Modeling the Burden of Abdominal Aortic Aneurysm in the USA in 2013

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Key Words

Epidemiology · Cardiovascular disease · Mortality · Survival · Aneurysm · Aortic dissection · Women

Abstract

Objectives: Abdominal aortic aneurysm (AAA) is a pathological condition characterized by an abnormal, localized dilatation of the lower part of the aorta. Due to a lack of data on the natural history of AAA and risk of death from other cardiovascular diseases attributable to AAA, the true number of AAA-attributable deaths may be higher than currently estimated. This study aims to produce more realistic estimates of the burden of AAA. **Methods:** A disease-modeling software, DisMod II, was used to assess the AAA burden via a multistate life table. Inputs included population, all-cause mortality, size- and sex-specific AAA prevalence, and relative risk of death estimates for persons with AAA compared with persons without AAA. **Results:** There were 2,347,339 prevalent cases of AAA in the USA in 2013 (95% CI: 2,131,964–2,524,116), resulting in 41,371 deaths attributable to AAA (95% CI: 34,090–49,234). Females constituted 21.1% of prevalent cases and 45.2% of deaths, compared with males constituting 78.9% of prevalent cases and 54.8% of deaths. **Conclusions:** This work shows that the burden of mortality at-

tributable to AAA is more than twice the current estimates from the American Heart Association. Females account for a disproportionately high percentage of deaths despite constituting a low percentage of prevalent cases.

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Introduction

Abdominal aortic aneurysm (AAA) is a pathological condition characterized by an abnormal, localized dilatation of the lower part of the aorta [1]. The general consensus for defining an AAA is aortic diameter ≥ 1.5 times the normal diameter at the level of the renal arteries, which typically equates to a minimum diameter of 3.0 cm to be considered an AAA [2]. The prevalence of AAA has previously been shown to be approximately 4–5% among adults over 50 years of age, although it is several times more common in men than in women [3–5].

The United States Preventive Services Task Force (USPSTF) currently recommends one-time screening for AAA in men aged 65–75 years who have ever smoked and recommends that clinicians selectively offer screening for AAA in men who have never smoked. However, the USPSTF concludes that the current evidence is insuffi-

Fig. 1. Mathematical model framework used in DisMod II.

cient to assess the balance of harms and benefits of screening for AAA in women aged 65–75 years who have ever smoked, and it recommends against the routine screening for AAA in women who have never smoked [6].

Due to implementation of the Screening Abdominal Aortic Aneurysms Very Efficiently (SAAAVE) Act in January 2007, Medicare began covering the costs of a one-time ultrasound screening of men aged 65–75 years who ever smoked in their lifetime, or men and women who have a family history of AAA. However, this is a fairly narrow screening program, and it has been shown that the SAAAVE Act has had no discernable effect on AAA rupture or all-cause mortality [7].

AAA patients have a higher prevalence of cardiovascular risk factors compared with those without AAA, as well as an increased risk of death due to aneurysm rupture [8, 9]. In a retrospective analysis of the National Inpatient Sample, the largest publicly available all-payer inpatient health care database in the USA, patients with ruptured AAA had a 39% in-hospital mortality rate [10]. Even among patients with successful repair of AAA, the average life expectancy is lower than in the general population [11].

According to the American Heart Association, in 2010 there were 16,417 any-mention deaths attributable to thoracic aortic aneurysm or AAA [12]. However, this number of aneurysm-related deaths may underestimate the true number of deaths due to the fact that patients with AAA ruptures outside of the hospital may not survive the trip to receive care [5]. According to a systematic review and meta-analysis, 32% of patients with AAA ruptures die before reaching the hospital [13].

Few data are available on the natural history of AAA and risk of death from other cardiovascular diseases attributable to AAA. Due to the relatively high prevalence of AAA among the elderly population, it is reasonable to assume that the true number of AAA-attributable deaths could be expected to be much higher than previously estimated.

Methods

This study used a disease-modeling software, DisMod II, developed by the World Health Organization for the Global Burden of Disease 2000 study. This has previously been used to model the burden of a wide range of other diseases, such as diabetes [14, 15], multiple sclerosis [16], schizophrenia [17], and malaria [18]. The mathematical model of DisMod II is a multistate life table describing a single disease, where transition hazards define the relationships between three states: healthy, diseased, and dead [19] (fig. 1). Those in the healthy state are defined as people being unaffected by the disease of interest. They are exposed to an incidence transition hazard, which may lead to them moving into the diseased state. From the diseased state they are exposed to a hazard of dying from the disease or a hazard of remission. The hazard of mortality from all other causes is the same for those in either the healthy or diseased state. A set of differential equations defines the relationships between the states and transition hazards, and allows for the calculation of the number of people in each state.

Input data for this study consisted of: age- and sex-specific population; age- and sex-specific all-cause mortality; size- and sex-specific AAA prevalence, and relative risk (RR) estimates of death for persons with AAA compared with persons without AAA, adjusted for age, ethnicity, height, weight, smoking, and cardiovascular disease history. AAA prevalence and RR estimates were segmented by size of aneurysm, where small AAA refers to aneurysms with an infrarenal diameter of 3.0–3.9 cm and large AAA refers to aneurysms with an infrarenal diameter of ≥ 4.0 cm.

Population data by sex and age were obtained from the United States Census Bureau's American FactFinder database [20]. All-cause mortality data by sex and age were obtained from the Centers for Disease Control and Prevention's National Vital Statistics System [21]. Estimates for prevalence came from results of the Department of Veterans Affairs Aneurysm Detection and Management (ADAM) study [4]. The ADAM study represents the largest AAA epidemiological study that involves the inclusion of women. A cubic spline interpolation curve was used to extend the prevalence estimates from 50–79 years to ≥ 50 years. Measures of RR of death for those with AAA came from the Cardiovascular Health Study, a longitudinal cohort study from the UK [22]. Confidence intervals (CI) were calculated within DisMod II via a Monte Carlo simulation (parametric bootstrapping).

Results

The numbers of calculated prevalent cases and AAA-attributable deaths based on the model are presented in tables 1 and 2, respectively. There were 2,347,339 total prevalent cases of AAA (95% CI: 2,131,964–2,524,116) resulting in 41,371 AAA-attributable deaths (95% CI: 34,090–49,234). Among males, there were 1,853,116 prevalent cases (95% CI: 1,686,511–1,995,377) and 22,680 AAA-attributable deaths (95% CI: 18,472–28,922), representing 78.9% of the total prevalent cases and 54.8% of the total AAA-attributable deaths, respectively. Among females, there were 494,223 prevalent cases (95% CI: 445,453–528,739) and 18,691 AAA-attributable deaths (95% CI: 15,618–20,312), representing 21.1% of the total prevalent cases and 45.2% of the total AAA-attributable deaths, respectively. The 22,680 deaths among males accounted for 1.7% of male all-cause deaths in 2013, while the 18,691 deaths among females accounted for 1.5% of female all-cause deaths. Combined, AAAs were responsible for 1.6% of all-cause deaths in 2013.

Small AAAs accounted for 72.7% of the total prevalent cases and 59.1% of total AAA-attributable deaths. Among males, 68.7% of prevalent cases and 33.1% of AAA-attributable deaths were due to small AAAs. 87.9% of female prevalent cases and 90.8% of female AAA-attributable deaths were due to small AAAs. Large AAAs accounted for 27.3% of total prevalent cases and 40.9% of total AAA-attributable deaths. Among males, large AAAs accounted for 31.3% of prevalent cases and 66.9% of AAA-attributable deaths, compared with 12.1% of prevalent cases and 9.2% of AAA-attributable deaths among females.

Among those ≥ 55 years of age, the AAA-attributable proportion of all-cause deaths increased to a peak between 75 and 84 years (fig. 2). For males in both age groups of 75–79 and 80–84 years, AAA-attributable

Table 1. Modeled prevalence of AAA, by sex and aneurysm size

Sex	Category	Prevalent cases, n	95% CI	
			lower	upper
Males	small AAA	1,272,483	1,159,455	1,369,366
	large AAA	580,633	527,056	626,011
	total	1,853,116	1,686,511	1,995,377
Females	small AAA	434,321	391,349	465,068
	large AAA	59,902	54,104	63,671
	total	494,223	445,453	528,739
Both	small AAA	1,706,804	1,550,804	1,834,434
	large AAA	640,535	581,160	689,682
	total	2,347,339	2,131,964	2,524,116

Table 2. Modeled mortality attributable to AAA, by sex and aneurysm size

Sex	Category	Deaths, n	95% CI		Proportion of all-cause deaths, %
			lower	upper	
Males	small AAA	7,500	5,839	11,670	0.57
	large AAA	15,180	12,633	17,252	1.16
	total	22,680	18,472	28,922	1.74
Females	small AAA	16,965	14,193	18,373	1.31
	large AAA	1,726	1,425	1,939	0.13
	total	18,691	15,618	20,312	1.45
Both	small AAA	24,465	20,032	30,043	0.94
	large AAA	16,906	14,058	19,191	0.65
	total	41,371	34,090	49,234	1.59

deaths accounted for 3.0% of all-cause deaths, compared with 1.9% for females in both age groups of 75–79 and 80–84 years.

Discussion

Modeling the burden of AAA using the DisMod II program resulted in over twice as many deaths attributable to AAA as current estimates by the American Heart Association. Interestingly, the results showed that females accounted for a disproportionately high percentage of total AAA-attributable deaths, 45.2%, despite only accounting for 27.3% of the total prevalent cases.

AAA-attributable deaths due to large AAAs represented a more significant burden among males than fe-

Fig. 2. Proportion of all-cause deaths attributable to AAA, by sex and selected age groups.

males: 66.9 versus 9.2%, respectively. This is most likely due to the lower prevalence of large AAAs among women (0.12%) compared with men (1.34%) [4].

This study suggests that while AAA is less common among females than males, it is more likely to result in death. Among males, there were 81.7 prevalent cases of AAA per each AAA-attributable death, whereas among females this ratio is much lower at only 26.4 prevalent cases per death. These results are in line with other research stating that although females are generally protected from the development of AAAs, the ones that do develop behave more aggressively with higher growth and rupture rates [23].

Due to females having a disproportionately high percentage of total AAA-attributable deaths, as well as a lower ratio of prevalent cases to deaths compared with males, it is not unreasonable to suggest that perhaps current screening procedures for AAA should be expanded to include a more focused effort on identifying affected females.

The aim of this study was to provide more realistic estimates of the burden of AAA. However, there are some important limitations. The prevalence estimates include both diagnosed and undiagnosed patients, and cubic spline interpolation was used in order to apply these estimates to the entire population aged ≥ 50 years rather than only 50–79 years as reported in the ADAM study. Also, due to a lack of available data, the RR of death input was taken from a study conducted in the UK and used in this model to estimate the disease burden in the USA. It is possible that there are underlying factors that would result in

risk values differing between these countries, although according to the World Health Organization the UK and USA have comparable age-standardized mortality rates due to cardiovascular disease [24]. There are also elements of DisMod II that are subjective to the researcher, such as using various statistical means of smoothing input variables or using different weights for input variables. Using DisMod II is an interactive exercise, and the output results of the model may differ based on how the researcher utilizes different settings. Inconsistency of cross-sectional variables describing a disease may be real or deceptive, and there are inherent difficulties in combining measurements from different sources [25]. Despite these potential limitations, the results of this study demonstrate that the burden of deaths attributable to AAA may be considerably higher than current estimates suggest, particularly among females.

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Conflict of Interest

The funder provided support in the form of a salary for the author, but did not have any additional role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

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