Abdominal Aortic Aneurysms, Increasing Infrarenal Aortic Diameter, and Risk of Total Mortality and Incident Cardiovascular Disease Events
10-Year Follow-Up Data From the Cardiovascular Health Study

Matthew S. Freiberg, MD, MSc; Alice M. Arnold, PhD; Anne B. Newman, MD, MPH; Matthew S. Edwards, MD, MS; Kevin L. Kraemer, MD, MSc; Lewis H. Kuller, MD, DrPH

Background—Long-term data describing small abdominal aortic aneurysms (AAAs) and increasing infrarenal aortic diameters and their relationship to future surgical repair, total mortality, and incident cardiovascular disease (CVD) events, particularly among women, are sparse.

Methods and Results—In 1992 to 1993, 4734 Cardiovascular Health Study participants ≥65 years old had an abdominal aortic ultrasound evaluation. Of those screened, 416 had an AAA (infrarenal aortic diameter ≥3.0 cm or an infrarenal/suprarenal ratio ≥1.2). By 2002, there were 56 surgical AAA repairs and 10 AAA-related deaths. A single ultrasound screening demonstrated that aneurysm dilation ≥3 cm identified 68% of all AAA repairs over the next 10 years and 6 of the 10 AAA-related deaths in 4% of the total population and that a ≥2.5-cm dilation identified 91% of all AAA repairs and 9 of the 10 deaths in 10% of the total population. With adjusted Cox proportional hazard models, AAAs were associated with a higher risk of total mortality (hazard ratio 1.44, 95% confidence interval 1.25 to 1.66) and incident CVD events (hazard ratio 1.52, 95% confidence interval 1.25 to 1.85). Compared with diameters <2.0 cm, infrarenal aortic diameters 2.0 to <3.0 cm were associated with increased risk of incident CVD events in women and total mortality in men.

Conclusions—This study suggests that a 1-time screening of the abdominal aorta can acceptably identify individuals with a clinically significant AAA. Infrarenal aortic diameters ≥2.0 cm are associated with a significantly increased risk of future CVD events and total mortality.

Key Words: aortic aneurysm, abdominal □ cardiovascular diseases □ mortality □ women

C

urrent guidelines recommend screening for abdominal aortic aneurysms (AAAs) in men to reduce AAA-related mortality.1–3 Screening among women is not currently recommended because data are sparse, the prevalence of AAA is low,4 and it is not considered to be clinically indicated.5 The benefits of screening, however, are based on mortality outcomes6–9 and not incident cardiovascular disease (CVD) events. Observational data suggest a strong association with atherosclerosis,10 subclinical coronary heart disease,11 and prevalent AAA.12,13 In the Cardiovascular Health Study (CHS), AAAs were associated with an increased risk of CVD mortality and incident CVD events after 4.5 years.14 The number of events during the follow-up period, however, precluded analyses examining these risks separately for men and women. Long-term data describing the association between small AAAs and the risk of surgical repair, total mortality, and incident CVD events, particularly among women, are sparse.5,15–17

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In this investigation, we evaluated the relationship between small AAAs and increasing infrarenal aortic diameter and future surgical repair, total mortality, and incident CVD events among a cohort of older adults who were followed up for 10 years after a 1-time initial ultrasound screening of the abdominal aorta. Because some evidence suggests the short-term natural history of small aneurysms is not the same for men and women,14 we examined the sex-specific relationship between small AAAs and future surgical repair, total mortality, and incident CVD events from 1992 to 2002.

Methods

Study Cohort

The CHS is a prospective cohort of men and women ≥65 years of age who were randomly selected from Medicare eligibility lists from
4 communities in the United States. Of the 5888 participants enrolled in the CHS study, 259 participants died before the ultrasonographic study, 755 were unable to attend the clinic visit to obtain an ultrasound, and 93 who attended the clinic visit when ultrasounds were performed did not obtain an ultrasound. Of the 4781 participants who had an abdominal aortic ultrasound, 47 had an unreadable ultrasound, which left 4734 participants in 1992 to 1993 who were eligible for the present study. All participants gave informed consent for the examination and follow-up. The institutional review board of each participating institution approved the protocol.

**Baseline Data Collection**

B-mode gray-scale ultrasonographic images of the abdominal aorta in the longitudinal and transverse projections were obtained by trained ultrasonographers. The suprarenal measure of the aortic diameter was taken 1 cm distal to the origin of the superior mesenteric artery, just above the level of the left renal artery. The infrarenal measure of aortic diameter was determined by the site of the maximum diameter aortic artery (lumen plus wall) below the renal arteries. We constructed 2 different variables to define AAA. The first (definition 1) defines AAA as an infrarenal aortic diameter \( \geq 3.0 \text{ cm} \) or an infrarenal-to-suprarenal ratio of \( \geq 1.2 \). Analyses that used this definition had the referent group defined as an infrarenal aortic diameter \( \leq 2.0 \text{ cm} \) and an infrarenal-to-suprarenal ratio of \( \leq 1.2 \). The second definition of AAA (definition 2), an infrarenal aortic diameter of \( \geq 3.0 \text{ cm} \), only used infrarenal aortic diameter and not the infrarenal-to-suprarenal ratio. For analyses that used this definition, the referent group was an infrarenal aortic diameter \( \leq 2.0 \text{ cm} \). All scans were read by readers who were blinded to all clinical information and subsequently were reread at a central location by a single vascular physician who was blinded to the participant’s cardiovascular history. Questionable scans were adjudicated by consultation with a second physician. The readers and ultrasonographers did not participate in subsequent outcome assessments. No repeat AAA ultrasound examinations were obtained through the CHS research protocol. Initial results of the 1-time screening were provided to the participants and their healthcare providers. Clinical recommendations were not provided.

Demographic characteristics, cardiovascular risk factors, markers of vascular disease, and medications used were included in the present analyses with assessments from the 1992 to 1993 examinations. If 1992 assessment data were missing, we used the 1989 to 1990 baseline assessment data. The demographic characteristics included age, race/ethnicity, gender, and measured height and weight. Cardiovascular risk factors included hypertension, diabetes mellitus, body mass index, cigarette smoking, pack-years of smoking.

### Table 1. Characteristics of Men and Women in the CHS With and Without AAA* (N=4734)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Normal Aorta</th>
<th>AAA</th>
<th>Normal Aorta</th>
<th>AAA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n=1701)</td>
<td>(n=252)</td>
<td>(n=2617)</td>
<td>(n=164)</td>
</tr>
<tr>
<td>Age, y</td>
<td>75.2 (5.6)</td>
<td>75.8 (5.1)</td>
<td>74.6 (5.2)</td>
<td>75.0 (5.4)</td>
</tr>
<tr>
<td>Infrarenal aortic diameter, mm</td>
<td>21.0 (2.9)</td>
<td>32.7 (11.2)</td>
<td>18.1 (2.7)</td>
<td>25.8 (8.9)</td>
</tr>
<tr>
<td>Infrarenal aortic diameter &lt;2 cm</td>
<td>36.3</td>
<td>5.1</td>
<td>79.1</td>
<td>27.4</td>
</tr>
<tr>
<td>White race</td>
<td>83.1</td>
<td>90.1‡</td>
<td>80.7</td>
<td>73.8§</td>
</tr>
<tr>
<td>Smoking status</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never-smoker</td>
<td>30.4</td>
<td>24.2</td>
<td>57.9</td>
<td>47.6</td>
</tr>
<tr>
<td>Past smoker</td>
<td>60.4</td>
<td>65.1</td>
<td>32.7</td>
<td>31.7</td>
</tr>
<tr>
<td>Current smoker</td>
<td>9.2</td>
<td>10.7</td>
<td>9.4</td>
<td>0.7§</td>
</tr>
<tr>
<td>History of hypertension</td>
<td>54.4</td>
<td>55.6</td>
<td>58.9</td>
<td>61.6</td>
</tr>
<tr>
<td>Diabetes by American Diabetes Association criteria</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impaired fasting glucose</td>
<td>12.3</td>
<td>11.1</td>
<td>9.4</td>
<td>9.8</td>
</tr>
<tr>
<td>Diabetic</td>
<td>18.4</td>
<td>15.9</td>
<td>13.3</td>
<td>15.3</td>
</tr>
<tr>
<td>History of CVD</td>
<td>35.2</td>
<td>44.8‡</td>
<td>22.2</td>
<td>37.2§</td>
</tr>
<tr>
<td>LDL cholesterol, mg/dL</td>
<td>121 (32)</td>
<td>124 (33)</td>
<td>131 (35)</td>
<td>138 (35)</td>
</tr>
<tr>
<td>HDL cholesterol level, mg/dL</td>
<td>47.2 (11.8)</td>
<td>45.2 (10.6)‡</td>
<td>58.2 (14.7)</td>
<td>54.2 (12.4)§</td>
</tr>
<tr>
<td>Height, cm</td>
<td>173 (6.7)</td>
<td>173 (6.4)</td>
<td>158 (6.3)</td>
<td>159 (7.0)</td>
</tr>
<tr>
<td>Weight, lb</td>
<td>174 (28)</td>
<td>174 (26)</td>
<td>150 (31)</td>
<td>154 (35)</td>
</tr>
<tr>
<td>Renal insufficiency†</td>
<td>8.9</td>
<td>16.7‡</td>
<td>4.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Ankle-arm index ( &lt;0.9 )</td>
<td>13.4</td>
<td>25.8‡</td>
<td>10.3</td>
<td>20.7§</td>
</tr>
<tr>
<td>Internal or common carotid wall thickness ( &gt;80\text{th} \text{ percentile} )</td>
<td>39.3</td>
<td>49.2‡</td>
<td>24.7</td>
<td>29.9</td>
</tr>
<tr>
<td>Major ECG abnormality</td>
<td>42.0</td>
<td>45.2</td>
<td>30.0</td>
<td>39.6§</td>
</tr>
<tr>
<td>Any subclinical cardiovascular disease</td>
<td>75.7</td>
<td>84.5‡</td>
<td>64.4</td>
<td>75.6§</td>
</tr>
</tbody>
</table>

Entries in the table are mean (SD) for continuous variables or (%) for categorical variables.  
*AAAs defined as an infrarenal aortic diameter of 3.0 cm or greater or an infrarenal-to-suprarenal ratio of 1.2 or greater.  
†Creatinine \( \geq 1.5 \text{ mg/dL} \) in men or \( \geq 1.3 \text{ mg/dL} \) in women.  
‡P<0.05 for comparisons between men with AAA and men without AAA.  
§P<0.05 for comparisons between women with AAA and women without AAA.
CoA (3-hydroxy-3-methylglutaryl coenzyme A) reductase inhibitors.

surgical repair in the CHS.

infrarenal aortic diameter cut points to predict the risk of AAA

Figure 1.

discharge summaries. The sensitivity and specificity of this method

441.4), as well as by clinical information in hospital records and

noses compatible with these diagnoses (38.44, 38.45, 441.3, and

Clinical Modification (ICD-9-CM) codes for procedures or diag-

tored, incident cases of AAA repair and rupture were identified by

not on death certificate coding. Maximum follow-up was 10 years.

mittee adjudicated all clinical CVD events and deaths. Events for the

were obtained for unreported hospitalizations. A CHS review com-

and medical procedures. Health Care Finance Administration records

obtain health records documenting new diagnoses, hospitalizations,

Participants were contacted twice annually from 1992 to 2002 to

Follow-Up Data Collection

Participants were contacted twice annually from 1992 to 2002 to

although ultrasonographic surveillance of AAAs was not moni-

tored, incident cases of AAA repair and rupture were identified by

review of all International Classification of Diseases, 9th Revision,

participants with AAA at baseline compared with performing exten-

for identifying those with an AAA repair among the Pittsburgh

participants with AAA at baseline compared with performing extensive

chart reviews were 90% and 100%, respectively. Only 1 of the

85 participants was misclassified. For all participants who died due to

atherosclerotic disease and not coronary heart disease or cerebro-

vascular disease, cause of death was reviewed for this category to

ascertain those who died of an AAA or other cause and to ensure that
deaths due to thoracic aneurysms (n=6) were not included in the

AAA-related death category.

Primary outcome variables included (1) AAA surgical repair, (2)
total mortality, and (3) incident CVD events, defined as coronary

heart disease, congestive heart failure, transient ischemic attack or

stroke, claudication, and atherosclerotic coronary heart disease
death.22–24 Secondary analyses also included specific causes of
death, incident claudication, and chronic kidney disease.

Statistical Analysis

We calculated the mean or prevalence of demographic characteristics,

cardiovascular risk factors, and clinical and subclinical measures of

atherosclerosis separately for men and women with and without AAAs,

and we evaluated differences by AAA status using a t test or \( \chi^2 \) test as appropriate.

All participants were followed up for evidence of AAA surgical

repair, death due to AAA and other causes, and incident CVD.

Receiver operating characteristic curves were constructed to deter-

mine which dichotomous cut point of infrarenal aortic diameter (eg,

\( \geq 2.0 \text{ cm}, \geq 2.5 \text{ cm}, \text{ or } \geq 3.0 \text{ cm} \)) measured by the 1-time ultrasound

screening was the most useful for identifying those at risk for future

AAA repair. Cause of death was ascertained and categorized by the

decedent’s baseline infrarenal aortic diameter. Participants were free

of prevalent CVD when the outcome of interest was incident CVD

events. Mortality and incident CVD rates were calculated by divid-
ing the total number of events in each group by the person-years at

risk. After determining that all Cox proportional hazard model

assumptions were met,25 we estimated the sex-specific hazard ratios

(HRs) and HRs for the entire cohort for total mortality and incident

CVD events associated with the presence of an aneurysm or

increasing infrarenal aortic diameter after adjusting for risk factors

(definitions 1 and 2). All analyses were done with SPSS software,

version 14 (SPSS, Inc, Chicago, Ill) or STATA, version 9 (Stata-

Corp, College Station, Tex).

The authors had full access to the data and take full responsibility

for its integrity. All authors have read and agree to the manuscript as

written.

Table 2. Association Between Baseline Infrarenal Aortic Diameter and AAA Surgical Repair Over 10 Years of Follow-Up in the CHS

<table>
<thead>
<tr>
<th>Baseline Infrarenal Aortic Diameter, cm (No. of Participants)</th>
<th>No. of Participants Who Underwent AAA Repair</th>
<th>Overall Percentage of Participants Who Underwent AAA Repair</th>
<th>Cumulative Percentage of AAA Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;2.0 (n=2747)</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>2.0 to &lt;2.5 (n=1492)</td>
<td>5</td>
<td>0.3</td>
<td>8.9</td>
</tr>
<tr>
<td>2.5 to &lt;3.0 (n=307)</td>
<td>13</td>
<td>4.2</td>
<td>32.1</td>
</tr>
<tr>
<td>3.0 to &lt;3.5 (n=93)</td>
<td>9</td>
<td>9.7</td>
<td>48.2</td>
</tr>
<tr>
<td>3.5 to &lt;4.0 (n=37)</td>
<td>4</td>
<td>10.8</td>
<td>55.5</td>
</tr>
<tr>
<td>4.0 to &lt;4.5 (n=22)</td>
<td>9</td>
<td>40.9</td>
<td>71.4</td>
</tr>
<tr>
<td>4.5 to &lt;5.0 (n=9)</td>
<td>3</td>
<td>33.3</td>
<td>76.8</td>
</tr>
<tr>
<td>5.0 to &lt;5.5 (n=13)</td>
<td>4</td>
<td>30.8</td>
<td>83.9</td>
</tr>
<tr>
<td>5.5 to &lt;6.0 (n=6)</td>
<td>4</td>
<td>66.7</td>
<td>91.1</td>
</tr>
<tr>
<td>6.0 to &lt;6.5 (n=3)</td>
<td>3</td>
<td>100.0</td>
<td>96.4</td>
</tr>
<tr>
<td>( \geq 6.5 ) (n=5)</td>
<td>2</td>
<td>20.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Total (n=4734)</td>
<td>56</td>
<td>1.2</td>
<td>( \ldots )</td>
</tr>
</tbody>
</table>

Figure 1. Receiver operating characteristic (ROC) curve for infrarenal aortic diameter cut points to predict the risk of AAA surgical repair in the CHS.
Results

CHS Participant Characteristics

The characteristics of the 4734 CHS participants in the present study are presented in Table 1. Thirteen percent of men and 6% of women met our first definition of AAA, whereas 7% and 1.7%, respectively, met our second definition. For both men and women, the prevalence of several cardiovascular risk factors was higher among those with an AAA (definition 1) than among those without an AAA (Table 1).

AAA Surgical Repair

During the 10-year follow-up period, 56 (1.3%) of the 4734 participants who were screened for AAA underwent AAA surgical repair. Among those who had surgical repairs, 78% (n=44) were men, 71% (n=40) met our first definition of AAA, and 68% (n=38) met our second definition. Of the 56 participants who underwent repair, 8 had procedures for emergent conditions (eg, rupture), and 4 died (all men) during surgery or as a result of postoperative complications, whereas

Table 3. Causes of Death (n=1822) for Women and Men in the CHS Stratified by Infrarenal Aortic Diameter

<table>
<thead>
<tr>
<th>Infrarenal Aortic Diameter, cm</th>
<th>No. of Participants</th>
<th>AAA*</th>
<th>Atherosclerotic CHD*</th>
<th>Cerebrovascular Disease*</th>
<th>Atherosclerotic Disease: Not CHD or CVD*</th>
<th>Other CVD: Not CHD, CVD, or Other</th>
<th>Atherosclerotic Disease* Non-CVD*</th>
<th>Total No. (%) of Deaths†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;2.0 cm</td>
<td>2113</td>
<td>0</td>
<td>134 (20.3)</td>
<td>85 (12.9)</td>
<td>10 (1.5)</td>
<td>20 (3.0)</td>
<td>410 (62.2)</td>
<td>659 (31.2)</td>
</tr>
<tr>
<td>2 to &lt;3.0 cm</td>
<td>619</td>
<td>2 (0.9)</td>
<td>56 (25.1)</td>
<td>23 (10.3)</td>
<td>7 (3.1)</td>
<td>9 (4.0)</td>
<td>126 (56.5)</td>
<td>233 (36.0)</td>
</tr>
<tr>
<td>3 to &lt;3.5 cm</td>
<td>26</td>
<td>0</td>
<td>6 (40.0)</td>
<td>1 (6.7)</td>
<td>1 (6.7)</td>
<td>0</td>
<td>7 (46.7)</td>
<td>15 (57.7)</td>
</tr>
<tr>
<td>≥3.5 cm</td>
<td>20</td>
<td>3 (25.0)</td>
<td>3 (25.0)</td>
<td>1 (8.3)</td>
<td>0</td>
<td>1 (8.3)</td>
<td>4 (33.3)</td>
<td>12 (60.0)</td>
</tr>
<tr>
<td>Total</td>
<td>2781</td>
<td>5 (0.6)</td>
<td>199 (21.9)</td>
<td>110 (12.1)</td>
<td>18 (2.0)</td>
<td>30 (3.3)</td>
<td>547 (60.2)</td>
<td>909 (32.7)</td>
</tr>
</tbody>
</table>

| Men                            |                     |      |                     |                         |                                        |                                  |                                |
| <2.0 cm                        | 631                 | 0    | 80 (29.7)           | 24 (8.9)                | 6 (2.2)                               | 7 (2.6)                          | 152 (56.5)                     | 269 (42.6)                |
| 2 to <3.0 cm                   | 1177                | 2 (0.4)| 151 (27.4)         | 41 (7.4)                | 7 (1.3)                               | 7 (1.3)                          | 344 (62.3)                     | 552 (46.9)                |
| 3 to <3.5 cm                   | 67                  | 0    | 15 (39.5)           | 3 (7.9)                 | 0                                      | 0                                | 20 (52.6)                      | 38 (56.7)                 |
| ≥3.5 cm                        | 75                  | 3 (5.6)| 20 (37.0)          | 1 (1.9)                 | 4 (7.4)                               | 1 (1.9)                          | 25 (46.3)                      | 54 (72.0)                 |
| Total                          | 1953                | 5 (0.6)| 266 (29.1)         | 69 (7.6)                | 22 (2.4)                               | 15 (1.6)                         | 541 (59.3)                     | 913 (46.7)                |

Values are n (%).

*No. of deaths within a cause-of-death category/No. of total deaths within an infrarenal aortic diameter category.

†No. of deaths within an infrarenal aortic diameter category/total No. of participants within an infrarenal aortic diameter category.

Table 4. Total Mortality Events Among Participants of the CHS by Infrarenal Aortic Diameter Stratified by Baseline CVD Status

<table>
<thead>
<tr>
<th>Definition</th>
<th>No Prevalent CVD</th>
<th>Total Sample at Baseline</th>
<th>Risk (IR*)</th>
<th>HR† (95% CI)</th>
<th>Risk (IR*)</th>
<th>HR‡ (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No AAA</td>
<td>970/3139 (37.0)</td>
<td>1597/4318 (45.9)</td>
<td>1.0 (Referent)</td>
<td>1.0 (Referent)</td>
<td>66/95 (127.1)</td>
<td>1.90 (1.46–2.46)</td>
</tr>
<tr>
<td>Ratio ≥1.2 and IRAD &lt;3.0</td>
<td>55/138 (42.9)</td>
<td>112/228 (64.9)</td>
<td>1.30 (0.98–1.72)</td>
<td>1.12 (0.96–1.29)</td>
<td>778/1799 (56.2)</td>
<td>1.14 (1.02–1.27)</td>
</tr>
<tr>
<td>3 ≤ IRAD &lt;3.5</td>
<td>33/61 (74.4)</td>
<td>53/93 (82.4)</td>
<td>1.75 (1.21–2.54)</td>
<td>1.45 (1.09–1.95)</td>
<td>66/95 (127.1)</td>
<td>1.90 (1.46–2.46)</td>
</tr>
<tr>
<td>IRAD ≥3.5</td>
<td>24/43 (90.3)</td>
<td>66/95 (127.1)</td>
<td>2.45 (1.62–3.71)</td>
<td>1.90 (1.46–2.46)</td>
<td>66/95 (127.1)</td>
<td>2.02 (1.55–2.65)</td>
</tr>
</tbody>
</table>

IR indicates incidence rate; IRAD, infrarenal aortic diameter (in centimeters).

†Adjusted for subclinical CVD, age, race, renal insufficiency, smoking status, pack-years of smoking, height, weight, hypertension, diabetes mellitus, and LDL and HDL cholesterol.

‡Adjusted for clinical CVD and all covariates above.

§Definition 1 uses no AAA (IRAD ≥3.0 cm or an infrarenal-to-suprarenal ratio ≥1.2) as the referent group, and definition 2 uses IRAD <2.0 cm as the referent group.
48 procedures were for elective repair, and 2 of these patients died of postoperative complications (no AAA size listed), for a total of 6 deaths related to repair. None of the participants undergoing an emergent repair had an AAA size recorded. A total of 6 deaths related to repair. None of the participants died of postoperative complications (no AAA size listed), for 48 procedures were for elective repair, and 2 of these patients died of an AAA. Six died in the setting of repair as noted above, and 4 additional participants died before emergent surgery could be performed or were not surgical candidates. The infrarenal aortic diameters for those 5 men and 5 women at the time of death were 7.0, 5.5, 7.0, and 9.7 cm, with 1 not recorded, and 9.0, 9.0, and 6.5 cm, with 2 not recorded, respectively. Among those who did not have an AAA size recorded at the time of death, the infrarenal aortic diameter measured at the time of the baseline ultrasound screening was 4.2 and 2.3 cm, respectively, for the women and 2.6 cm for the men (Table 3). The latter 2 participants did not meet either definition of AAA. Their time to death was 8.4 and 9.6 years, respectively, whereas the mean time to death for men and women with AAA at baseline was 6.3 and 7.1 years, respectively.

The risk of total mortality was higher among those participants with an AAA (definition 1) at baseline than among those without an AAA at baseline (HR 1.44, 95% confidence interval [CI] 1.25 to 1.66) after adjustment for demographic characteristics and possible confounders. The risk of mortality also increased with increasing infrarenal aortic diameter regardless of baseline CVD status (Table 4; Figure 2). When CVD was a time-dependent covariate, the HR of death for those with small aneurysms (3 to 3.5 cm) was 1.39 (95% CI 1.04 to 1.85) compared with those without an AAA (definition 1) and 1.47 (95% CI 1.10 to 1.98) compared with those with an infrarenal aortic diameter <2.0 cm (definition 2). The relationship between AAAs and mortality was not altered by the addition of β-blockers or HMG-CoA reductase inhibitors to our models. The risk was similar for men and women with AAAs (definition 1, adjusted HR 1.50, 95% CI 1.26 to 1.80 for men and adjusted HR 1.33, 95% CI 1.04 to 1.70 for women) and increased with increasing infrarenal aortic diameter. For women with small aneurysms at baseline (3.0 to 3.5 cm), the risk of death was significantly higher (adjusted HR 2.26, 95% CI 1.32 to 3.88) than for women who did not have an AAA at baseline (definition 1; Data Supplement, Appendix). This risk persisted among women with small aneurysms at baseline (3.0 to 3.5 cm), the risk of death was significantly higher (adjusted HR 2.26, 95% CI 1.32 to 3.88) than for women who did not have an AAA at baseline (definition 1; Data Supplement, Appendix). This risk persisted among women with small aneurysms at baseline (3.0 to 3.5 cm), the risk of death was significantly higher (adjusted HR 2.26, 95% CI 1.32 to 3.88) than for women who did not have an AAA at baseline (definition 1; Data Supplement, Appendix).
have an AAA (definition 1). Similarly, for hypertensive but not nonhypertensive men, there was an increased risk of death when the infrarenal to suprarenal aortic diameter ratio was ≥1.2 and the infrarenal aortic diameter was <3.0 cm (adjusted HR 1.81, 95% CI 1.41 to 2.32) for men and 1.18 (95% CI 1.18 to 2.32) for women. Despite these apparent differences between men and women, there was no significant interaction between infrarenal diameter size and gender when size was measured in groups as in Table 5, definitions 1 and 2, or linearly (P<0.20 for all).

CVD Events
There were 1231 incident CVD events after 10 years of follow-up among the 3381 participants who were free of CVD at the time of the abdominal scan. The risk of an incident CVD event was significantly higher among participants with AAA at baseline (definition 1) than among participants who did not have an AAA at baseline (adjusted HR 1.52, 95% CI 1.25 to 1.85) and increased with increasing infrarenal aortic diameter (Figure 2). Among those with small aneurysms (3 to 3.5 cm), the risk of incident CVD and intermittent claudication was increased (HR 2.31, 95% CI 1.63 to 3.28 and HR 3.05, 95% CI 2.13 to 4.30, respectively; Table 5) compared with those who had an infrarenal aortic diameter <2.0 cm. There was a marginally statistically significant interaction between presence of AAA and gender in the fully adjusted model (P=0.041). The relative risk for incident CVD events for participants with an AAA compared with those without was 1.81 (1.41 to 2.32) for men and 1.18 (0.85 to 1.64) for women. Among women who had only mildly increased infrarenal aortic diameter (2.0 cm to <3.0 cm), the risk of incident CVD events was 23% higher (HR 1.23, 95% CI 1.02 to 1.48) than for women with infrarenal aortic diameters <2.0 cm. The HR for men with infrarenal diameters between 2 and 3 cm was 1.15 (95% CI 0.94 to 1.40). However, for men with a ratio of infrarenal to suprarenal aortic diameter ≥1.2 and an infrarenal diameter <3 cm, risk of incident CVD was 50% higher (HR 1.51, 95% CI 1.03 to 2.21) than that of men with no evidence of an aneurysm. No increased risk due to an elevated ratio was observed for women. Despite these apparent differences between men and women, there was no significant interaction between infrarenal diameter size and gender when size was measured in groups as in Table 5, definitions 1 and 2, or linearly (P<0.20 for all).

There was a significant interaction between low-density lipoprotein cholesterol level and AAAs (definition 1) in women for CVD outcomes (P=0.002). Among women in the highest quartile of low-density lipoprotein (153 to 262 mg/dL), those who had an AAA were twice as likely to have an incident CVD event as women who did not have an AAA (HR 2.08, 95% CI 1.22 to 3.54). AAAs were not associated with an increased risk of CVD among women in the lower 3 quartiles of low-density lipoprotein (<153 mg/dL). For men, there was a significant interaction between renal insufficiency (creatinine ≥1.5 mg/dL) and AAA (P=0.048). The HR for incident CVD among men with an AAA without renal insufficiency was 1.68 (95% CI 1.28 to 2.2) and increased to 3.52 (95% CI 1.77 to 6.99) among men with renal insufficiency. We had few incident events to assess the risk of incident chronic kidney disease and AAA; however, regardless of definition, increasing infrarenal aortic diameter was associated with an increasing prevalence of chronic kidney disease, defined as an estimated glomerular filtration rate <60 mL·min⁻¹·m⁻². Among those with an infrarenal aortic diameter ≥3.5 cm, the prevalence of chronic kidney disease was higher (OR 1.71, 95% CI 1.08 to 2.72) than for those who had an infrarenal aortic diameter <2 cm.

Discussion
After a 1-time ultrasound screening of the abdominal aorta, we observed that few CHS participants had AAA surgical
repairs or died of an AAA during the 10-year follow-up period. The majority who had a repair or died of AAA had infrarenal aortic diameters ≥2.5 cm. Small aneurysms (3.0 to 3.5 cm) were associated with an increased risk of total mortality and incident CVD for men and women. Infrarenal aorta diameters of 2.0 to <3.0 cm were associated with an increased risk of death for men and an increased risk of incident CVD events among women.

The results of the present study are consistent with previous studies among men that concluded that a 1-time ultrasound screening of the abdominal aorta adequately identifies those who have AAAs of “clinical significance” and those who are at “low risk from rupture who do not require surveillance.”2,26–30 Similarly, the present finding of a low prevalence of AAA (infrarenal aortic diameter ≥3.0 cm) among women is consistent with the Chichester study, which concluded that screening was not beneficial among women for reducing AAA related deaths.5,10 Interestingly, however, for those with an infrarenal aortic diameter ≥3.0 cm in the CHS, albeit their numbers were small (Table 3), the risk of AAA-related mortality among women appeared to be the same as or higher than that of men.

In the CHS, AAAs were associated with CVD risk factors, subclinical atherosclerotic disease, and incident CVD and CVD-related mortality events after 4.5 years.13,14 However, the number of events during the follow-up period precluded analyses examining the risks of incident CVD events for men and women separately. In the present study, after 10 years of follow-up, AAAs were again associated with an increased risk of total mortality and incident CVD events; however, now there is also evidence to suggest that this risk may extend to those with infrarenal aortic diameters between 2.0 and 3.0 cm, particularly among women. This increased risk among women may be related to the fact that women in the CHS had smaller infrarenal aortic diameters than men at baseline, and as a result, small but not aneurysmal dilatation of the aorta might represent a greater increase in infrarenal aortic diameter for women than for men. Given these data, infrarenal aortic diameters between 2.0 and 3.0 cm could be considered another manifestation of subclinical atherosclerosis (Table 1). Whether screening for AAA could be used to identify those at high risk for CVD and to justify aggressive risk factor management, however, remains unknown.

The present study has several limitations. First, because no additional ultrasonography was obtained, we could not assess the change in size of the infrarenal aortic diameter over time. Second, the prevalence of participants at high risk (infrarenal aortic diameters >4.0 cm) was low in the present population sample. Few women had diameters >3.0 cm, which limits our statistical power to assess gender differences in risk associated with diameter size. Third, the number of CHS participants screened was relatively small compared with some other cohorts. Fourth, examination of the association between AAA and outcomes in cohort studies is limited by the fact that the reporting of infrarenal aortic diameter results to a participant’s clinician could result in treatment interventions that would potentially alter the relationship and therefore introduce bias with regard to the relationship between AAA and CVD or mortality. Fifth, the low prevalence of AAA, particularly among women, results in a low positive predictive value even for infrarenal aortic diameter cutpoints with high sensitivity and specificity (ie, 2.5 cm). Finally, the CHS cohort was generally healthier at baseline than community-dwelling adults of the same age, which may contribute to the lower number of AAA repairs and deaths due to AAA in the present study.

In conclusion, the present study suggests that a 1-time screening of the abdominal aorta can acceptably identify men and women with a clinically significant AAA. For those with an infrarenal aortic diameter >2.0 cm, there was a significantly higher risk of future CVD events and total mortality. These findings suggest that increased aortic diameter is another measure of subclinical atherosclerosis.

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Disclosures
None.

References

**CLINICAL PERSPECTIVE**

A 1-time ultrasound screening of the abdominal aorta over a 10-year follow-up may identify men and women over the age of 65 years who develop clinically significant abdominal aortic aneurysms. Measuring the infrarenal abdominal aorta may help clinicians identify patients who are at increased risk of future cardiovascular disease events. The risk of future cardiovascular disease events was increased even among individuals who were 65 years or older with an infrarenal aortic diameter between 2.0 and 3.0 cm compared with those who had infrarenal aortic diameters <2.0 cm. Measurement of the infrarenal aortic diameter with ultrasound may be another potential risk equivalent for cardiovascular disease.
Abdominal Aortic Aneurysms, Increasing Infrarenal Aortic Diameter, and Risk of Total Mortality and Incident Cardiovascular Disease Events: 10-Year Follow-Up Data From the Cardiovascular Health Study
Matthew S. Freiberg, Alice M. Arnold, Anne B. Newman, Matthew S. Edwards, Kevin L. Kraemer and Lewis H. Kuller

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