OBJECTIVE — To examine associations in nondiabetic individuals of 1-h postload plasma glucose measured in young adulthood and middle age with subsequent Medicare expenditures for cardiovascular disease (CVD), diabetes, cancer, and all health care at age 65 years or older using data from the Chicago Heart Association Detection Project in Industry (CHA).

RESEARCH DESIGN AND METHODS — Medicare data (1984–2000) were linked with CHA baseline records (1967–1973) for 8,580 men and 6,723 women ages 33–64 years who were free of coronary heart disease, diabetes, and major electrocardiogram (ECG) abnormalities and who were Medicare eligible (65+ years) for at least 2 years. Participants were classified based on 1-h postload plasma glucose levels <120, 120–199, or ≥200 mg/dl.

RESULTS — With adjustment for baseline age, cigarette smoking, serum cholesterol, systolic blood pressure, BMI, ethnicity, education, and minor ECG abnormalities, the average annual and cumulative Medicare, total, and diabetes- and CVD-related charges were significantly higher with higher baseline plasma glucose in women, while only diabetes-related charges were significantly higher in men. For example, in women, multivariate-adjusted CVD-related cumulative charges were, respectively, $14,260, $18,909, and $21,183 for the three postload plasma glucose categories (P value for trend = 0.035).

CONCLUSIONS — These findings suggest that maintaining low glucose levels early in life has the potential to reduce health care costs in older age.

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self-administered questionnaire was used to collect demographic data and diabetes, smoking, and hypertension history. Height, weight, blood pressure, and serum total cholesterol were obtained with standardized methods by trained staff. Electrocardiograms (ECGs), recorded while the participants were at rest, were classified as showing major, minor, or no abnormalities on the basis of the criteria of the Hypertension Detection and Follow-up Program (8).

Individuals not currently receiving treatment for diabetes were given a 50-g glucose load (customary at that time) to test for hyperglycemia without regard to fasting status or time of day. Venous blood for plasma glucose measurement was drawn ~1 h after loading and measured with the auto-analyzer adaptation of Hoffman’s method (9). The study has received periodic institutional review board approval, and a waiver as described by the Health Insurance Portability and Accountability Act (HIPAA) was granted by the institutional review board before commencement of the study. Further, appropriate administrative and physical safeguards were established to protect the confidentiality of the data and to prevent unauthorized use or access.

Follow-up data
Medicare fee-for-service claims data were obtained from the Centers for Medicare and Medicaid Services for participants ages 65 years or older who were thus eligible for Medicare benefits from 1984 (the 1st year Medicare data were available for research use) through 2000. Medicare files for each participant were cross-referenced by social security number, sex, and birth date. For each medical service billed to Medicare, records include date of service, total charges, principal diagnosis, and up to nine other diagnoses coded according to the ICD-9-CM (10). Charges for health care services with primary ICD-9-CM discharge diagnosis codes 390–459 were selected for CVD-related charges, codes 250.x were selected for diabetes-related charges, and codes 140–209 were selected for cancer-related charges.

Medicare claims data for acute inpatient (including skilled nursing facility) and outpatient hospital-related care were available from 1984 to 2000; these data were used in the main analyses of the study. In addition, the analyses based on the annualized Medicare charges were repeated for the period from 1992 to 2000 with the inclusion of physician visits, durable medical equipment claims, home health agency, and hospice claims. Outpatient charges encompass emergency room visits, clinic and ambulatory surgery, laboratory tests, radiography, rehabilitation therapy, radiation therapy, and renal dialysis. Physician-visit claims include charges for physician fees, visits to doctors’ offices, and other non–hospital-related ambulatory care services.

All health care charges were totaled and then annualized by dividing the total by the number of years of Medicare coverage for all participants 65 years or older. For the subgroup of individuals with data from age 65 years to death or to the attainment of age 80 years, cumulative charges were summed across all years.

To account for inflation, all charges were adjusted to year 2000 dollars with use of the hospital and related services component of the consumer price index (11).

Glycemic status
Glycemic status at baseline was classified into three categories: <120, 120–199, and ≥200 mg/dl. These categories were used to maintain consistency with previous reports from the CHA study (5,12). In addition, because some people with 1-h postload glucose levels ≥200 mg/dl may have undiagnosed diabetes or impaired glucose tolerance, glycemic status was also classified into two categories: <200 and ≥200 mg/dl.

Eligibility
Of the 39,522 CHA participants, 20,950 men and women (baseline ages 33–64 years) were eligible for Medicare benefits between 1984 and 2000 (i.e., were not deceased before 1984 and were ≥65 years of age during 1984–2000). To increase the likelihood that participants would have incurred Medicare charges, participants with <2 years of eligibility for Medicare coverage (n = 2,096) were excluded. Of the remaining participants, 2,314 were excluded due to the following baseline criteria: diagnosed diabetes (n = 409), CHD (n = 225), major ECG abnormality (n = 1,635), and missing data on covariates (n = 45). We also excluded people whose blood was drawn before 30 min or after 65 min after the 50-g glucose load and those with missing or implausi-ble times (n = 1,237) (12). Thus, this report is based on 15,303 participants (8,580 men and 6,723 women).

For the subcohort with available data for cumulative charges from age 65 to death or to the attainment of age 80 years (n = 2,540), we excluded the top 0.5% of individuals with the highest total charges to reduce overall skewness of charges. In sum, 1,479 men and 1,048 women, representing 99.5% of the study population, were included in the analyses on cumulative charges.

Statistical analyses
Analyses were undertaken for men and women separately. Baseline characteristics were compared across the three glucose strata. χ² (for categorical variables) or F (for continuous variables) tests were used to assess statistical significance of differences across strata.

Medicare charges (CVD, diabetes, cancer related, and total) were compared across glycemic strata using two general linear models. We performed comparisons for the three glucose categories (<120, 120–199 and ≥200 mg/dl) as well as for the two categories (<200 and ≥200 mg/dl). Model I included adjustment for baseline age, race (black versus nonblack), and years of education. Model II included adjustment for all variables in model I plus multiple baseline CVD risk factors (smoking, BMI, serum total cholesterol, systolic blood pressure, and minor ECG abnormalities) to examine the potential impact of adjustment for these variables on associations of glucose level with Medicare charges.

Given the skewed nature of charge data, a modified Cox regression technique was used to test for statistical significance of associations between baseline glucose levels and Medicare charges. In essence, this approach involves the inversion of the data (i.e., people with no charges were considered to have the longest survival time). Each person’s average annual/cumulative charge was subtracted from the maximal average annual/cumulative charge. This inverted value of charges was treated as “survival time.” Data on individuals with no charges were censored at the maximal charge. The method was used previously to analyze the cost data (3).

Linear trends across the three glucose strata were tested using the significance level for coefficients for glucose as a con-
Table 1—Baseline characteristics and Medicare information of the study participants by baseline postload glucose (1967–1973)

<table>
<thead>
<tr>
<th>Variable</th>
<th>&lt;120</th>
<th>120–199</th>
<th>≥200</th>
<th>P value†</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>2,755</td>
<td>4,967</td>
<td>858</td>
<td>—</td>
</tr>
<tr>
<td>Glucose level (mg/dl)</td>
<td>101.1 ± 13.0</td>
<td>151.6 ± 21.9</td>
<td>234.1 ± 46.6</td>
<td>—</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>26.5 ± 3.2</td>
<td>27.2 ± 3.4</td>
<td>27.9 ± 3.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age (years)</td>
<td>45.2 ± 7.0</td>
<td>47.9 ± 7.5</td>
<td>50.0 ± 7.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>White (%)</td>
<td>94.5</td>
<td>95.4</td>
<td>96.4</td>
<td>0.042</td>
</tr>
<tr>
<td>Education (years)</td>
<td>13.3 ± 2.9</td>
<td>13.0 ± 2.8</td>
<td>12.8 ± 2.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Minor ECG abnormalities (%)</td>
<td>6.8</td>
<td>7.5</td>
<td>7.9</td>
<td>0.401</td>
</tr>
<tr>
<td>Smoking (% smoker)</td>
<td>38.3</td>
<td>36.5</td>
<td>39.4</td>
<td>0.133</td>
</tr>
<tr>
<td>Cigarettes/day (smokers)</td>
<td>8.6 ± 13.1</td>
<td>8.3 ± 12.8</td>
<td>9.5 ± 14.0</td>
<td>0.029</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>134.8 ± 16.4</td>
<td>140.2 ± 18.3</td>
<td>147.4 ± 21.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>80.3 ± 10.2</td>
<td>83.5 ± 11.1</td>
<td>86.6 ± 11.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cholesterol (mg/dl)</td>
<td>206.2 ± 36.1</td>
<td>211.3 ± 35.1</td>
<td>214.4 ± 36.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Medicare eligibility‡</td>
<td>8.9 ± 4.8</td>
<td>9.8 ± 4.8</td>
<td>9.8 ± 4.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Vital status (death, %)</td>
<td>23.8</td>
<td>33.1</td>
<td>48.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>2,502</td>
<td>3,659</td>
<td>562</td>
<td></td>
</tr>
<tr>
<td>Glucose level (mg/dl)</td>
<td>100.1 ± 13.8</td>
<td>149.7 ± 21.5</td>
<td>231.7 ± 47.1</td>
<td>—</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.5 ± 4.0</td>
<td>25.3 ± 4.4</td>
<td>25.4 ± 4.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age (years)</td>
<td>47.5 ± 6.9</td>
<td>49.9 ± 7.1</td>
<td>51.3 ± 6.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>White (%)</td>
<td>91.3</td>
<td>94.9</td>
<td>95.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Education (years)</td>
<td>12.0 ± 2.1</td>
<td>11.9 ± 2.2</td>
<td>11.9 ± 2.2</td>
<td>0.030</td>
</tr>
<tr>
<td>Minor ECG abnormalities (%)</td>
<td>4.6</td>
<td>5.2</td>
<td>5.7</td>
<td>0.426</td>
</tr>
<tr>
<td>Smoking (% smoker)</td>
<td>35.6</td>
<td>34.0</td>
<td>39.2</td>
<td>0.043</td>
</tr>
<tr>
<td>Cigarettes/day (smokers)</td>
<td>6.1 ± 10.0</td>
<td>6.1 ± 9.9</td>
<td>7.2 ± 10.8</td>
<td>0.049</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>130.4 ± 17.6</td>
<td>136.5 ± 19.5</td>
<td>141.2 ± 20.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>77.5 ± 10.6</td>
<td>80.0 ± 11.4</td>
<td>83.4 ± 11.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cholesterol (mg/dl)</td>
<td>212.4 ± 41.2</td>
<td>218.7 ± 39.4</td>
<td>227.1 ± 41.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Medicare eligibility‡</td>
<td>10.7 ± 4.8</td>
<td>11.5 ± 4.8</td>
<td>11.6 ± 4.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Vital status (death, %)</td>
<td>21.0</td>
<td>29.1</td>
<td>40.9</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Data are means ± SD unless otherwise indicated. *Divide by 18 to convert mg/dl to nmol/l. †P values for overall group comparison based on F or χ² tests. ‡Number of years eligible for Medicare coverage during 1984 through 2000.

RESULTS — The follow-up period after the baseline survey averaged ~28 years. The study cohort had a mean baseline age of 47.3 years for men and 49.2 years for women. The majority of the study population was white (94.5%) with an average of 12.5 years of education (data not shown). In general, mean age, systolic and diastolic blood pressure, BMI, and total cholesterol were higher with higher glucose levels in both men and women, while mean education was lower (Table 1). In addition, the percentage of participants who died between 1984 and 2000 was also higher with higher baseline glucose levels in both men and women.

Table 2 shows adjusted average annual Medicare charges for inpatient and outpatient care (1984–2000) across glycemic strata by sex. For men, except for charges for cancer, there was a significant positive association between glucose level and age-, race-, and education-adjusted Medicare charges (model I). For instance, the average annual total Medicare charges were $6,952, $7,349, and $9,124 for men with plasma glucose levels <120, 120–199, and ≥200 mg/dl, respectively.

With additional adjustment for multiple baseline CVD risk factors (model II), glucose was no longer significantly associated with CVD-related or total charges (P values for trend 0.315 and 0.258, respectively). This suggests that for men the associations of glucose level with CVD and total charges are due in part to associations of glucose with other CVD risk factors. As expected, the association of glucose with diabetes-related charges remained significant with adjustment for other CVD risk factors (P value for trend <0.001). In contrast, glucose was not associated with cancer-related charges. Similar findings were also obtained for comparisons between plasma glucose levels <200 and ≥200 mg/dl.

Women generally had lower CVD-related, cancer-related, and total charges but higher diabetes charges than men. For example, among individuals with glucose ≥200 mg/dl, average annual CVD-related and diabetes-related charges with adjust-

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Postload glucose and Medicare costs

Table 2—Adjusted* average annual Medicare charges† for inpatient and outpatient care from 1984 through 2000 by baseline postload glucose (1967–1973) and sex

<table>
<thead>
<tr>
<th>Postload glucose‡</th>
<th>n</th>
<th>CVD</th>
<th>Diabetes</th>
<th>Cancer</th>
<th>Total</th>
<th>n</th>
<th>CVD</th>
<th>Diabetes</th>
<th>Cancer</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;120 mg/dl</td>
<td>2,755</td>
<td>2,259</td>
<td>15</td>
<td>990</td>
<td>6,952</td>
<td>2,502</td>
<td>1,261</td>
<td>13</td>
<td>685</td>
<td>5,276</td>
</tr>
<tr>
<td>120–199 mg/dl</td>
<td>4,967</td>
<td>2,421</td>
<td>569</td>
<td>1,034</td>
<td>7,349</td>
<td>3,659</td>
<td>1,584</td>
<td>749</td>
<td>684</td>
<td>6,253</td>
</tr>
<tr>
<td>≥200 mg/dl</td>
<td>858</td>
<td>3,259</td>
<td>1389</td>
<td>1,449</td>
<td>9,124</td>
<td>562</td>
<td>2,409</td>
<td>453</td>
<td>967</td>
<td>8,913</td>
</tr>
<tr>
<td>P trend#</td>
<td></td>
<td>&lt;0.001</td>
<td>0.552</td>
<td>0.018</td>
<td>&lt;0.001</td>
<td>0.473</td>
<td>0.002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;200 mg/dl</td>
<td>7,722</td>
<td>2,364</td>
<td>42</td>
<td>1,018</td>
<td>7,208</td>
<td>6,161</td>
<td>1,453</td>
<td>49</td>
<td>685</td>
<td>5,859</td>
</tr>
<tr>
<td>≥200 mg/dl</td>
<td>858</td>
<td>3,255</td>
<td>137</td>
<td>1,448</td>
<td>9,113</td>
<td>562</td>
<td>2,401</td>
<td>452</td>
<td>967</td>
<td>8,889</td>
</tr>
<tr>
<td>P value##</td>
<td></td>
<td>&lt;0.001</td>
<td>0.939</td>
<td>0.008</td>
<td>&lt;0.001</td>
<td>0.790</td>
<td>0.053</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 2</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;120 mg/dl</td>
<td>2,412</td>
<td>20</td>
<td>1,009</td>
<td>7,211</td>
<td>1,354</td>
<td>33</td>
<td>699</td>
<td>5,516</td>
<td></td>
<td></td>
</tr>
<tr>
<td>120–199 mg/dl</td>
<td>2,388</td>
<td>599</td>
<td>1,034</td>
<td>7,307</td>
<td>1,548</td>
<td>624</td>
<td>679</td>
<td>6,151</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥200 mg/dl</td>
<td>2,960</td>
<td>1304</td>
<td>1,385</td>
<td>8,536</td>
<td>2,228</td>
<td>443</td>
<td>941</td>
<td>5,808</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P trend#</td>
<td></td>
<td>&lt;0.001</td>
<td>0.531</td>
<td>0.258</td>
<td>&lt;0.001</td>
<td>0.468</td>
<td>0.002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;200 mg/dl</td>
<td>2,396</td>
<td>43</td>
<td>1,025</td>
<td>7,273</td>
<td>1,470</td>
<td>50</td>
<td>687</td>
<td>5,896</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥200 mg/dl</td>
<td>2,961</td>
<td>129</td>
<td>1,383</td>
<td>8,531</td>
<td>2,220</td>
<td>442</td>
<td>941</td>
<td>8,481</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P value##</td>
<td></td>
<td>&lt;0.001</td>
<td>0.874</td>
<td>0.055</td>
<td>&lt;0.001</td>
<td>0.856</td>
<td>0.053</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Model I included baseline age, race (indicator for black), and education (years); model II included all variables in model I in addition to smoking (cigarettes/day), serum cholesterol (mg/dl), systolic blood pressure (mmHg), minor electrocardiographic abnormalities, and BMI (kg/m²). †Charges were adjusted to year 2000 U.S. dollars. ‡Divide by 18 to convert mg/dl to mmol/l. §Values for trend in charges by glucose level as a continuous variable based on modified Cox models; ¶P value for comparisons between groups (<120 mg/dl) based on modified Cox models. ##P value for comparisons between groups (<200 mg/dl and ≥200 mg/dl) based on modified Cox models.

Patterns of associations of glucose and Medicare charges for women were similar to those for men. However, associations of glucose with CVD-related and total charges remained significant with adjustment for other CVD risk factors (model II) in women only (P values for trend 0.030 and 0.002, respectively).

With exclusion of individuals with diabetes diagnoses in 1984–2000 (data not shown), Medicare charges were still the highest for participants with the highest glucose levels, particularly among women, but differences in charges between individuals with the highest (≥200 mg/dl) and those with the lowest (<120 mg/dl) glucose levels were smaller than those with inclusion of individuals with diabetes (e.g., $768 vs. $2,992, respectively, for multivariate-adjusted average annual total charges in women; corresponding total charges with the inclusion of individuals with diabetes for the two groups are $5,516 vs. $8,508 [Table 2]).

Subgroups with Medicare data from age 65 years to death or to attainment of age 80 years

Patterns of associations between glycemic status and cumulative Medicare charges for both men and women were similar to those observed for annual charges, except for cumulative total charges in men (Table 3). Women in general had lower cumulative charges than men. With multiple

Table 3—Adjusted* cumulative Medicare charges† for inpatient and outpatient care from age 65 years to death or to attainment of age 80 years (1984–2000) by baseline postload glucose (1967–1973) and sex

<table>
<thead>
<tr>
<th>Postload glucose‡</th>
<th>n</th>
<th>CVD</th>
<th>Diabetes</th>
<th>Cancer</th>
<th>Total</th>
<th>n</th>
<th>CVD</th>
<th>Diabetes</th>
<th>Cancer</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;120 mg/dl</td>
<td>452</td>
<td>23,741</td>
<td>152</td>
<td>12,572</td>
<td>79,181</td>
<td>403</td>
<td>14,260</td>
<td>309</td>
<td>10,587</td>
<td>62,808</td>
</tr>
<tr>
<td>120–199 mg/dl</td>
<td>865</td>
<td>26,467</td>
<td>621¶</td>
<td>13,928</td>
<td>85,560</td>
<td>533</td>
<td>18,909</td>
<td>700¶</td>
<td>9,686</td>
<td>73,823</td>
</tr>
<tr>
<td>≥200 mg/dl</td>
<td>162</td>
<td>30,174</td>
<td>1,699¶</td>
<td>18,186</td>
<td>91,602</td>
<td>112</td>
<td>21,183¶</td>
<td>1,079¶</td>
<td>10,808</td>
<td>87,246¶</td>
</tr>
<tr>
<td>P trend#</td>
<td></td>
<td>&lt;0.001</td>
<td>0.638</td>
<td>0.944</td>
<td>&lt;0.001</td>
<td>0.419</td>
<td>0.039</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;200 mg/dl</td>
<td>1,317</td>
<td>26,220</td>
<td>461</td>
<td>13,466</td>
<td>83,391</td>
<td>936</td>
<td>16,917</td>
<td>531</td>
<td>10,072</td>
<td>69,104</td>
</tr>
<tr>
<td>≥200 mg/dl</td>
<td>162</td>
<td>30,156</td>
<td>1,686</td>
<td>18,152</td>
<td>91,442</td>
<td>112</td>
<td>21,102</td>
<td>1,075</td>
<td>10,824</td>
<td>87,054</td>
</tr>
<tr>
<td>P value##</td>
<td></td>
<td>&lt;0.001</td>
<td>0.193</td>
<td>0.308</td>
<td>&lt;0.001</td>
<td>0.173</td>
<td>0.054</td>
<td></td>
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*Adjusted for baseline age, race (indicator for black), education (years), smoking (cigarettes/day), serum cholesterol (mg/dl), systolic blood pressure (mmHg), minor electrocardiographic abnormalities, and BMI (kg/m²). †Charges were adjusted to year 2000 U.S. dollars. ¶Divide by 18 to convert mg/dl to mmol/l. §P values for trend in charges by glucose level as a continuous variable based on modified Cox models; ¶P < 0.05, ||P < 0.01, |||P < 0.001 for comparisons with the first group (<120 mg/dl) based on modified Cox models. ###P value for comparisons between groups (<200 mg/dl and ≥200 mg/dl) based on modified Cox models.
baseline risk-factor adjustment, there was
a strong positive association between glu-
cose and cumulative diabetes charges in
both men and women (both P values for
trend <0.001). Glucose was also signifi-
cantly related to cumulative CVD-related
and total charges with adjustment for
CVD risk factors in women (P values for
trend 0.035 and 0.039, respectively) but
not in men. Similar findings were also ob-
served for comparisons between plasma
glucose levels of <200 and ≥200 mg/dl.
Glucose was not significantly related to
cumulative cancer charges in men or
women.

CONCLUSIONS — Our main find-
ing is that postload plasma glucose in
middle age is positively associated with
age-, race-, and education-adjusted CVD-
related, diabetes-related, and total Medi-
care charges in older age for both women
and men. In general, charges were the
highest for individuals with the highest
glucose levels (≥200 mg/dl) and the low-
est for individuals with the lowest glucose
values (<120 mg/dl). With adjustment for
CVD risk factors, the association be-
tween glucose level and diabetes charges
remained significant for both men and
women. Associations of glucose with
CVD and total charges remained signifi-
cant with adjustment for multiple CVD
risk factors in women but not in men.
There was no association between glucose
and cancer charges in either men or
women.

To date, there has been little research
on the association of long-term economic
consequences (e.g., effects on Medicare
expenditures) with blood glucose levels.
While a few studies have focused on the
combined effects of multiple risk factors,
including blood glucose concentration,
on health care costs (13–15), to our
knowledge, only two studies (13,14) have
shown that high blood glucose levels are
associated with higher health care costs.
For example, Goetzel et al. (14) found
that employees who reported having a
high glucose level had 35% higher health
care expenditures than those who did not.
However, these studies examined glucose
level only as a dichotomous variable and
had short-term follow-up (up to 3 years).
To our knowledge, the impact of midlife
glucose levels on health care costs in-
curred in older age among nondiabetic
individuals has not previously been ex-
amined.

It should be noted that >40% of in-
dividuals reported to have diabetes are
older than 65 years (16) and that direct
medical expenditures attributable to dia-
betes among the elderly were almost two-
thirds of all direct medical expenditures
attributable to diabetes (2). With the pro-
portion of Americans ages 65 years and
older increasing rapidly (from ~12% of
the population currently to 20% by 2050
[17]), costs due to diabetes and related
disease among the elderly have important
implications for expenditures by Medi-
care. The predictive role of an early
screening test for diabetes on subsequent
Medicare charges therefore has important
implications for Medicare expenditures.

Findings from our study are consist-
tent with hypothesized mechanisms. Peo-
ple with high blood glucose levels are at
higher risk of developing diabetes, CVD,
and other diabetes complications and
have higher mortality rates than those
with normal glucose tolerance. We found
Medicare charges to be highest for indi-
viduals with blood glucose levels ≥200
mg/dl. These levels were also associated
with higher diabetes charges after adjust-
ment for CVD risk factors. Our findings of
multiple-adjusted relations of glucose
levels and CVD-related and total charges
in women (but not in men) are consistent
with results from a previous study on as-
ociations of glucose levels and coronary
heart disease mortality in the same cohort
(5) and with other studies (18,19) show-
ning that the relative impact of diabetes on
CVD morbidity and mortality risk was
more marked in women than in men.

These results suggest that even a ca-
sual assessment of blood glucose at
younger ages can identify individuals at
risk for diabetes and/or CVD later in life
who are therefore likely to ultimately suf-
fer from the ravages of diabetes and CVD
as well as to incur increased health care
costs at older ages. This further suggests
that early screening may provide an op-
portunity for primary prevention before
the development and diagnosis of frank
disease, with the potential for reducing
personal suffering, debility, and Medicare
health care costs.

This study has several strengths, in-
cluding the availability of blood glucose
and other potential risk factors (including
BMI) from a large sample of men and
women with long-term follow-up (mean
follow-up time 28 years). However, a sin-
gle measurement of blood glucose instead
of multiple measurements and the lack of
information on fasting status and time of
day when the blood was drawn are likely
to bias results toward the null. Moreover,
the use of 1-h glucose levels after a 50-g

glucose dose (instead of the current rec-
ommended 2-h glucose levels with a 75-g

glucose load [20]) may lead to lower glu-
cose levels; therefore, many participants
with levels ≥200 mg/dl may have had un-
diagnosed diabetes.

Other limitations of the study include
the use of charges instead of costs.
Charges may be higher than costs, but
they are highly correlated (21). Neverthe-
less, using estimated costs (obtained by
applying annual cost-to-charge ratios for
hospital patient care services [22] to each
year’s Medicare charges), similar patterns
of associations and levels of significance
were observed.

In addition, there is no information
on costs for long-term nursing home care
and prescription drugs, which are not
covered by Medicare. As a result, we are
unable to estimate the health care costs for
the use of those services. Furthermore,
the use of only fee-for-service Medicare
data may also lead to underestimation of
actual total health care costs, since health
care costs incurred outside the Medicare
system, mainly HMO and Veterans Ad-
ministration (VA) costs, are not included.
However, exclusion of beneficiaries en-
rolled in managed care organizations dur-
ing 1992–2000 did not have any
significant impact on the associations of
glucose with Medicare charges in both
men and women. Moreover, only a very
small proportion (<2%) of our cohort
had VA health care utilization and billing
records. Data on out-of-pocket payments
are also not available, although these con-
stitute only a small proportion of total ex-
penditures. It is highly likely that income
influences these and other health care ex-
penditures not covered by Medicare.

Nonetheless, all analyses were adjusted
for education, which has been shown to
be strongly correlated with income. In ad-
dition, Medicare is the largest single
source of health care spending in the U.S.,
covering almost all of the elderly popula-
tion (23). Therefore, it is a valuable source
for studies of costs incurred by the el-
derly.

In conclusion, our findings demon-
strate an important association between
glucose level in middle age and future
Medicare charges. Among individuals
Postload glucose and Medicare costs

with low levels of plasma glucose in middle age, the costs of health care in older age are markedly lower. Low plasma glucose levels in middle age may not only reduce the risk of diabetes, CVD, other diabetes-related chronic complications, and mortality, but could also potentially decrease subsequent Medicare expenditures. With the current trend of increasing diabetes prevalence, preventive measures are important not only to reduce the burden of disease and disability associated with diabetes, but also to decrease future health care costs in the aging population. Public health efforts need to include comprehensive national strategies and resources for primary prevention of diabetes including screening for high blood glucose levels from early life on, with the goal to end the diabetes epidemic and reduce health care costs among older individuals.

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