Longitudinal Prevalence of Major Eye Diseases

Paul P. Lee, MD, JD; Zachary W. Feldman, BA; Jan Ostermann, PhD; Derek S. Brown, MA; Frank A. Sloan, PhD

Objective: To describe the prevalence across time of 3 chronic eye diseases among a representative cohort of elderly subjects.

Study Design: Longitudinal observation of Medicare claims.

Population: A random sample of Medicare beneficiaries 65 years and older, nationally representative at baseline.

Main Outcome Measures: Diagnosis of diabetic retinopathy, glaucoma, and age-related macular degeneration.

Methods: Beneficiaries were followed from 1991 to 1999 unless mortality or enrollment in a health maintenance organization for 6 or more months in a year intervened. Claims data were analyzed for the presence of codes from the International Classification of Diseases, Ninth Revision, Clinical Modification, indicating 1 of the 3 conditions. Transitions between severity stages were also evaluated.

Results: Of 20325 beneficiaries in 1991, 10476 were available for analysis in 1999. The prevalence of diabetes mellitus increased from 14.5% in 1991 to 25.6% by 1999, with diabetic retinopathy among persons with diabetes mellitus increasing from 6.9% to 17.4%. Primary open-angle glaucoma increased from 4.6% to 13.8%. The percentage of glaucoma suspects increased from 1.5% to 6.5%, as did the percentage of narrow-angle glaucoma (0.7%-2.7%). The prevalence of age-related macular degeneration increased from 5.0% to 27.1%. Overall, the proportion of subjects with at least 1 of these 3 diseases increased from 13.4% to 45.4%.

Conclusions: The clinical diagnosis of major chronic eye diseases associated with aging increased dramatically in a longitudinal sample. At the end of 9 years, nearly half of the surviving Medicare beneficiaries had at least 1 of these diseases.

Arch Ophthalmol. 2003;121:1303-1310

Many elderly individuals develop eye diseases, most of which have causes that are either preventable or treatable. Spending by and on behalf of elderly people represents a considerable burden, both to insurers and to the elderly patients themselves. Of the 44 million annual visits to ophthalmologists in 1991, more than half were by elderly persons. The US population 65 years and older will grow from 34.4 million in 2000 to 70.3 million by 2030. The number of persons older than 85 years will grow slightly faster: from 4.1 to 8.9 million, implying further increases in the prevalence of major eye diseases.

Information on the prevalence of these diseases comes mainly from sectional studies of populations in defined geographic areas. In these studies, the prevalence of each disease has been analyzed separately. Limited studies are available on the incidence of eye diseases or on longitudinal changes within a population. Information from limited geographic areas may be problematic for generalization and thus may not fully reflect the importance of chronic eye diseases for purposes of payment, public health monitoring, or resource allocation. In addition, by analyzing eye diseases separately, studies are not able to measure the co-occurrence of these diseases in the population. Furthermore, the expense of conducting population-based studies limits the total number of persons enrolled, particularly for important demographic subgroups.

The use of existing databases offers an alternative approach to estimating disease prevalence. A recent national study of utilization of eye care services using the Medi-
related macular degeneration (ARMD) in a nationally rep-
diagnosed diabetic retinopathy, glaucoma, and age-
study, we present longitudinal data on the prevalence of
cross-sectional rather than longitudinal in nature. In this
ation on diagnosed disease prevalence, but the analysis was
claims database36 provided important new informa-
Medicare health maintenance organizations for more than 6 months were
1994, or 1999, with linked Medicare vital statistics data. For the analysis
Survey were 65 years or older at their first interview in 1982, 1984, 1989,
Sample selection process. Persons enrolled in the National Long-Term Care
entire population 65 years and older.
caused the NLTCS was originally designed for studying disabil-
Center for Demographic Studies (Durham, NC). Be-
the National Long-Term Care Survey (NLTCS). The NLTCS is
at the time of entry into the study and who were enrolled in
baseline sample were enrolled in an HMO for more than 6
mean of 51 individuals per year). Approximately 6% of the
service plans was added back into each year's sample (a
individuals who subsequently reenrolled in Medicare fee-for-
ment files. The prevalence data included all individuals who
in a year. This was required because Medicare did not
maintenance organizations (HMOs) for more than 6 months
in a year. This required because Medicare did not receive utilization information about beneficiaries in HMOs
until after 1999. Whether a beneficiary belonged to an HMO
each month was obtained from separate Medicare enrollment
files. The prevalence data included all individuals who
were enrolled in Medicare fee-for-service plans for more than 6 months in a year. Attrition due to enrollment in
HMOs was permitted to be temporary; the small number of
individuals who subsequently reenrolled in Medicare fee-for-
service plans was added back into each year's sample (a
mean of 51 individuals per year). Approximately 6% of the
baseline sample were enrolled in an HMO for more than 6
months in 1991; by 1999, more than 17% of the surviving
individuals were enrolled in an HMO for more than half of
the year. The number of persons excluded from the analysis
as a result of HMO coverage varied each year and ranged
from 1319 in 1991 to 2193 in 1999.

INITIAL SAMPLE SELECTION

We used the NLTCS for our study sample selection and to iden-
tify beneficiary links to Medicare claims. The purpose of this
study was to examine the longitudinal rates of diagnosed eye
disease in our population. To do this, we used Medicare claims
data. We limited our study population to individuals with claims
from 1991 onward, the year in which Medicare part B data (mainly
physician data) first contained diagnostic informa-
tion. Thus, our study population consisted of persons 65 years
and older as of 1991.

Our initial sample selection process is shown in the
Figure. Our data spanned the years 1991 to 1999, yielding a
maximum of 9 years of data for subjects who were alive for
the full period. We were able to match 41931 people to
Medicare vital statistics records to obtain the exact dates of
birth and death (when applicable). Next, we eliminated
11023 individuals who were included in the NLTCS sample
in 1982, 1984, or 1989 but died before the beginning of our
study period in 1991. We also eliminated 8238 individuals
who were younger than 65 years in 1991—persons who
became part of the NLTCS sample in 1994 or 1999—because
they were not age eligible for Medicare and our study
focused on the elderly population. We removed 573 indi-
viduals who died between January 1, 1991, and June 30,
1991, for whom we had less than 6 months of claims data. Of
the remaining sample, we were unable to match 98 indi-
viduals to 1991-1999 Medicare enrollment records for
unknown reasons; 338 individuals also had incomplete
enrollment data (missing data for 1 or more years) between
1991 and 1999. Finally, we removed 17 people with duplic-
ate and conflicting enrollment records, leaving us with a
net eligible sample of 21644 Medicare beneficiaries.

We also removed from the annual prevalence calculations
individuals who were enrolled in Medicare health
maintenance organizations (HMOs) for more than 6 months
in a year. This required because Medicare did not receive utilization information about beneficiaries in HMOs
until after 1999. Whether a beneficiary belonged to an HMO
each month was obtained from separate Medicare enrollment
files. The prevalence data included all individuals who
were enrolled in Medicare fee-for-service plans for more than 6 months in a year. Attrition due to enrollment in
HMOs was permitted to be temporary; the small number of
individuals who subsequently reenrolled in Medicare fee-for-
service plans was added back into each year's sample (a
mean of 51 individuals per year). Approximately 6% of the
baseline sample were enrolled in an HMO for more than 6
months in 1991; by 1999, more than 17% of the surviving
individuals were enrolled in an HMO for more than half of
the year. The number of persons excluded from the analysis
as a result of HMO coverage varied each year and ranged
from 1319 in 1991 to 2193 in 1999.

IDENTIFYING THE DISEASE COHORTS

Using the baseline sample of 21644 subjects, less HMO en-
rollees, we identified 3 disease cohorts: diabetes, glaucoma,
and ARMD. We searched for specific diagnosis codes (pri-
mary or secondary) from the International Classification of
Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) in
7 different types of Medicare claims files for the 1984-1999
period: carrier (physician supplier/part B), outpatient, inpa-
tient, skilled nursing, home health agency, hospice, and
durable medical equipment (for diabetes only). We selected the
diabetes sample using the following criteria: 2 or more claims
of nonhospital services or 1 or more claims of hospital, hos-
pice, or skilled-nursing services.37
Although the reported prevalence figures were limited to the 1991-1999 period, we used earlier Medicare part A claims information (outpatient, inpatient, skilled nursing, home health agency, and hospice) for individuals who were eligible for Medicare prior to 1991 to more accurately date their onset of disease. Because individuals may have been given a diagnosis prior to 1991, using the 1984-1990 data to establish prior diagnoses minimized left censoring (with the index conditions dating the onset to points after an unobserved prior medical diagnosis) and substantially reduced the error rate during the first period of observation, in which initial prevalence rates may have been too low. First diagnoses for nearly a third of patients with diabetes were recorded before 1991. Among patients with diagnosed glaucoma and ARMD, only about 1% had diagnoses recorded before 1991. The numerator of patients for the analysis was identified using the ICD-9-CM diagnosis codes in Table 1.

PREVALENCE

We specified disease onset using the earliest ICD-9-CM diagnosis code found in the claims. Once an individual was identified with a disease, he or she remained in a disease cohort for the remainder of the analysis. We did, however, allow for disease progression into subgroups, as indicated in the Tables. The diagnosis of a more severe condition was treated as the transition date into a different disease subgroup. For example, once a diabetic patient with background diabetic retinopathy had a claim listing proliferative diabetic retinopathy, we placed that individual into the latter subgroup. Additionally, we allowed for coexistence among the 3 diseases. Annual disease-specific prevalence rates were calculated using the number of persons alive and not in an HMO for at least 6 months during the year as the denominator.

RESULTS

In 1991, our sample of Medicare beneficiaries was representative of the United States population 65 years and older (Table 2). Sample proportions by age group, sex, and race were very similar to those of the entire US population. Aging of the study sample between 1991 and 1999 due to the longitudinal nature of our analysis caused the age distribution in 1999 to differ from that of the US population 65 years and older, whereas the sample distribution by sex and race remained relatively unchanged.

There was substantial mortality-related attrition in our sample between 1991 and 1999 (Table 3). Annual mortality increased from 5.2% in 1992 to 7.8% in 1999; 41.5% of the sample died between 1991 and 1999. The number of persons covered by an HMO for at least 6 months during any given year increased monotonically between 1991 and 1999, even as the total sample size decreased. The percentage of persons covered by an HMO for at least 6 months increased from 6.1% in 1991 to 17.3% in 1999. Excluding deaths occurring prior to July 1 of each year and persons covered by an HMO for at least 6 months during the year, the sample size decreased by almost 50%, from 20325 in 1991 to 10476 in 1999.

Prevalence rates of diabetes mellitus and diabetes-related eye diseases increased considerably during the observational period (Table 4). The prevalence of diabetes mellitus increased from 14.5% in 1991 to 25.6% in 1999. Among persons with diabetes, the prevalence of diabetic retinopathy or macular edema increased from 6.9% to 17.4%. The most common form was background diabetic retinopathy, accounting for about 80% of all retinopathy cases. The prevalence of proliferative diabetic retinopathy almost doubled, from 2.1% to 3.8% of persons with diagnosed diabetes, whereas that of macular edema increased 5-fold, from 0.4% to 2.1%.

Glaucoma prevalence increased from 8.4% to 25.4%, a 3-fold increase in 9 years (Table 5). Most persons were diagnosed as having primary open-angle glaucoma (POAG). The prevalence of POAG increased from 4.6% to 13.8% in 9 years. That of narrow-angle glaucoma increased from 0.7% to 2.7%, and glaucoma suspects from 1.5% to 6.5%.

The prevalence of ARMD increased more than 5-fold: from 5.1% to 27.1% (Table 6). Dry ARMD, the atrophic form of the disease, was most prevalent, increasing from 1.4% to 13.6% in 1999. The prevalence of wet ARMD, the exudative and most severe form, increased 10-fold: from 0.5% to 5.2%. Wet ARMD almost doubled as a percentage of all ARMD cases, from 10.6% in 1991 to 19.0% in 1999.

Almost half (45.4%) of all respondents had developed at least 1 of the 3 diseases by 1999 (Table 7). Most of these individuals had either glaucoma or ARMD. However, about one third of persons with glaucoma also had ARMD, and vice versa; almost two thirds of those with diabetic retinopathy were diagnosed as having ARMD and/or glaucoma. The prevalence of persons with all 3 diseases increased 17-fold, from only 0.03% to 0.58%.

COMMENT

One of our major study goals was to determine the usefulness of this longitudinal, nationally representative database to provide estimates of prevalence rates (and in-
cidence rates, described in our companion article\(^3\) of eye conditions beyond those already assessed in population-based studies. To provide confidence in the estimates of those less common conditions, we wanted to validate the database using diseases for which comparable population-based estimates exist, namely, ARMD, diabetic retinopathy, and glaucoma. The results of the analyses demonstrate that the estimates from this database fall within the range of population-based study estimates, so those for the less common conditions are likely realistic estimates of the disease burden in the Medicare population.

Glaucoma, ARMD, and diabetic retinopathy are 3 of the 4 most prevalent eye diseases (the other being cataract) in the elderly population. In 1999, among the surviving members of our sample of persons 65 years and older at baseline who were not enrolled in an HMO for most of that year, nearly half had been diagnosed as having at least 1 of these 3 diseases. The prevalence rate for each disease increased appreciably in the 9-year period.

### Table 2. Comparison of the Distribution by Age, Sex, and Race in the Medicare Sample and US Population

<table>
<thead>
<tr>
<th>Source Population</th>
<th>Men, %</th>
<th>Women, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>White</td>
<td>Minority</td>
</tr>
<tr>
<td>1998, US Census Bureau</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>65-74</td>
<td>21.2</td>
<td>2.7</td>
</tr>
<tr>
<td>75-84</td>
<td>12.5</td>
<td>1.3</td>
</tr>
<tr>
<td>≥85</td>
<td>3.1</td>
<td>0.4</td>
</tr>
<tr>
<td>Total</td>
<td>36.9</td>
<td>4.4</td>
</tr>
<tr>
<td>1991, Medicare claims</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>65-74</td>
<td>19.8</td>
<td>2.1</td>
</tr>
<tr>
<td>75-84</td>
<td>10.9</td>
<td>1.1</td>
</tr>
<tr>
<td>≥85</td>
<td>3.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Total</td>
<td>34.5</td>
<td>3.8</td>
</tr>
<tr>
<td>1999, Medicare claims</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>65-74</td>
<td>1.9</td>
<td>0.2</td>
</tr>
<tr>
<td>75-84</td>
<td>23.7</td>
<td>2.4</td>
</tr>
<tr>
<td>≥85</td>
<td>7.0</td>
<td>0.9</td>
</tr>
<tr>
<td>Total</td>
<td>32.5</td>
<td>3.6</td>
</tr>
</tbody>
</table>

Abbreviation: HMO, health maintenance organization; NA, not applicable.

*Data are presented as number of patients.

### Table 3. Sample Selection for Prevalence Calculations*

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting sample size</td>
<td>21 644</td>
<td>21 644</td>
<td>21 644</td>
<td>21 644</td>
<td>21 644</td>
<td>21 644</td>
<td>21 644</td>
<td>21 644</td>
<td>21 644</td>
</tr>
<tr>
<td>Exclusions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Died before July 1</td>
<td>NA</td>
<td>1116</td>
<td>2216</td>
<td>3368</td>
<td>4583</td>
<td>5753</td>
<td>6836</td>
<td>7902</td>
<td>8975</td>
</tr>
<tr>
<td>HMO coverage for &gt;6 mo</td>
<td>1319</td>
<td>1345</td>
<td>1355</td>
<td>1435</td>
<td>1549</td>
<td>1750</td>
<td>1968</td>
<td>2156</td>
<td>2193</td>
</tr>
<tr>
<td>Net sample size</td>
<td>20 325</td>
<td>19 183</td>
<td>18 073</td>
<td>16 841</td>
<td>15 512</td>
<td>14 141</td>
<td>12 840</td>
<td>11 586</td>
<td>10 476</td>
</tr>
</tbody>
</table>

*Data are presented as percentage of subjects with diabetes unless otherwise indicated.

### Table 4. Prevalence of Diabetes Mellitus and Diabetic Retinopathy*

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>20 325</td>
<td>19 183</td>
<td>18 073</td>
<td>16 841</td>
<td>15 512</td>
<td>14 141</td>
<td>12 840</td>
<td>11 586</td>
<td>10 476</td>
</tr>
<tr>
<td>Diabetes mellitus, % of total sample</td>
<td>14.5</td>
<td>16.5</td>
<td>18.1</td>
<td>19.7</td>
<td>21.2</td>
<td>22.6</td>
<td>23.7</td>
<td>25.0</td>
<td>25.6</td>
</tr>
<tr>
<td>Proliferative diabetic retinopathy</td>
<td>2.1</td>
<td>2.2</td>
<td>2.2</td>
<td>2.6</td>
<td>3.1</td>
<td>3.4</td>
<td>3.5</td>
<td>3.7</td>
<td>3.8</td>
</tr>
<tr>
<td>Background diabetic retinopathy</td>
<td>5.4</td>
<td>7.2</td>
<td>8.6</td>
<td>10.0</td>
<td>11.1</td>
<td>12.3</td>
<td>13.5</td>
<td>13.9</td>
<td>15.1</td>
</tr>
<tr>
<td>Macular edema</td>
<td>0.4</td>
<td>0.6</td>
<td>0.8</td>
<td>0.8</td>
<td>1.2</td>
<td>1.3</td>
<td>1.5</td>
<td>1.8</td>
<td>2.1</td>
</tr>
<tr>
<td>Any diabetic retinopathy or macular edema</td>
<td>6.9</td>
<td>9.0</td>
<td>10.5</td>
<td>12.0</td>
<td>13.4</td>
<td>14.2</td>
<td>15.6</td>
<td>16.2</td>
<td>17.4</td>
</tr>
<tr>
<td>Any diabetic retinopathy or macular edema, % of total sample</td>
<td>1.0</td>
<td>1.5</td>
<td>1.9</td>
<td>2.4</td>
<td>2.8</td>
<td>3.2</td>
<td>3.7</td>
<td>4.0</td>
<td>4.4</td>
</tr>
</tbody>
</table>

*Data are presented as percentage of subjects with diabetes unless otherwise indicated.
during which the median age rose from 74 to 81 years. Moreover, the prevalence of diagnosed diabetes increased to slightly more than a quarter of the population, nearly doubling in 9 years.

There were 34.4 million people 65 years and older in 2000. The 3 major eye diseases that we analyzed in this study are common among the elderly population. Applying our prevalence rates to this cohort, we estimate that 6.5 million persons had at least 1 of the 3 diseases in that year: 3.8 million persons had glaucoma, 490,000 had diabetic retinopathy, and 2.8 million had ARMD. In addition, 671,000 persons had 2 of these diseases, and 22,000 had all 3.

Our documented increases in prevalence rates were due to the diagnosis of new disease (an increase in the true disease prevalence) as well as delayed detection of existing disease. Thus, the increases in true underlying disease prevalence may have been somewhat less than the changes we reported. Our prevalence rates were based on rates of diagnosis using the criteria of prevailing medical practice. By contrast, previous studies of the prevalence of these diseases have been based on population screening with explicit and standardized diagnostic criteria, which may be different from the standards used in practice by community health care professionals. Unlike population-based studies in a specific geographic area, our database provides national coverage for the Medicare population. Any discrepancies could also be due to the different populations covered in this study relative to the previous geographically based studies.

Only 1 national study used physician/part B Medicare claims data to estimate prevalence rates of eye diseases in elderly subjects. This cross-sectional study obtained a prevalence ranging from 1.4% (1991) to 2.6% (1998) for diabetic retinopathy, 6.8% (1991) to 9.3% (1998) for glaucoma, and 3.2% (1991) to 4.5% (1998) for ARMD. The fundamental difference between the study by Ellwein and Urato and ours is that we used longitudinal methods following the same cohort of beneficiaries for a 9-year period, whereas theirs used individual

---

**Table 5. Prevalence of Glaucoma**

<table>
<thead>
<tr>
<th>Year</th>
<th>Sample Size</th>
<th>Without Glaucoma</th>
<th>Glaucoma Suspects</th>
<th>Narrow-Angle Glaucoma</th>
<th>POAG</th>
<th>Other Glaucoma</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>20,325</td>
<td>91.6</td>
<td>1.5</td>
<td>0.7</td>
<td>4.6</td>
<td>1.5</td>
</tr>
<tr>
<td>1992</td>
<td>19,183</td>
<td>88.9</td>
<td>2.3</td>
<td>1.0</td>
<td>6.1</td>
<td>1.8</td>
</tr>
<tr>
<td>1993</td>
<td>18,073</td>
<td>86.7</td>
<td>2.9</td>
<td>1.3</td>
<td>7.2</td>
<td>1.9</td>
</tr>
<tr>
<td>1994</td>
<td>16,841</td>
<td>84.5</td>
<td>3.6</td>
<td>1.5</td>
<td>8.4</td>
<td>2.0</td>
</tr>
<tr>
<td>1995</td>
<td>15,512</td>
<td>82.0</td>
<td>4.2</td>
<td>1.8</td>
<td>9.9</td>
<td>2.1</td>
</tr>
<tr>
<td>1996</td>
<td>14,141</td>
<td>79.8</td>
<td>4.8</td>
<td>2.1</td>
<td>11.0</td>
<td>2.3</td>
</tr>
<tr>
<td>1997</td>
<td>12,840</td>
<td>77.9</td>
<td>5.5</td>
<td>2.3</td>
<td>12.0</td>
<td>2.4</td>
</tr>
<tr>
<td>1998</td>
<td>11,586</td>
<td>76.0</td>
<td>6.0</td>
<td>2.6</td>
<td>13.0</td>
<td>2.4</td>
</tr>
<tr>
<td>1999</td>
<td>10,476</td>
<td>74.6</td>
<td>6.5</td>
<td>2.7</td>
<td>13.8</td>
<td>2.4</td>
</tr>
</tbody>
</table>

**Table 6. Prevalence of ARMD**

<table>
<thead>
<tr>
<th>Year</th>
<th>Sample Size</th>
<th>Without ARMD</th>
<th>Unspecified ARMD</th>
<th>Dry ARMD</th>
<th>Wet ARMD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>20,325</td>
<td>95.0</td>
<td>3.1</td>
<td>1.4</td>
<td>0.5</td>
</tr>
<tr>
<td>1992</td>
<td>19,183</td>
<td>91.6</td>
<td>4.8</td>
<td>2.6</td>
<td>0.9</td>
</tr>
<tr>
<td>1993</td>
<td>18,073</td>
<td>88.9</td>
<td>6.0</td>
<td>3.6</td>
<td>1.4</td>
</tr>
<tr>
<td>1994</td>
<td>16,841</td>
<td>86.4</td>
<td>6.7</td>
<td>5.1</td>
<td>1.8</td>
</tr>
<tr>
<td>1995</td>
<td>15,512</td>
<td>83.3</td>
<td>7.5</td>
<td>6.9</td>
<td>2.3</td>
</tr>
<tr>
<td>1996</td>
<td>14,141</td>
<td>80.7</td>
<td>7.9</td>
<td>1.4</td>
<td>3.0</td>
</tr>
<tr>
<td>1997</td>
<td>12,840</td>
<td>77.9</td>
<td>8.0</td>
<td>10.2</td>
<td>3.9</td>
</tr>
<tr>
<td>1998</td>
<td>11,586</td>
<td>75.2</td>
<td>8.1</td>
<td>12.2</td>
<td>4.5</td>
</tr>
<tr>
<td>1999</td>
<td>10,476</td>
<td>72.9</td>
<td>8.3</td>
<td>13.6</td>
<td>5.2</td>
</tr>
</tbody>
</table>

**Table 7. Joint Prevalence of Diabetic Retinopathy, Glaucoma, and ARMD**

<table>
<thead>
<tr>
<th>Year</th>
<th>Sample Size</th>
<th>Without Diabetic Retinopathy, Glaucoma, or ARMD</th>
<th>Diabetic Retinopathy Only</th>
<th>Glaucoma Only</th>
<th>ARMD Only</th>
<th>Diabetic Retinopathy and Glaucoma</th>
<th>Diabetic Retinopathy and ARMD</th>
<th>Glaucoma and ARMD</th>
<th>Diabetic Retinopathy, Glaucoma, and ARMD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>20,325</td>
<td>86.6</td>
<td>0.7</td>
<td>7.5</td>
<td>4.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.7</td>
<td>0.0</td>
</tr>
<tr>
<td>1992</td>
<td>19,183</td>
<td>81.2</td>
<td>1.0</td>
<td>9.2</td>
<td>6.5</td>
<td>0.2</td>
<td>0.1</td>
<td>0.6</td>
<td>0.1</td>
</tr>
<tr>
<td>1993</td>
<td>18,073</td>
<td>76.7</td>
<td>1.2</td>
<td>10.7</td>
<td>8.5</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>1994</td>
<td>16,841</td>
<td>72.7</td>
<td>1.4</td>
<td>12.0</td>
<td>10.0</td>
<td>0.4</td>
<td>0.4</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td>1995</td>
<td>15,512</td>
<td>68.1</td>
<td>1.5</td>
<td>13.2</td>
<td>11.8</td>
<td>0.5</td>
<td>0.5</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>1996</td>
<td>14,141</td>
<td>64.5</td>
<td>1.5</td>
<td>14.1</td>
<td>13.1</td>
<td>0.6</td>
<td>0.5</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td>1997</td>
<td>12,840</td>
<td>60.9</td>
<td>1.6</td>
<td>14.8</td>
<td>14.6</td>
<td>0.7</td>
<td>0.5</td>
<td>0.9</td>
<td>0.5</td>
</tr>
<tr>
<td>1998</td>
<td>11,586</td>
<td>57.3</td>
<td>1.7</td>
<td>15.5</td>
<td>16.1</td>
<td>1.6</td>
<td>0.6</td>
<td>0.9</td>
<td>0.6</td>
</tr>
<tr>
<td>1999</td>
<td>10,476</td>
<td>54.6</td>
<td>1.6</td>
<td>15.8</td>
<td>17.3</td>
<td>1.7</td>
<td>0.8</td>
<td>1.1</td>
<td>0.6</td>
</tr>
</tbody>
</table>
cross sections from the 5% Medicare sample for each year. In addition, we based diagnoses on all types of Medicare claims rather than on part B claims only. At baseline, our estimates were somewhat higher for glaucoma and ARMD but slightly lower for diabetic retinopathy; these higher estimates reflect our use of 1984-1990 data on diagnoses and our use of all types of Medicare claims files.

Our estimates are considerably higher for at least 2 reasons. First, because we based our prevalence estimates on diagnoses from 1984 onward rather than data from a single year, we were able to include individuals with a particular disease who may not have had an eye examination during the study year or who did not have the diagnosis coded on that year’s visit(s) and thus were not reflected in the claims data; being able to follow claims and diagnoses across time is a major advantage of our longitudinal approach. Second, our estimates reflect the effect of population aging in a longitudinal cohort, whereas the cross-sectional study method will result in an increasingly younger cohort in comparison with longitudinal data across time and will therefore have a lower prevalence of age-related eye diseases.

It is important to place these estimates in context with prior population-based studies to ascertain comparability of the results. Estimates of diabetes prevalence in persons 75 years and older from the National Health and Nutrition Examination Survey III (1988-1994) show a prevalence of 13.2% for diagnosed diabetes and 5.7% for undiagnosed diabetes, for a total prevalence of 18.9%. This compares with 25.6% in our similarly aged sample in 1999. In the National Health and Nutrition Examination Survey, the diagnosis of diabetes was from patient self-report as well as screening for fasting blood glucose levels in subjects without known diabetes. The reason for the higher measured rate in our study may be the oversampling of individuals 95 years and older and the exclusion of Medicare beneficiaries enrolled in HMOs.

In population-based studies, the prevalence of diabetic retinopathy as a percentage of persons with diabetes ranged from 21% to 47% with a median value of 36.8%, appreciably higher than our figure of 17.4% in 1999. In these studies, however, the prevalence of diabetes was generally lower than in our sample (25.6% in 1999). As a result, the percentage of persons in our entire cohort with diabetic retinopathy was similar to that measured in previous studies. The disparity in diabetes and diabetic retinopathy rates between our study and those of population-based studies most likely reflects at least 2 factors. First is the older age of the patients in our sample. Although the prevalence of diabetes rises as the population ages, individuals diagnosed as having diabetes at an older age are less likely to develop retinopathy. Second are issues related to the under-diagnosis of diabetic retinopathy among community-based health care professionals as compared with a photographic standard.

The prevalence of POAG has generally been reported according to race and age group in previous studies. To compare these results with ours, we weighted their reported rates according to the race and age distribution of our sample in 1999. The weighted prevalence in these studies ranged from 2.4% to 6.6% in white subjects (median, 3.1%) and 9.7% to 19.8% in black subjects (median, 10.5%). The 1999 prevalence for our sample, in which 90.2% of subjects were white and 9.8% were from minority backgrounds, was 12.7% compared with a weighted average value from the other studies of 3.9%. Applying our 1992 prevalence estimate to 2000 yields an estimated 2.1 million persons 65 years and older with POAG, which is comparable to a prior published estimate of 2.5 million for the entire population.

To compare our prevalence rates of ARMD with prior estimates, those from previous studies were weighted according to the age distribution in our 1999 sample. The weighted values ranged from 14.2% to 35.9% (median, 27.0%) compared with our figure of 27.1% in 1999.

Our prevalence estimates for diabetic retinopathy and ARMD are consistent overall with previous population-based studies. In contrast, our rates of glaucoma are considerably higher than in most of these studies. In examining the reason for the disparity in glaucoma rates, we first examined definitional differences. Our definition of POAG included some codes for open-angle glaucoma without the primary designation. However, limiting the rates to cases with a primary designation (codes 365.11 and 365.12) reduced the prevalence by only 2.4% in 1999. Second, we investigated the possibility that the difference was due to the older ages of persons in our sample. Even though our comparisons accounted for broad differences in age distribution, we may have failed to adequately account for differences in the proportions of very old individuals in our sample vs others. In 1999, 63.1% of individuals in our sample were 80 years or older, much higher than the proportion of persons in this age group in previous studies. Although persons 95 years and older were intentionally overrepresented in the NLTC sample, when we analyzed our prevalence rates in 1999 for each age group, the rates in every group were considerably higher than those measured in all prior studies except for the Barbados Eye Study, which was conducted in a black population in contrast to our study’s predominantly white population. Thus, the difference in measured glaucoma rates is not primarily attributable to differences in the age distributions of the samples. Our sample restriction to persons not enrolled in HMOs for more than 6 months may increase prevalence rates if HMO enrollees are generally healthier. The literature offers mixed opinions, but the dominant findings indicate that Medicare HMO enrollees do tend to be healthier. On the other hand, more comprehensive coverage of vision services in Medicare HMOs may disproportionately attract individuals with vision problems.

The main factor in the discrepancy in glaucoma prevalence rates between this study and previous population-based studies may therefore be differences in diagnostic criteria or disease coding. Population-based studies of glaucoma have used rigorous criteria for diagnosis, generally requiring evidence of optic nerve damage (visual field loss and/or optic disc changes consistent with glaucoma). Diagnostic criteria in the community may be less clearly defined. For this reason, the diagnosis of glaucoma in Medicare claims may be made more freely than in previous studies of prevalence. This view is sup-
ported by evidence from a study by Bohn et al.,44 which reported that only 50% of patients receiving medication for chronic glaucoma had documentation of elevated intraocular pressure.

A key issue is the confidence in case ascertainment in the database. At one level, the case definition is the most clinically pertinent factor of all possible variants; these cases include patients whom physicians have coded as having some form of eye condition and who have been treated as having that condition (whether or not they actually have it). At another level, true cases could be missed, or persons without disease could be falsely coded as having disease. In other words, errors could be made in either direction. Although there may be a financial bias toward coding patients as having disease for coverage purposes, codes such as dry eye syndrome or cataract are much more readily accessible and less likely to cause concern with patients. For physicians who may be inclined to falsely code for reimbursement purposes (a dangerous decision with increasing government oversight), the codes used would likely not be the same as those used in this study for uncommon conditions. Fundamentally, however, empirical evidence of such false coding on any systematic basis is lacking. Both types of errors may offset each other to a significant degree, and the estimates on the whole are probably substantially accurate. Proof of this can be seen in the direct comparison with population-based studies.

Finally, ascertainment bias from not seeing an eye care provider should have lowered this study’s prevalence estimates. We used data on diagnoses as reported in the Medicare claims. To be diagnosed, a person must have been seen by a provider. Because patients who did not see a provider were counted as having no disease, this would have a tendency to underestimate prevalence. With a longer period of study, this error decreases in size. Of our entire sample, 27% of the beneficiaries did not receive an eye examination by an ophthalmologist or optometrist between 1991 and 1999. More important, of the persons who survived through 1999 (and thus could be observed for the full 9 years), only 15% did not receive a visual examination throughout the duration of the study.

Together these findings raise interesting issues, at least in the elderly population. It has been estimated that half of people with glaucoma do not know that they have the disease.45 Our results indicate that only 15% of Medicare beneficiaries do not see an eye care provider within a given 9-year period, so failure to detect this disease would more likely reflect deficiencies in diagnostic acumen rather than access to care. Our results also raise concerns about possible overdiagnosis and overtreatment of glaucoma in the elderly population relative to the diagnostic criteria used in previous population-based studies.

These limitations also exist for diabetic retinopathy and ARMD; however, the prevalence rates we measured for these diseases in the final years of our study are very similar to those of population-based studies. This suggests that claims data can be used to obtain a reasonable estimate of disease prevalence rates in a large population in which diagnostic criteria are more precise. In contrast to well-defined diagnostic criteria with reference standards for diabetic retinopathy and ARMD, glaucoma is marked by a less precise set of criteria (characteristic changes that are not fully defined). Even for diabetic retinopathy and ARMD, accurate results can be obtained only after several years of data are analyzed. In a shorter period, the number of patients with a particular disease who are not seen by a provider (causing a downward error in prevalence estimates) becomes more significant.

An alternative approach, which was used in a national study of eye disease prevalence with Medicare claims data,46 is to assess the proportion of Medicare beneficiaries receiving each diagnosis in a given year, thereby providing a cross-sectional estimate of prevalence for each year. This differs from our longitudinal approach: Ellwein and Urate selected the sample of Medicare beneficiaries each year rather than conducting follow-up on a single group of people for 9 years. The cross-sectional method allows comparisons to be made from year to year in samples representative of the population 65 years and older in the United States. The longitudinal method that we used enabled us to predict future prevalence nearly a decade in advance in an elderly population. Furthermore, we were able to estimate prevalence rates more precisely with several years of data than with data from a single year because there is much less ascertainment bias in a cohort spanning many years.

Unlike the other studies that provided point prevalence data and assessed diseases individually, we studied disease prevalence longitudinally and jointly. From longitudinal data, one can infer that persons who reach age 65 years have a .45 probability or higher of acquiring at least 1 of the 3 major eye diseases that we addressed in our study as they age (projecting our results to account for sample censoring), an inference that can be made only with longitudinal data. As the US population ages, already high prevalence rates can be expected to grow given current diagnostic criteria and their application in the community setting.

The continued aging of the baby boomer population will result in an even greater burden of eye disease in the United States than previous cross-sectional estimates indicated. This increased burden has important implications for the nation’s public health, for resource allocation, and for the financing of vision care in the future. As more elderly individuals live longer, we may see a rise in the prevalence of chronic eye diseases that will significantly challenge our ability to provide care.

Submitted for publication September 24, 2002; accepted May 23, 2003.

This study was supported in part by grant 1RO1-AG-17473 from the National Institute on Aging, Washington, DC, and by a Lew Wasserman Merit Award (Dr Lee) from Research to Prevent Blindness, New York, NY.

Corresponding author: Frank A. Sloan, PhD, Center for Health Policy, Law, and Management, Box 90253, Duke University, Durham, NC 27708 (e-mail: fsloan@hpolicy.duke.edu).

REFERENCES

2. Javitt JC, Chiang YP. Preparing for managed competition: utilization of ophthal-


