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Relative importance of aneurysm diameter and body size for predicting AAA rupture in men and women

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Abstract

Objectives—Women have been shown to have up to a four-fold higher risk of abdominal aortic aneurysm (AAA) rupture at any given aneurysm diameter compared to men, leading to recommendations to offer repair to women at lower diameter thresholds. Although this higher risk of rupture may simply reflect greater relative aortic dilatation in women who have smaller aortas to begin with, this has never been quantified. Our objective was therefore to quantify the relationship between rupture and aneurysm diameter relative to body size and to determine whether a differential association between aneurysm diameter, body size, and rupture risk exists for men and women.

Methods—We performed a retrospective review of all patients in the Vascular Study Group of New England (VSGNE) database who underwent endovascular or open AAA repair. Using each patient's height and weight, body mass index (BMI) and body surface area (BSA) were calculated. Next, indices of each measure of body size (height, weight, BMI, BSA) relative to aneurysm diameter were calculated for each patient. To generate these indices, we divided aneurysm diameter (in cm) by the measure of body size [e.g. aortic size index (ASI) = aneurysm diameter (cm) / BSA (m2)]. Along with other relevant clinical variables, we used these indices to construct different age-adjusted and multivariable-adjusted logistic regression models to determine predictors of ruptured repair vs. elective repair. Models for men and women were developed separately and different models were compared using the area under the curve (AUC).

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Results—We identified 4045 patients who underwent AAA repair (78% male, 53% EVAR). Women had significantly smaller diameter aneurysms, lower BSA, and higher BSA indices than men (Table 1). For men, the variable that increased the odds of rupture the most was aneurysm diameter (AUC = 0.82). Men exhibited an increased rupture risk with increasing aneurysm diameter (<5.5cm: OR 1.0; 5.5–6.4cm: OR 0.9, 95% CI 0.5–1.7, P=.771; 6.5–7.4cm: OR 3.9, 95% CI 1.9–1.0, P<.001; 7.5+ cm: OR 11.3, 95% CI 4.9–25.8, P<.001). In contrast, the variable most predictive of rupture in women was ASI (AUC = 0.81), with higher odds of rupture at higher ASI(ASI >3.5–3.9: OR 6.4, 95% CI 1.7–24.1, P=.006; ASI 4.0+: OR 9.5, 95% CI 2.3–39.4, P=.002). For women, aneurysm diameter was not a significant predictor of rupture after adjusting for ASI.

Conclusion—Aneurysm diameter indexed to body size is the most important determinant of rupture for women whereas aneurysm diameter alone is most predictive of rupture for men. Women with the largest diameter aneurysms and the smallest body sizes are at the greatest risk of rupture.

INTRODUCTION

Women have frequently been shown to have worse outcomes following abdominal aortic aneurysm (AAA) repair compared to men[1–5]. Though the reasons for this are likely multifactorial and include older age, higher operative risk due to undiagnosed cardiovascular comorbidity[4], and smaller caliber vessels and challenging anatomy[6, 7], one hypothesis has been that because women are generally smaller than men, an aneurysm of a certain size in a woman represents a greater relative dilatation of the aorta compared to the same sized aneurysm in a man. If this were true, women would effectively have more advanced disease at the time of treatment. Proponents of this theory cite the UK Small Aneurysm Trial[8–10], which reported that rupture risk is 3–4 times higher in women and that women rupture at smaller aneurysm diameters than men. Largely in light of these findings, in their 2003 guidelines for AAA treatment,[11] the Joint Council of the American Association of Vascular Surgery and the Society of Vascular Surgery (SVS) suggested that a lower threshold diameter for repair (4.5–5.5cm) could be considered for women. In the 2009 SVS Practice Guidelines, the suggestion was again made that women may benefit from early repair[12].

However, opponents argue that the level of evidence to support differential treatment of women is lacking[13]. A recent Cochrane review of four randomized controlled trials that compared the long-term survival of patients with small aneurysms (4.0–5.5cm) undergoing either early repair or ultrasound surveillance concluded that there was no evidence to suggest a benefit to early repair[14]. However, out of the four trials, only the UK Small Aneurysm Trial (UKSAT)[15] had a representative sample of women. Women were underrepresented in the Aneurysm Detection and Management (ADAM)[16, 17], Comparison of Surveillance Versus Aortic Endografting for Small Aneurysm Repair (CEASAR)[18], and Positive Impact of Endovascular Options for treating Aneurysms Early (PIVOTAL)[19, 20] trial, in which the proportion of women was only 1% (n=10), 4% (n=15), and 15% (n=97), respectively.

We felt there would be value to using a large multicenter database with good female representation to quantify the relationship between rupture and aneurysm diameter relative to body size, and determine whether a differential association between aneurysm diameter, body size, and rupture risk exists for men and women.

METHODS

We performed a retrospective review of all patients in the Vascular Study Group of New England (VSGNE) database who underwent endovascular or open AAA repair. The VSGNE is a regional collaboration between 30 academic and community hospitals in the six New England states. Data on commonly performed vascular procedures from each participating institution are collected and maintained in a prospective registry. Details about this registry can be found at http://www.vsgne.org. At the time of this analysis, the registry included data on 1,887 open AAA repairs and 2,158 endovascular aortic aneurysm repair (EVAR) procedures. Presentation was categorized as ruptured if there was computed tomography (CT) or angiographic evidence of rupture or if rupture was found at exploration. Patients who underwent AAA repair as a planned or scheduled procedure, or those who had surgery within 24 hours of pain and/or tenderness but without radiographic evidence of rupture were categorized as non-ruptured.

The body mass index (BMI) and body surface area (BSA) of each patient were calculated using height and weight information. We used the standard formula for BMI:

$$\mathrm{BMI}=\mathrm{weight\ (kg)}/[\mathrm{height\ (m)}]^2$$

The Dubois & Dubois formula[21] was used to calculate BSA:

$$\mathrm{BSA}=[\mathrm{weight\ (kg)}^{0.425}\times \mathrm{height\ (m)}^{0.725}]\times 0.20247$$

We next generated indices of each measure of body size (height, weight, BMI, and BSA) relative to the maximum antero-posterior aneurysm diameter, which was obtained from preoperative radiologic studies. If the antero-posterior diameter was not specified, the largest diameter was used. If more than one preoperative imaging study was obtained, the following hierarchy was used to obtain the diameter: CT, magnetic resonance imaging (MRI), echocardiogram, arteriogram. These indices were calculated by dividing aneurysm diameter (in cm) by each measure of body size [e.g. BSA index = aneurysm diameter (cm) / BSA (m^2)]. The BSA index will hereafter be referred to as aortic size index (ASI) in order to establish consistency with previously published terminology[22]. Measures of body size and their respective aortic indices were divided into clinically relevant categories or based on quantiles (tertiles, quartiles, or quintiles). The BSA of men and women were compared to their gender-specific means (1.9m^2 for men and 1.6m^2 for women)[23, 24].

Differences in categorical variables were compared using the Pearson χ^2 and two-tailed Fisher's exact test and differences in continuous variables were compared using student's t-test. Using the indices of aneurysm size relative to body size, we constructed multivariable-adjusted logistic regression models using forward selection to determine predictors of ruptured vs. elective repair. We started with one model inclusive of gender as well as interaction terms between gender and ASI and gender and aortic diameter. Given that the interaction term between gender and ASI was borderline significant (p=.06), models for men and women were developed separately and the optimal model for each gender was chosen using the Area Under the Curve (AUC). Because covariates may potentially overlap in their ability to explain the variability in rupture rates we checked the beta coefficients and standard errors with and without suspected collinear covariates in the model. Covariates were considered confounders if they changed the coefficients by 20% and were included in the model. Covariates were classified as collinear if they did not substantially change the coefficient but increased the standard error by >20%. Additionally, cumulative distribution curves were generated to evaluate rupture as a function of either aneurysm diameter or ASI. The cumulative distribution curves between men and women were compared with the Kolmogorov-Smirnov test. Statistical analyses were performed using SAS (version 9.3; SAS Institute, Cary, NC) and Stata version 12.0 (Stata Corp, College Station, Tex).

RESULTS

We identified 4,045 patients who underwent AAA repair, of which 2,158 (53%) underwent EVAR. In total, there were 440 ruptures (11%), comprising 18% of open repairs and 4% of EVARs. Women represented 22% of all patients. In general, women were older, less likely to have a smoking history and CAD, but more likely to have COPD than men. Women underwent EVAR for intact aneurysms less often than men (50% vs 60%, P<.001) but more underwent EVAR for rupture (26% vs 20%, P=.183) (Table I).

Compared to men, the mean aneurysm diameter in women was 2mm smaller for intact aneurysms and 7mm smaller for ruptured aneurysms(Table II). More women underwent repair of intact aneurysms at diameters<5.5cm (43% vs. 36%, P<.001) and <5.0cm (13% vs. 11%, P<.050) (Table II & Figure 1). A substantial proportion of aneurysms in both men and women ruptured at diameters <5.5cm. However, the difference between men and women did not reach statistical significance (10%vs. 17%, P=.093). A similar proportion of men and women ruptured at diameters <5.0cm (4% for both, P=1.000)and at diameters <4.5cm (3% vs. 0%, P=.361).

Men were generally taller and heavier and thus had significantly higher BSAs than women (Table II). However, women were more likely to have a BSA greater than their gender-specific mean. Based on BMI, women were more likely to be underweight and of normal weight compared to men, who were more likely to be obese. When aortic diameter was indexed to height, weight, BMI and BSA, women had larger aortas relative to height, weight, and BSA, but not BMI (Table III& Figure 2). These differences were non-significant between men and women with ruptured aneurysms, likely due to the small size of these subgroups.

Multivariable-adjusted logistic regression models were constructed for men and women separately (Table IV). Men who had a past history of smoking had approximately half the odds of undergoing ruptured repair (OR 0.6, 95% CI 0.4–0.9, P=.014) but the same effect was not observed among men who reported to be current smokers. Similarly, there was no association between past or current smoking and intact vs. ruptured repair for women. For men, the strongest predictor of ruptured repair was aortic diameter. Compared to men with aneurysms <5.5cm, men with aneurysms 6.5–7.4cm had 4-fold higher odds of ruptured repair (95% CI 1.9–8.2, P<.001) and men with aneurysms ≥ 7.5cm had 12-fold higher odds of undergoing ruptured repair (95% CI 5.2–27.2, P<.001).

In contrast, for women, the strongest predictor of ruptured repair was ASI (Table IV). Compared to women with a ASI between 3.0 and 3.4cm/m^2, women with ASI 3.5–3.9cm/m^2 had 6.4 times the odds (95% CI 1.7–24.1, P=.006) and women with ASI ≥ 4.0cm/m^{2}had 9.5 times the odds (95% CI 2.3–39.4, P=.002) of undergoing AAA repair for ruptured aneurysms. In a multivariable model adjusting for ASI as well as aneurysm diameter and other covariates, aneurysm diameter alone was not a significant predictor of ruptured repair for women. Of note, the average aneurysm diameter of women with an ASI ≤ 3.5cm/m^2 was 5.3cm. The corresponding average aneurysm diameter of men with an ASI ≤ 3.5cm/m^2 was 6.0cm.

When the cumulative proportion of rupture repair was plotted against aneurysm diameter (Figure 3), we observed that in general, women had a 1.4 fold higher odds of ruptured repair at any given aneurysm diameter (95% CI 1.1–1.8, P=.014). When we adjusted aneurysm diameter for body size and plotted the cumulative proportion ruptured against ASI rather than aneurysm diameter (Figure 4), a difference between rates of ruptured repair between men and women was no longer observed (HR 0.9, 95% CI 0.6–1.2, P=0.315).

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There were 12 women who underwent repair of ruptured aneurysms that were smaller than 5.5cm (Table V). Of these 12, 10 (or 83%) may potentially have avoided rupture had an ASI threshold of ≥2.5cm/m^2 been used to recommend elective repair (Table VI). Of the two that would have been missed, their aneurysm diameters were 4.8cm and 5.0cm. An additional 20 women underwent repair of symptomatic aneurysms <5.5cm. Of these, 14 had an ASI > 2.5cm/m^2 (mean ASI 2.7 ± 0.4cm/m^2).

Conversely, of 322 women who underwent elective repair of intact, asymptomatic aneurysms that were smaller than 5.5cm, 61 had an ASI of <2.5cm/m^2 This suggests that, if using size criteria alone as indication for elective repair, up to 19% of these women could potentially have safely continued to undergo surveillance. The mean aneurysm diameter of these women was 4.2cm.

DISCUSSION

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The Joint Council of the American Association of Vascular Surgery and the Society of Vascular Surgery has suggested a lower diameter threshold for AAA repair in women[11]. This recommendation was made based on observations that women have a higher risk of aneurysm rupture at any given diameter and that women rupture at smaller diameters than men[10, 25,26]. Consistent with these previous reports, we found that a considerable proportion of patients who underwent rupture repair (10% of men and 17% of women in our series) have aneurysms smaller than 5.5cm and that the average diameter of ruptured aneurysms in women was 7mm smaller than in men. Using BSA, we were able to show that accounting for body size bridged the gender discrepancy in rupture rates. This gives credence to what many have previously suspected: that the reason women rupture at smaller aortic diameters is that their aneurysms are larger relative to their body size compared to men. It is important to note that BSA and ASI account for body size and are not simply measures of obesity. Notably, BMI, the standard measure of obesity, and its associated BMI index, were not predictive of rupture in the multivariable model. Thus, although obesity correlates with higher ASI, we cannot conclude that obesity is protective against rupture.

The results from our multivariable models indicated that ASI was a better predictor of rupture repair than aneurysm diameter alone for women. One might naturally wonder why there should be a differential importance of body size in predicting rupture repair for women versus men such that ASI is predictive for women but not men. We believe this is because the women in the VSGNE had a greater variation in body size than the men. Thus, indexing aneurysm diameter to body size provides little additional information than aneurysm size alone in men. In contrast, in women who have greater diversity in body size, ASI has more predictive power. If validated, using an ASI threshold of ≥2.5cm/m^2 may help identify women with aneurysms <5.5cm who would benefit from early repair. For men, it appears aneurysm diameter alone remains the primary determinant of rupture risk.

ASI has also been shown to be a better predictor of rupture in thoracic aortic aneurysms. Davies et al. analyzed the association of ASI to the incidence of adverse events (rupture, dissection, or death)[22]. In all analyses, they found ASI to be a better predictor of adverse events than maximum aortic diameter alone. Using ASI, they stratified patients into three levels of risk. Those with ASI <2.75cm/m^{2}were considered low risk (yearly risk approximately 4%), those with ASI between 2.75 and 4.25cm/m^{2}were considered at moderate risk (yearly risk approximately 8%), and those with ASI above 4.25cm/m^2 were categorized as high risk (yearly risk, approximating 20–25%).

Other groups have previously attempted indexing aneurysm diameter to other measures of body size. Forbes et al. calculated the relative dilatation of aneurysms (108 men, 21 women) undergoing elective EVAR by indexing maximum aneurysm diameter to suprarenal aortic diameter[27]. Using this index, they found relative dilatation to be greater in women and, through linear regression modeling, demonstrated that 5.5cm aneurysms in men translated to 5.2cm aneurysms in women. However, because their study included only patients undergoing elective repair, they could not comment on rupture risk prediction.

Ouriel et al. indexed aneurysm diameter to the transverse diameter of the third lumbar vertebral body[28]. They used this index to evaluate the CT scans of 100 patients undergoing elective AAA repair compared to 36 patients with ruptured aneurysms. When using a threshold value of 1.0, they found this measure to be a more accurate predictor of rupture than diameter alone. However, a gender-specific analysis was not performed.

Fillinger et al. have investigated the association of peak aortic wall stress to rupture risk. Using finite element analysis and three-dimensional (3D) CT reconstruction to measure peak mechanical wall tensile stress, they demonstrated first that wall stress was significantly different between intact and ruptured aneurysms[29], and later that wall stress could reliably predict rupture risk in patients undergoing surveillance[30]. They are currently undertaking a large, prospective, multicenter study to validate this promising metric[29] and one of their goals is to determine if there are any significant differences in aneurysm wall thickness, wall strength, or both between men and women since they initially observed that a higher proportion of aneurysms in women had high wall stress[30]. However, currently 3D CT reconstruction is not universally available and wall stress analysis is currently too complex for broad application. In contrast, ASI is quick and simple to calculate and therefore easily adoptable into clinical practice.

In addition to rupture risk, the decision to operate for AAAs should take into account the risk of the procedure and the patient's predicted late survival. Opponents to adopting a lower aneurysm size threshold for women point out that women have frequently been shown to have significantly higher perioperative morbidity and mortality compared to men[1–3, 31–33], effectively diminishing or even negating any benefit to earlier repair. However, in our previous analysis of gender differences in AAA presentation, management, and outcomes using the same database as this current study[34], we observed gender disparities in perioperative and 1-year mortality only among patients undergoing ruptured repair. Within the VSGNE at the time of our analysis, 43% of women underwent elective AAA repair at aneurysm diameters <5.5cm and we found that both men and women who were repaired for such "small" aneurysms had significantly better perioperative and 1-year survival. On the surface these results may appear to contradict the conclusions made by the UKSAT and other randomized controlled trials[16–18] that failed to show any benefit of early repair of small aneurysms. However, these women (and also the 35% of men undergoing AAA repair at aneurysm diameters <5.5cm) were clearly a group of carefully selected patients chosen for repair because of their more favorable risk profile. They were younger and had lower rates of congestive heart failure and chronic obstructive pulmonary disease and were more likely to undergo EVAR rather than open repair. Thus, when considering patients for "early repair," appropriate patient selection is still the most important determinant of patient outcomes[35]. We therefore would not advocate repair of aneurysms <5.5cm in women who are not suitable surgical candidates.

Smoking has been shown to be a risk factor for AAA expansion, rupture, and poor long-term survival after repair[36]. Paradoxically, in our study, a positive smoking history was correlated with elective rather than ruptured repair in men. This may be perhaps because patients with a smoking history are more likely to be screened for AAA and subsequently referred for elective repair. It is also plausible that patients seen electively have smoking history more accurately recorded than patients who present emergently with rupture.

In addition to its retrospective design, our study is limited by the absence of information regarding patients treated non-operatively. It must be emphasized that since the VSGNE only captures patients who underwent repair, patients who were denied or who declined repair or died before reaching a hospital were excluded. The individuals included in the VSGNE are more likely to have smaller aneurysms and/or have a more favorable surgical risk profile, which has clearly led to some degree of selection bias. Furthermore, since patients in this database underwent repair when they reached appropriate size criteria or became symptomatic, they were eliminated from further analysis. This may in part explain why the relationship between repair for rupture and ASI is J-shaped rather than linear for women. Thus, a prospective study inclusive of patients with AAA managed with surveillance is necessary to validate the results of our study.

Additionally, the VSGNE lacks data on aneurysm expansion rate, tortuosity, diameter asymmetry, fusiform vs. saccular configuration, presence of thrombus, adequacy of blood pressure control, and other anatomic and clinical factors that have previously been shown to affect rupture risk[26, 37, 38]. Thus the prognostic utility of ASI is unclear in cases in which these factors are a major concern.

It can be argued that because the majority of men and women in the VSGNE had larger-than-normal body size indices (i.e. BMI, BSA) that our findings are limited to "larger" patients. However, most patients with AAA (and in fact most typical patients in America) tend to be overweight. Furthermore, recent studies have demonstrated associations between obesity and abdominal adiposity and increased incidence and expansion of AAA[39, 40]. We therefore do not think the overrepresentation of larger patients in our study jeopardizes the generalizability of our study's results.

Finally, although the VSGNE captures more than 4,000 patients undergoing AAA repair, the number of men and women undergoing repair for small, ruptured aneurysms were comparatively small, potentially introducing instability in the multivariable models and increasing the risk of statistical error.

CONCLUSIONS

A significant proportion of patients with AAA rupture do so at aneurysm diameters less than 5.5cm. At the time of repair, women generally have larger aneurysms relative to their body size than men. For men, aneurysm size is still the strongest predictor of rupture. For women, aneurysm size indexed to body surface area is more predictive of rupture than aneurysm size alone. ASI may help identify women who would benefit from early repair of aneurysms <5.5cm.

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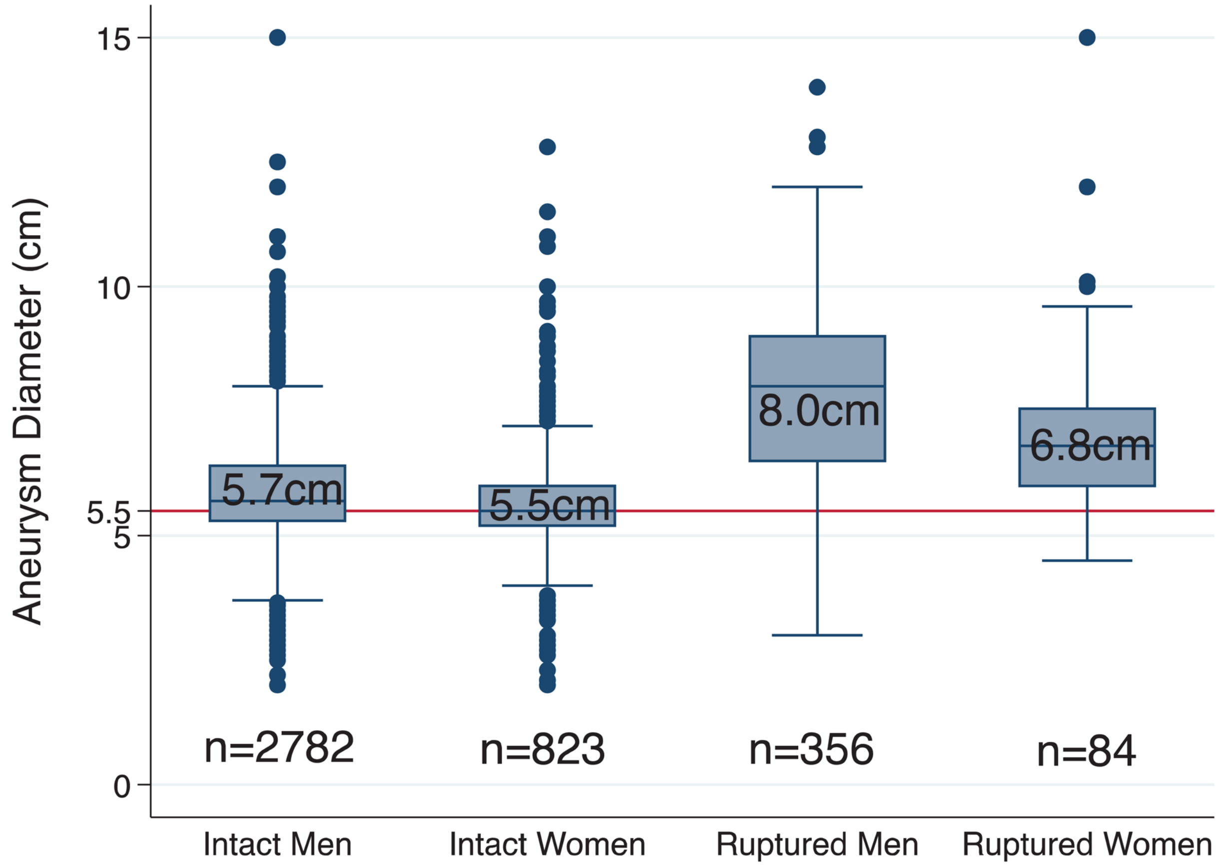

FIGURE 1. Aneurysm diameter of men and women undergoing repair for intact and ruptured AAA

Box includes 25th to 75th percentiles (with median as number in box); whiskers include values within 1.5X the interquartile range; and remaining data are shown as individual data points.

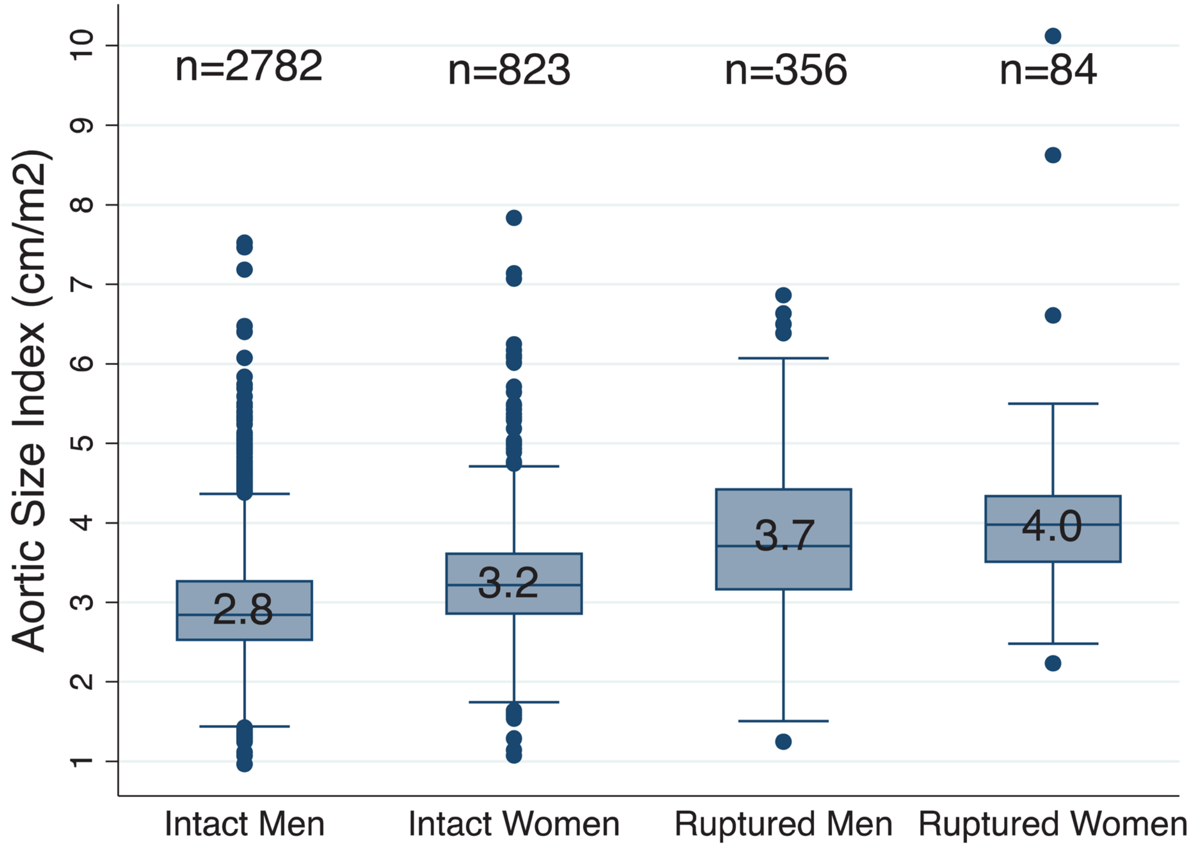

FIGURE 2. Aortic size index (ASI) of men and women undergoing AAA repair by gender and rupture status

Box includes 25th to 75th percentiles (with median as number in box); whiskers include values within 1.5X the interquartile range; and remaining data are shown as individual data points.

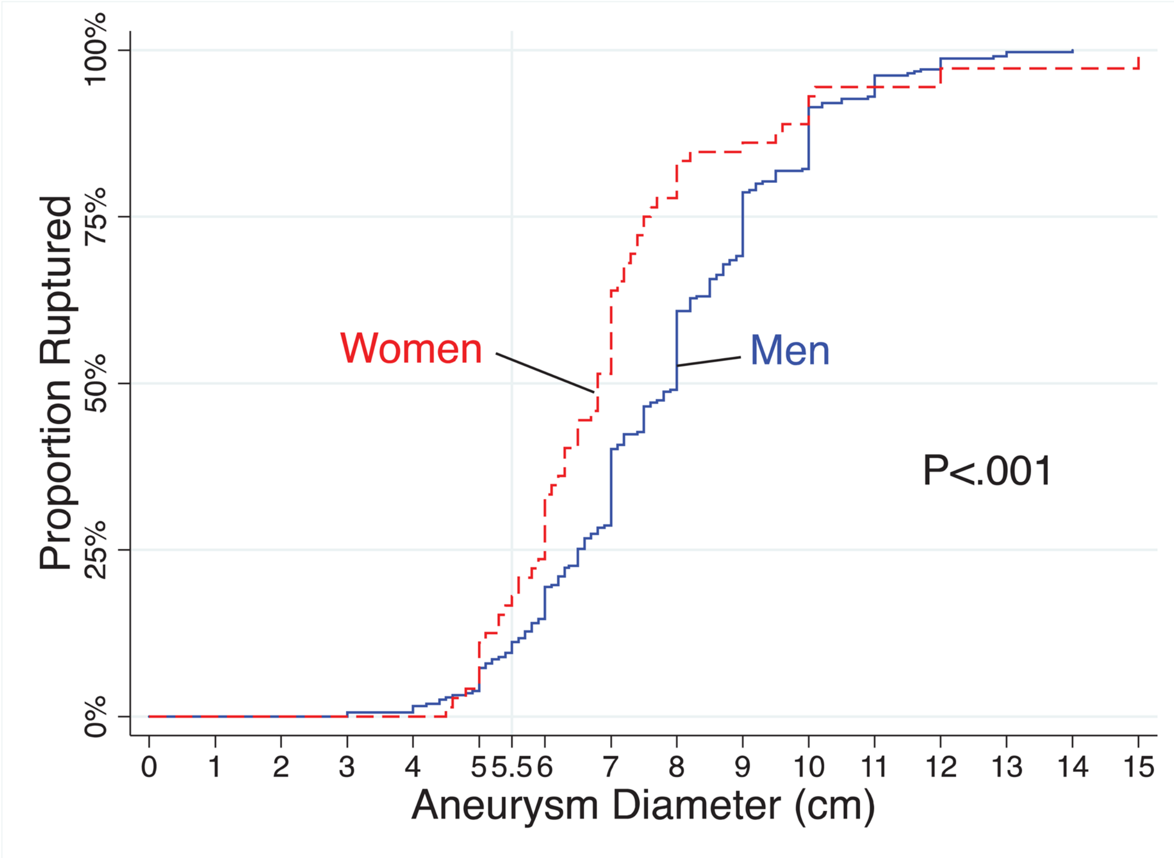

FIGURE 3.
Cumulative distribution of rupture repair as a function of aortic diameter.

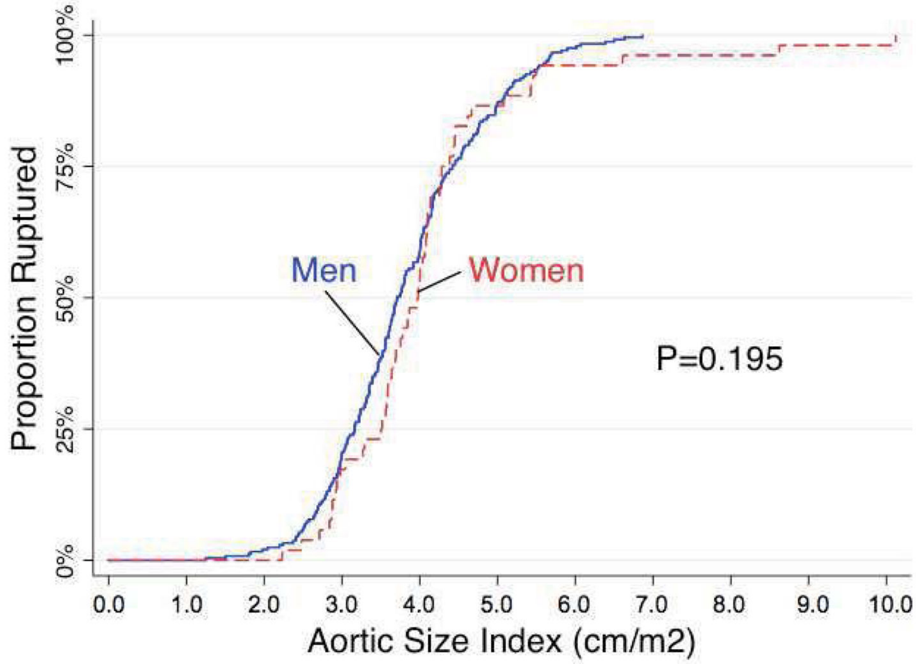

FIGURE 4.

Cumulative distribution of rupture repair as a function of aortic size index.

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TABLE I

Demographics and comorbidities of men and women undergoing ruptured and non-ruptured AAA repair.

	Total			Non-ruptured			Ruptured		
	Men	**Women**	**P-value**	**Men**	**Women**	**P-value**	**Men**	**Women**	**P-value**
No, %	3138 (76)	907 (22)		2,782 (69)	823 (20)		356 (8.8)	84 (2)	
EVAR, %	55	47	<.001	60	50	<.001	20	26	0.183
Age (y), mean ± SD	72 ± 9	74.3 ± 8	<.001	72 ± 9	74 ± 8	<.001	72 ± 9	78 ± 7	<.001
Smoking History, %									
Never	11	16		10	15		14	27	
Past	53	47	<.001	55	48	<.001	45	35	0.025
Current	36	37		35	37		41	38	
HTN, %	83	85	0.115	83	86	0.119	81	81	0.899
CAD, %	36	27	<.001	36	26	<.001	32	31	0.893
Diabetes, %	18	16	0.210	18	16	0.13	14	16	0.596
COPD, %	34	43	<.001	34	43	<.001	37	45	0.246

TABLE II

Differences in measures of body size by gender and rupture status.

	Total			Non-ruptured			Ruptured		
	Men	Women	P-value	Men	Women	P-value	Men	Women	P-value
AAA Diameter (cm), mean ± SD	6.1 ± 1.4	5.8 ± 1.3	<.001	5.9 ± 1.2	5.7 ± 1.1	<.001	7.8 ± 1.9	7.1 ± 2.1	0.006
<5.5, %	33	41	<.001	36	43	<.001	10	17	0.093
<5.0, %	10	12	0.035	11	13	0.050	4	4	1.000
<4.5, %	5	5	0.671	6	5	0.796	3	0	0.361
Height (m), mean ± SD	1.8 ± 0.1	1.6 ± 0.1	<.001	1.8 ± 0.1	1.6 ± 0.1	<.001	1.8 ± 0.1	1.6 ± 0.1	<.001
Weight (kg), mean ± SD	85 ± 18	71 ± 16	<.001	85 ± 18	71 ± 17	<.001	85 ± 21	70 ± 14	<.001
BSA (m^2), mean ± SD	2.0 ± 0.2	1.7 ± 0.2	<.001	2.0 ± 0.2	1.7 ± 0.2	<.001	2.0 ± 0.2	1.7 ± 0.2	<.001
BSA > gender-specific mean, %	75	79	0.011	74	78	0.008	82	83	0.874
BMI, mean ± SD	28 ± 5	27 ± 6	0.004	28 ± 5	27 ± 6	0.007	28 ± 5	27 ± 6	0.297
Underweight, %	3	5		2	4		4	9	
Normal weight, %	28	33		28	34		27	29	
Overweight, %	40	33	<.001	41	33	<.001	35	41	0.174
Obese, %	22	20		21	20		27	14	
Morbidly obese, %	7	9		7	9		8	7	

Underweight, BMI <18.5; normal weight, BMI 18.5–24.9; overweight, 25.0–29.9; obese, 30–39.9; morbidly obese, ≥ 40

TABLE III

Measures of body size indexed to aortic diameter by gender and rupture status.

	Total			Non-ruptured			Ruptured		
	Men (%)	Women (%)	P-value	Men (%)	Women (%)	P-value	Men (%)	Women (%)	P-value
AD (cm) / height (cm), mean ± SD	0.034 ± 0.008	0.036 ± 0.008	<.001	0.034 ± 0.007	0.035 ± 0.007	<.001	0.044 ± 0.011	0.044 ± 0.013	0.966
< 0.030, %	27	13		28	14		10	6	
0.030–0.034, %	38	40	<.001	41	41	<.001	11	15	0.378
0.035–0.044, %	25	38		24	38		37	45	
≥ 0.045, %	10	9		7	7		42	34	
AD (cm) / weight (kg), mean ± SD	0.075 ± 0.027	0.086 ± 0.030	<.001	0.073 ± 0.025	0.085 ± 0.029	<.001	0.099 ± 0.039	0.105 ± 0.041	0.275
< 0.060, %	28	13		30	14		8	4	
0.060–0.079, %	39	34	<.001	41	35	<.001	27	19	0.389
0.080–0.099, %	19	29		18	29		27	30	
≥ 0.100, %	13	24		11	22		38	47	
AD (cm) / BMI (m/kg^2), mean ± SD	0.23 ± 0.07	0.22 ± 0.07	0.196	0.22 ± 0.06	0.22 ± 0.06	0.655	0.29 ± 0.09	0.27 ± 0.11	0.343
< 0.20, %	39	42		41	44		14	19	
0.20–0.24, %	32	31	0.173	33	31	0.468	23	31	0.213
≥ 0.25, %	29	27		26	25		63	50	
AD (cm) / BSA (m^2), mean ± SD	3.0 ± 0.8	3.3 ± 0.8	<.001	3.0 ± 0.7	3.3 ± 0.7	<.001	3.8 ± 1.0	4.1 ± 1.3	0.109
< 2.5, %	21	9		23	9		6	4	
2.5–2.9, %	36	25		38	26		14	13	
3.0–3.4, %	22	33	<.001	22	35	<.001	19	6	0.135
3.5–3.9, %	11	19		10	18		20	29	
≥ 4.0, %	10	14		7	12		41	48	

AD, aortic diameter; BMI, body mass index; BSA, body surface area

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TABLE IV

Multivariable-adjusted predictors of ruptured repair.

	Men*		Women**	
	OR (95% CI)	P	OR (95% CI)	P
Age			1.0 (1.0, 1.1)	0.140
Smoking				
Never	-		-	
Past	0.6 (0.4, 0.9)	0.014	0.6 (0.3, 1.2)	0.142
Current	0.8 (0.5, 1.2)	0.232	0.6 (0.3, 1.5)	0.319
Diabetes	0.7 (0.5,1.1)	0.116	0.9 (0.4, 2.1)	0.789
Aortic Diameter (cm)				
<5.5	-		-	
5.5–6.4	0.9 (0.5, 1.7)	0.774	1.1 (0.3, 3.7)	0.852
6.5–7.4	4.0 (1.9, 8.2)	<.001	3.3 (0.8,12.7)	0.089
≥ 7.5	12.0 (5.2, 27.2)	<.001	3.2 (0.7, 14.5)	0.125
ASI (cm/m^2)				
< 2.5	1.3 (0.7, 2.8)	0.413	3.9 (0.5, 28.2)	0.175
2.5–2.9	1.6 (0.7, 3.7)	0.284	3.3 (0.8, 14.5)	0.111
3.0–3.4	-		-	
3.5–3.9	1.3 (0.5, 3.3)	0.597	6.4 (1.7, 24.1)	0.006
≥ 40	2.2 (0.8, 5.7)	0.118	9.5 (2.3, 39.4)	0.002

*AUC = 0.82

**AUC = 0.81

Table V

Size of aneurysms that ruptured under 5.5cm in women.

Aneurysm Diameter (cm)	#
4.5	1
4.6	1
4.8	1
5.0	5
5.1	1
5.3	2
5.4	1
Mean Diameter: 5.0	Total: 12

Table VI

ASI thresholds and the corresponding number (and percentage) of ruptured aneurysms <5.5cm that would have been selected for elective repair.

ASI (cm/m2)	Ruptured Aneurysms <5.5cm # (%)
≥ 4.0	3 (25)
≥ 3.5	4 (33)
≥ 3.0	5 (42)
≥ 2.5	10 (83)
≥ 2.0	12 (100)