteristics of the 136 Subjects Diagnosed as Having Open-angle Glaucoma, by Race***

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Whites (n = 79)</th>
<th>Blacks (n = 57)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y†</td>
<td>81.3 ± 4.5</td>
<td>80.4 ± 4.3</td>
</tr>
<tr>
<td>Bilateral</td>
<td>40.5</td>
<td>67.9‡</td>
</tr>
<tr>
<td>Deviation†‡</td>
<td>−6.8 ± 5.8</td>
<td>−12.5 ± 8.7‡</td>
</tr>
<tr>
<td>Pattern SD†‡</td>
<td>6.3 ± 3.6</td>
<td>7.1 ± 3.4</td>
</tr>
<tr>
<td>Vertical cup-disc ratio Value†</td>
<td>0.79 ± 0.14</td>
<td>0.88 ± 0.80‡</td>
</tr>
<tr>
<td>Asymmetry &gt;0.2</td>
<td>34.2</td>
<td>20.4</td>
</tr>
<tr>
<td>Intraocular pressure, mm Hg‡</td>
<td>16.6 ± 3.1</td>
<td>18.6 ± 6.1§</td>
</tr>
<tr>
<td>Glaucoma diagnosis and treatment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ever been told you have glaucoma</td>
<td>69.2</td>
<td>63.2</td>
</tr>
<tr>
<td>History of use of glaucoma medicines</td>
<td>61.4</td>
<td>56.1</td>
</tr>
<tr>
<td>Currently taking medicine</td>
<td>55.7</td>
<td>54.4</td>
</tr>
<tr>
<td>Previous laser treatment</td>
<td>15.2</td>
<td>24.6</td>
</tr>
<tr>
<td>Previous surgery</td>
<td>6.3</td>
<td>8.8</td>
</tr>
<tr>
<td>Visual impairment</td>
<td>12.7</td>
<td>12.3</td>
</tr>
<tr>
<td>Bilaterally blind</td>
<td></td>
<td>1.3</td>
</tr>
</tbody>
</table>

*Data are given as percentage of each group unless otherwise indicated.
†Data are given as mean ± SD.
‡P < .001.
§P < .05.

Best-corrected visual acuity in the better-seeing eye, 20/200 or worse.
pate in research studies. We believe that the findings from our study population are relatively representative of all older individuals in the Salisbury region because of our response rates over time. In any case, those who did not return were more likely to be older, to have more health problems, and to be more frail. If anything, the rates of glaucoma may be even higher if the nonresponders had been included.

Previous studies among whites have reported a prevalence of OAG among white persons older than 75 years to be as low as 2% or as high as about 8% (Table 4). Our rate is slightly higher than the higher estimate from the Vision Impairment Project, but the Blue Mountains Eye Study reported similarly high rates among white persons in the 80- to 84-year age range. None of these previous studies reported exactly what the participation rates were in these older age ranges, and it may have been the case that those with known eye diseases were less likely to participate because they were already under care.

The Barbados Eye Study reported OAG rates for blacks comparable to those in the present study, with 52 (23.2%) of 224 persons aged 80 to 86 years identified as having definite or probable OAG. Similarly high rates were reported for Hispanics older than 80 years, with an estimated prevalence of primary OAG of 22%. The Baltimore Eye Survey described 13 of 101 blacks 80 years and older as having OAG (adjusted prevalence of 13.3%).

Our estimate is consistent with that of the Barbados Eye Study. More than 20% of black persons older than 75 years had glaucoma in this study. Medical record review and review of photographs and VFs were performed without any knowledge of the race of the study participant. More aggressive screening for glaucoma in this population should be considered given the high pretest probability of disease and the known benefit of treatment in slowing the progression of the disease.

The present study has some limitations. The sample size, while higher in this age group than in other studies, is still not large. We enrolled a total of 112 black persons older than 80 years, resulting in a relatively wide 95% CI for the estimate of primary OAG prevalence in this group (Table 1). In addition, while the response rate for the present study was relatively high for persons in this age group, it is possible that those who did not respond may have different rates of glaucoma than those who did respond. Follow-up rates since the initial round have been more than 90%. We did not examine nursing home residents from the original cohort. These subjects likely have more eye disease than their community-dwelling counterparts, so our estimates cannot be applied to populations that include nursing home residents. Finally, because VFs were frequently abnormal and unreliable, using a "one-size-fits-all" definition of glaucoma was difficult in this population. Still, if we had applied a suggested standardized approach to defining glaucoma, the overall estimated prevalence of glaucoma would have been reduced by only 2.7%, from 11.2% to 8.5%. The rates of OAG among the oldest individuals remain high regardless of the criteria used. Furthermore, as noted in Table 2, individuals defined as having glaucoma in this study had a mean VCDR of 0.79 for whites and 0.88 for blacks, and 92.7% had disc and VF abnormalities.

Blacks in our study may have had more severe glaucoma compared with whites, with a significantly larger VCDR, a higher IOP, a greater mean deviation on the VF, and more bilateral disease (Table 2). The rate of blindness in black patients with glaucoma was 5.3% vs 1.3% in whites, but was not statistically significant (P = .19, Fisher exact test). The Baltimore Eye Survey found that glaucoma was responsible for more blindness among black subjects. Whether this represents an earlier age of onset (and, therefore, longer duration), later diagnosis (and, therefore, less effect of treatment), or a more rapidly progressive course among black individuals with glaucoma cannot be determined in this study.

### Table 3. Diagnostic Criteria for the 136 Subjects Diagnosed as Having Open-angle Glaucoma

<table>
<thead>
<tr>
<th>Criterion</th>
<th>No. (%) of Subjects*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two abnormal visual field test results and optic nerve damage characteristic of glaucoma in at least 1 eye†</td>
<td>110 (80.9)</td>
</tr>
<tr>
<td>One abnormal visual field test result and optic nerve damage characteristic of glaucoma in at least 1 eye (second field not tested)†</td>
<td>16 (11.8)</td>
</tr>
<tr>
<td>Borderline visual field test results with optic nerve damage characteristic of glaucoma</td>
<td>2 (1.5)</td>
</tr>
<tr>
<td>Normal visual field test results with marked asymmetry</td>
<td>1 (0.7)</td>
</tr>
<tr>
<td>Optic nerve damage characteristic of glaucoma, no visual field testing done, and participant’s medical record review confirms the diagnosis</td>
<td>5 (3.7)</td>
</tr>
<tr>
<td>Optic nerve damage characteristic of glaucoma, no visual field testing done, and vertical cup-disc ratio &gt; 0.85‡</td>
<td>2 (1.5)</td>
</tr>
</tbody>
</table>

*Percentages do not total 100 because of rounding.
†An abnormal visual field is indicated by a glaucoma hemifield test result outside of normal limits or pattern SD of less than 5%.
‡Optic nerve damage characteristic of glaucoma is indicated by a vertical cup-disc ratio of greater than 0.6, vertical cup-disc ratio asymmetry of greater than 0.2, or the presence of notching.

### Table 4. Summary of Previous Prevalence Estimates of Open-angle Glaucoma Among Elderly Persons*

<table>
<thead>
<tr>
<th>Age, y</th>
<th>Blacks</th>
<th>Whites</th>
<th>Barbados Eye Study</th>
<th>Melbourne, Australia</th>
<th>Sydney, Australia</th>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70–79</td>
<td>349 (9.2)</td>
<td>631 (2.9)</td>
<td>883 (13.8)</td>
<td>445 (5.8)</td>
<td>959 (4.7)</td>
</tr>
<tr>
<td>≥80</td>
<td>101 (11.3)</td>
<td>206 (2.2)</td>
<td>224 (23.2)</td>
<td>162 (7.4)</td>
<td>367 (11.4)</td>
</tr>
</tbody>
</table>

*Data are given as the total (percentage) examined in each age group in each of the studies listed. Adjusted prevalence (accounting for persons who did not attend the definitive examination). For Beaver Dam, Wis, the prevalence for those 75 years and older was approximately 7%.
In summary, we found that 9.4% of white persons and 23.2% of black persons older than 75 years have OAG, and OAG prevalence seems to stabilize after this age. The high rate of OAG among these older populations has important implications for public health initiatives. Screening programs may be of benefit for these individuals. Furthermore, even though this population had participated in a vision research study for nearly a decade, many were undiagnosed (even though a third of these individuals had been referred for additional care) and nearly half were untreated. More research is needed to determine how best to screen for and bring into treatment these individuals.

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REFERENCES