Are outcomes of thoracoabdominal aortic aneurysm repair different in men versus women? A propensity-matched comparison

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ABSTRACT

Objective: Women fare worse than men after many cardiovascular operations, including coronary artery bypass grafting and valve surgery. We sought to determine whether sex affects outcomes after open thoracoabdominal aortic aneurysm repair.

Methods: We evaluated data on 3353 consecutive patients (1281 women, 38.2%) who underwent open thoracoabdominal aortic aneurysm repair between October 1986 and July 2015. We compared preoperative characteristics, surgical variables, and outcomes between men and women in the overall group. A propensity-matching analysis was performed to adjust for preoperative and intraoperative differences. A multivariable analysis was conducted to identify predictors of poor outcomes using relevant preoperative and intraoperative factors.

Results: Men had a significantly higher prevalence of comorbid conditions, including coronary artery disease, and presented more often with dissection; women were slightly older than men (median age, 69 [62-74] years vs 67 [57-73] years; $P < .001$) and more often symptomatic. Men underwent extent II and IV repairs more often, whereas women more often had extent I and III repairs. The propensity analysis resulted in 958 matched pairs. Overall, women and men had similar early mortality (7.9% vs 7.2%, $P = .5$) and adverse event rates (14.8% vs 14.1%, $P = .6$), which were similar in propensity-matched groups. Multivariable analysis showed that predictors of operative death and adverse event differed between the sexes. Survival and freedom from repair failure were similar between the overall and matched groups.

Conclusions: Men and women who undergo thoracoabdominal aortic aneurysm repair have similar outcomes, but there are important differences in several perioperative factors and predictors of poor outcomes. (J Thorac Cardiovasc Surg 2017;154:1203-14)

Age-adjusted survival for propensity-matched men and women after open TAAA repair.

Central Message

Outcomes after open TAAA repair are similar in propensity-matched groups of men and women, but predictors of operative mortality and adverse event differ between sexes.

Perspective

Although women tend to fare worse after procedures such as CABG, heart valve surgery, and AAA repair, we show that early and long-term outcomes are similar between men and women in 3353 patients who underwent open TAAA repair, including 958 propensity-matched pairs. Important preoperative and perioperative differences between the sexes were noted.

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Over the last 20 years, considerable research has focused on analyzing the differences between men and women in outcomes after cardiovascular surgery procedures, including

coronary artery bypass grafting (CABG),¹⁻⁷ aortic valve replacement surgery,^{8,9} combined CABG and valve surgery,^{10,11} and abdominal aortic aneurysm (AAA) repair.¹²⁻¹⁸ The results of several cardiovascular studies have shown that women typically have worse outcomes than men.^{2,3,7-12,19} Moreover, in some studies, female sex

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Abbreviations and Acronyms

AAA	= abdominal aortic aneurysm
CABG	= coronary artery bypass grafting
CSFD	= cerebrospinal fluid drainage
eGFR	= estimated glomerular filtration rate
HCA	= hypothermic circulatory arrest
LHB	= left heart bypass
RRR	= relative risk ratio
TAAA	= thoracoabdominal aortic aneurysm

was an independent predictor of higher postoperative morbidity and mortality, even after adjustment for age and comorbidities.^{2,8,12,13,17-19}

Open thoracoabdominal aortic aneurysm (TAAA) repair is a challenging operation with significant risks, including paraplegia, renal failure, stroke, and death. The use of adjunctive techniques for organ protection, such as left heart bypass (LHB), cerebrospinal fluid drainage (CSFD), and cold renal artery perfusion,²⁰⁻²³ may contribute to improved postoperative outcomes. Although most patients who present with a TAAA requiring open surgical repair are men,²⁴ there is scant evidence indicating the impact of sex on postoperative outcomes. We sought to examine the effect of sex on postoperative outcomes after open TAAA repair.

PATIENTS AND METHODS

Study Enrollment and Patient Characteristics

Baylor College of Medicine's institutional review board approved our clinical research protocol in 2006. For patients who underwent operation after protocol approval, clinical data were collected prospectively, and informed consent was obtained whenever possible. A waiver of consent was approved for patients who were unable to provide consent because of their illness and had no family members available who could provide consent for them. For patients who underwent surgery before the protocol was approved, data were collected retrospectively from medical records and consent was waived.

From October 1986 to July 2015, 3365 consecutive open TAAA repairs were performed on our service. We were unable to obtain consent from 12 patients (0.4%) with repairs performed after our protocol was approved; these patients are excluded from this report. The remaining 3353 repairs form the basis of this report; 2072 (61.8%) of the patients were men, and 1281 (38.2%) were women.

Study Definitions and Follow-up

All data were collected by using standard definitions, as reported in recent publications.^{24,25} Patients were considered symptomatic if they showed symptoms associated with aortic disease, such as pain, hoarseness, or dysphagia. We defined operative death as death occurring within 30 days of surgery or before final discharge from our hospital or any other hospital (or long-term acute care facility) where a patient might have been transferred. Adverse event was defined as a composite end point comprising operative death or persistent (ie, present at hospital discharge) stroke, paraplegia, paraparesis, or renal failure requiring dialysis.²⁶ Proximal aortic repair included repair of the aortic root, ascending aorta, or aortic arch and did not include isolated aortic valve repair. Distal aortic repair included repair of the descending thoracic aorta, thoracoabdominal aorta, or abdominal aorta. Preoperative chronic renal insufficiency was

defined as having a serum creatinine level 3.0 mg/dL or greater or requiring dialysis. To estimate the glomerular filtration rate, we used the Chronic Kidney Disease Epidemiology Collaboration equation.²⁷ Repair failure was defined as graft infection, fistula, pseudoaneurysm, or patch aneurysm directly related to the index TAAA repair and did not include subsequent repair in an adjacent aortic section. Postoperative surveillance information was obtained via clinic visit, telephone interview, or written correspondence. The Social Security Death Index and internet obituary searches were used to identify deaths among patients who were lost to follow-up.

Surgical Techniques

Over time, we have refined our operative strategies for open TAAA repair. We use a multimodal adjunctive protocol for organ protection based on the Crawford classification of the extent of TAAA repair.^{24,25,28} Our operative strategy has been largely standardized since 2005; the evolution of our surgical approach and 30-year clinical practice has been described.^{24,28} More protective adjuncts are typically used in the most extensive repair: Crawford extent II repair, which generally replaces the aorta from just distal to the left subclavian artery to the aortic bifurcation. In brief, our operative strategy involves moderate systemic heparinization (1.0 mg/kg) and mild permissive hypothermia (32°C–34°C). When appropriate, we reattach 1 or more pairs of intercostal and lumbar arteries (especially between T8 and L1) and intermittently perfuse the renal arteries with a cold (4°C) solution whenever the renal ostia are accessible. We use LHB and CSFD mainly for extent I and II TAAA repairs, for which we also provide selective visceral perfusion with isothermic oxygenated blood to the celiac axis and the superior mesenteric artery through the rerouted LHB circuit. CSFD is used selectively in extent III and IV TAAA repairs, such as in cases of reoperation after previous abdominal aortic replacement or endovascular aneurysm repair. In cases of aortic dissection extending into the visceral arteries, we ensure true lumen flow by fenestrating or excising the dissection flap, or by obliterating the false lumen, either by direct suture closure or by implanting small balloon-expandable stent-grafts. We commonly use 1 or more branch-grafts in patients in whom the visceral arteries are severely diseased or displaced, as might occur in patients with chronic dissections. We do not routinely use hypothermic circulatory arrest (HCA); rather, we reserve its use for select patients in whom the proximal aorta cannot be safely clamped.

Statistical Analysis

Statistical analyses were performed using SAS version 9.4 (SAS Institute, Inc, Cary, NC) and STATA version 13 (StataCorp, LP, College Station, Tex). Continuous variables are presented as mean $\pm$ standard deviation or median [interquartile range], as appropriate. Categorical variables are presented as number and percentage. Univariate comparisons were conducted with the Pearson chi-square test, Fisher exact test, or nonparametric Wilcoxon rank-sum test, as appropriate.

Because of the heterogeneity between men and women, we used a 1:1 nearest neighbor matching without replacement and a caliper size of 0.005 to generate propensity score–matched pairs from clinically relevant preoperative and operative variables in the overall cohort; the variables used are shown in Tables 1 and 2 (Table E1 shows a list of >50 variables). We did not include 3 continuous variables (estimated glomerular filtration rate [eGFR], body mass index, and maximum distal aortic diameter) in the propensity score analysis because of missing data, and we purposely excluded variables that were linear combinations of other variables.

To identify independent predictors of adverse event and operative death after 3353 TAAA repairs, we built multivariable logistic regression models by using all clinically relevant preoperative and intraoperative factors that showed a univariate association with a *P* value of less than .1. Multivariable models were built for the overall cohort (*n* = 3353; the variable sex did not qualify for model entry and was forced into the model) and for separate, sex-specific models (*n* = 2072 men; *n* = 1281 women), which were then combined for a saturated model. Postoperative complications were not

TABLE 1. Preoperative characteristics

Variable	Overall cohort				Propensity-matched cohort			
	Overall (n = 3353)	Men (n = 2072)	Women (n = 1281)	P value	All matched (n = 1916)	Men (n = 958)	Women (n = 958)	P value
Age, y	67 [59-73]	67 [57-73]	69 [62-74]	<.001	68 [60-73]	68 [59-73]	68 [61-74]	.2
Age ≤50 y	446 (13.3)	300 (14.5)	146 (11.4)	.01	250 (13.0)	122 (12.7)	128 (13.4)	.7
Heritable thoracic aortic disease	323 (9.6)	190 (9.2)	133 (10.4)	.5	217 (11.3)	110 (11.5)	107 (11.2)	.8
Marfan syndrome	294 (8.8)	176 (8.5)	118 (9.2)	.5	194 (10.1)	100 (10.4)	94 (9.8)	.7
Aortic aneurysm without dissection	2143 (63.9)	1201 (58.0)	942 (73.5)	<.001	1302 (68.0)	648 (67.6)	654 (68.3)	.8
Aortic dissection	1210 (36.1)	871 (42.0)	339 (26.5)	<.001	614 (32.0)	310 (32.4)	304 (31.7)	.8
Acute or subacute	166 (5.0)	98 (4.7)	68 (5.3)	.4	106 (5.5)	52 (5.4)	54 (5.6)	.8
Chronic	1044 (31.1)	773 (37.3)	271 (21.2)	<.001	508 (26.5)	258 (26.9)	250 (26.1)	.7
DeBakey type I	437 (13.0)	333 (16.1)	104 (8.1)	<.001	202 (10.5)	100 (10.4)	102 (10.6)	.9
DeBakey type III	737 (22.0)	514 (24.8)	223 (17.4)	<.001	392 (20.5)	201 (21.0)	191 (19.9)	.6
DeBakey type IIIa	125 (3.7)	69 (3.3)	56 (4.4)	.1	89 (4.6)	46 (4.8)	43 (4.5)	.7
DeBakey type IIIb	612 (18.3)	445 (21.5)	167 (13.0)	<.001	303 (15.8)	155 (16.2)	148 (15.4)	.7
Localized dissection	33 (1.0)	22 (1.1)	11 (0.9)	.6	19 (1.0)	9 (0.9)	10 (1.0)	.8
Maximum distal aortic diameter, cm (n = 2972)	6.2 [5.5-7.2]	6.3 [5.6-7.4]	6.0 [5.5-7.0]	<.001	6.2 [5.5-7.2]	6.3 [5.7-7.2]	6.1 [5.5-7.2]	.02
Diameter >7.5 cm	573 (17.1)	397 (19.2)	176 (13.7)	<.001	294 (15.3)	146 (15.2)	148 (15.4)	.9
Hypertension	2848 (84.9)	1784 (86.1)	1064 (83.1)	.02	1602 (83.6)	805 (84.0)	797 (83.2)	.6
Hyperlipidemia	992 (29.6)	652 (31.5)	340 (26.5)	.002	537 (28.0)	274 (28.6)	263 (27.5)	.6
Diabetes	270 (8.1)	180 (8.7)	90 (7.0)	.09	149 (7.8)	72 (7.5)	79 (8.2)	.7
Coronary artery disease	1123 (33.5)	774 (37.4)	349 (27.2)	<.001	575 (30.0)	281 (29.3)	294 (30.7)	.5
Prior CABG	503 (15.0)	372 (18.0)	131 (10.2)	<.001	229 (12.0)	111 (11.6)	118 (12.3)	.6
Prior MI	658 (19.6)	461 (22.2)	197 (15.4)	<.001	333 (17.4)	165 (17.2)	168 (17.5)	.9
Cerebrovascular disease	584 (17.4)	358 (17.3)	226 (17.6)	.8	317 (16.5)	156 (16.3)	161 (16.8)	.8
Prior stroke	341 (10.2)	205 (9.9)	136 (10.6)	.5	185 (9.7)	92 (9.6)	93 (9.7)	.9
eGFR (n = 3064)	64 [48-83]	65 [49-83]	62 [46-82]	.02	64 [48-83]	65 [50-84]	62 [47-82]	.03
Chronic renal insufficiency	101 (3.0)	77 (3.7)	24 (1.9)	.002	43 (2.2)	21 (2.2)	22 (2.3)	.9
History of renal failure requiring dialysis*	63 (1.9)	44 (2.1)	19 (1.5)	.2	32 (1.7)	14 (1.5)	18 (1.9)	.5
Body mass index (n = 2865)	25.8 [22.8-29.1]	26.6 [23.8-29.6]	24.3 [21.5-28.0]	<.001	25.4 [22.5-28.8]	25.7 [23.0-28.7]	25.1 [22.0-29.1]	.1
Pulmonary disease	1309 (39.0)	748 (36.1)	561 (43.8)	<.001	777 (40.6)	390 (40.7)	387 (40.4)	.9
History of COPD/emphysema/bronchitis	1223 (36.5)	701 (33.8)	522 (40.8)	<.001	726 (37.9)	365 (38.1)	361 (37.7)	.9
Current tobacco use	988 (29.5)	553 (26.7)	435 (34.0)	<.001	598 (31.2)	295 (30.8)	303 (31.6)	.7
Asymptomatic	1202 (35.8)	802 (38.7)	400 (31.2)	<.001	651 (34.0)	332 (34.7)	319 (33.3)	.5
Symptomatic	2151 (64.2)	1270 (61.3)	881 (68.8)	<.001	1265 (66.2)	626 (65.3)	639 (66.7)	.5
Acute	555 (16.6)	320 (15.4)	235 (18.3)	.03	342 (17.8)	168 (17.5)	174 (18.2)	.7
Both acute and chronic	97 (2.9)	48 (2.3)	49 (3.8)	.01	60 (3.1)	31 (3.2)	29 (3.0)	.8
Chronic	1693 (50.5)	998 (48.2)	695 (54.3)	<.001	983 (51.3)	489 (51.0)	494 (51.6)	.8
Peripheral vascular disease	861 (25.7)	520 (25.1)	341 (26.6)	.3	484 (25.3)	242 (25.3)	242 (25.3)	.9
Rupture	171 (5.1)	102 (4.9)	69 (5.4)	.6	102 (5.3)	52 (5.4)	50 (5.2)	.8
Prior aortic repair†	1494 (44.6)	1054 (50.9)	440 (34.4)	<.001	760 (39.7)	388 (40.5)	372 (38.8)	.5
Prior open aortic repair	1374 (41.0)	962 (46.4)	412 (32.2)	<.001	701 (36.6)	355 (37.1)	246 (25.7)	.5
Proximal	762 (22.7)	501 (24.2)	261 (20.4)	.01	413 (21.6)	206 (21.5)	207 (21.6)	.95
Distal	789 (23.5)	574 (27.7)	215 (16.8)	<.001	393 (20.5)	203 (21.2)	190 (19.8)	.5
Prior distal aortic repair	801 (23.9)	584 (28.2)	217 (16.9)	<.001	396 (20.7)	204 (21.3)	192 (20.0)	.5
Prior endovascular	70 (2.1)	51 (2.5)	19 (1.5)	.05	31 (1.7)	14 (1.5)	17 (1.8)	.6
Failure of prior distal aortic repair‡	137 (4.1)	96 (4.6)	41 (3.2)	.04	74 (3.9)	36 (3.8)	38 (4.0)	.8

Data are presented as n (%) or median [interquartile range]. CABG, Coronary artery bypass grafting; MI, myocardial infarction; eGFR, estimated glomerular filtration rate; COPD, chronic obstructive pulmonary disease. *Serum creatinine level ≥3.0 mg/dL or dialysis. †Prior open or endovascular aortic repair. ‡Failure of prior distal open or endovascular aortic repair necessitating in-window repair.

TABLE 2. Operative details

Variable	Overall cohort				Propensity-matched cohort			
	Overall (n = 3353)	Men (n = 2072)	Women (n = 1281)	P value	All matched (n = 1916)	Men (n = 958)	Women (n = 958)	P value
Urgency of operation								
Elective	2617 (78.0)	1657 (80.0)	960 (75.0)	<.001	1461 (76.3)	730 (76.2)	731 (76.3)	.9
Urgent or emergency	736 (22.0)	415 (20.0)	321 (25.1)	<.001	455 (23.7)	228 (23.8)	227 (23.7)	.96
Extent of repair								
Extent I	926 (27.6)	523 (25.2)	403 (31.5)	<.001	576 (30.1)	283 (29.5)	293 (30.6)	.6
Extent II	1083 (32.3)	702 (33.9)	381 (29.7)	.01	571 (29.8)	289 (30.2)	282 (29.4)	.7
Extent III	670 (20.0)	382 (18.4)	288 (22.5)	.004	421 (22.0)	218 (22.8)	203 (21.2)	.4
Extent IV	674 (20.1)	465 (22.4)	209 (16.3)	<.001	348 (18.2)	168 (17.5)	180 (18.8)	.5
Redo thoracotomy and/or laparotomy	564 (16.8)	415 (20.0)	149 (11.6)	<.001	269 (14.0)	141 (14.7)	128 (13.4)	.4
Reverse elephant trunk	83 (2.5)	50 (2.4)	33 (2.6)	.8	43 (2.2)	21 (2.2)	22 (2.3)	.9
Elephant trunk completion repair	140 (4.2)	91 (4.4)	49 (3.8)	.4	74 (3.9)	40 (4.2)	34 (3.5)	.5
Clamping proximal to left subclavian artery	529 (15.8)	356 (17.2)	173 (13.5)	.004	277 (14.5)	139 (14.5)	138 (14.4)	.9
Intercostal/lumbar artery reattachment	1618 (48.3)	1050 (50.7)	568 (44.3)	.004	915 (47.8)	459 (47.9)	456 (47.6)	.9
Aortic clamp time, min	50 [38-66]	53 [40-70]	45 [33-59]	<.001	48 [36-62]	48 [37-62]	47 [35-61]	.2
Management of visceral/renal arteries								
Bypass graft	846 (25.2)	566 (27.3)	280 (21.9)	<.001	449 (23.4)	227 (23.7)	222 (23.2)	.8
Endarterectomy	873 (26.0)	485 (23.4)	388 (30.3)	<.001	514 (26.8)	261 (27.2)	253 (26.4)	.7
Stenting	269 (8.0)	161 (7.8)	108 (8.4)	.5	149 (7.8)	73 (7.6)	76 (7.9)	.8
Endarterectomy, stenting, or bypass	1385 (41.3)	837 (40.4)	548 (42.8)	.2	780 (40.7)	396 (41.3)	384 (40.1)	.6
Adjuncts								
CSFD	1551 (46.3)	966 (46.6)	585 (45.7)	.6	893 (46.6)	463 (48.3)	430 (44.9)	.1
LHB	1506 (45.0)	959 (46.3)	547 (42.7)	.04	825 (43.1)	416 (43.4)	409 (42.7)	.7
HCA	51 (1.5)	31 (1.5)	20 (1.6)	.9	30 (1.6)	13 (1.4)	17 (1.8)	.5
Cold renal perfusion	1969 (58.7)	1265 (61.1)	704 (55.0)	<.001	1082 (56.5)	546 (57.0)	536 (56.0)	.6
Selective perfusion of visceral arteries	796 (23.7)	525 (25.3)	271 (21.2)	.006	409 (21.3)	209 (21.8)	200 (20.9)	.6

Data presented as n (%) or median [interquartile range]. CSFD, Cerebrospinal fluid drainage; LHB, left heart bypass; HCA, hypothermic circulatory arrest.

entered into the models. Model fit was assessed with likelihood ratio chi-square tests, goodness-of-fit tests, and pseudo R^2 .

The differences in postoperative estimated survival and freedom from repair failure between men and women were estimated by Kaplan–Meier curve by using log-rank test or Cox regression method adjusted for age. STATA package “stcrreg” was used to perform unadjusted and age-adjusted competing risk analyses; the assumption of proportional hazards was examined by using time-dependent covariates.

RESULTS

Preoperative Characteristics

The preoperative characteristics of men and women undergoing TAAA repair and their propensity-matched cohorts are presented in Table 1. In the overall cohort (n = 3353), the median age of women was greater than that of men (69 vs 67 years, $P < .001$), but men had more cardiovascular comorbid conditions (eg, hypertension, coronary artery disease, or a previous myocardial infarction or

CABG procedure) and a worse metabolic profile (eg, hyperlipidemia, obesity, and diabetes mellitus). Women were more likely to be current tobacco users and to have pulmonary disease and a history of chronic obstructive pulmonary disease, emphysema, or bronchitis. After propensity-matching analysis, 958 pairs of men and women were identified. The matched groups had comparable preoperative characteristics except that men had a larger distal aortic diameter (6.3 [5.7-7.2] cm vs 6.1 [5.5-7.2] cm, $P = .02$) and a greater median eGFR value (65 [50-84] mL/min/1.73 m² vs 62 [47-82] mL/min/1.73 m², $P = .03$). The remaining unmatched group comprised 1114 men and 323 women. Many differences were noted in preoperative characteristics for the unmatched group, including women being older than men; however, the rates of cerebrovascular disease, heritable thoracic aortic disease, and rupture were similar (Table E2).

Operative Details

Operative details of men and women undergoing TAAA repair and their propensity-matched cohorts are presented in Table 2. In the overall cohort (n = 3353), women were more likely than men to have an urgent or emergency operation (25.1% vs 20.0%, $P < .001$). TAAA extent I and III repairs were more common in women, whereas men more often had extent II and IV repairs. Although women in the overall group received surgical adjuncts less often during repair, there were no significant differences in the use of adjuncts between men and women when comparing their use in extent II repairs (Table E3). In propensity-matched groups, men and women had comparable operative variables (Table 2). In unmatched groups, there were many differences, including a shorter aortic clamp time in women (Table E4).

Early Outcomes

The overall operative mortality rate was 7.5% (n = 251). Early outcomes of men and women undergoing TAAA repair and their propensity-matched cohorts are presented in Table 3. In the overall cohort (n = 3353), women and men had similar early outcomes, including the incidence

of operative death (7.9% vs 7.2%, $P = .5$), adverse event (14.0% vs 14.1%, $P = .6$), and life-altering complications (7.5% vs 7.4%, $P = .96$). In propensity-matched groups, men and women had comparable outcomes regarding operative mortality (7.0% vs 7.2%, $P = .8$), adverse event (13.5% vs 14.6%, $P = .5$), and life-altering complications (7.0% vs 8.0%, $P = .4$). However, women had more pulmonary complications (40.3% vs 32.3%, $P < .001$), whereas persistent paraplegia was more common in men (3.4% vs 2.0%, $P = .046$). Although there was a statistically significant difference in both intensive care unit and overall length of stay for both the overall and propensity-matched groups, this was not considered clinically relevant. In unmatched groups, key early outcomes were similar, but women had higher rates of pulmonary complication and tracheostomy and a longer length of hospital stay (Table E5).

Multivariable Modeling

Independent predictors of adverse event and operative death for the overall cohort (n = 3353) are shown in Table 4; notably, sex was not found to be predictive of either outcome. Separate models for each sex were developed to

TABLE 3. Early outcomes

Variable	Overall cohort				Propensity-matched cohort			
	Overall (n = 3353)	Men (n = 2072)	Women (n = 1281)	P value	All matched (n = 1916)	Men (n = 958)	Women (n = 958)	P value
Adverse event*	483 (14.4)	293 (14.1)	190 (14.8)	.6	269 (14.0)	129 (13.5)	140 (14.6)	.5
Operative death	251 (7.5)	150 (7.2)	101 (7.9)	.5	136 (7.1)	67 (7.0)	69 (7.2)	.8
In-hospital	239 (7.1)	142 (6.9)	97 (7.6)	.4	131 (6.8)	64 (6.7)	67 (7.0)	.8
30-d	161 (4.8)	94 (4.5)	67 (5.2)	.4	85 (4.4)	37 (3.9)	48 (5.0)	.2
Stroke	106 (3.2)	66 (3.2)	40 (3.1)	.9	58 (3.0)	24 (2.5)	34 (3.5)	.2
Persistent†	79 (2.4)	51 (2.5)	28 (2.2)	.6	42 (2.2)	19 (2.0)	23 (2.4)	.5
Spinal cord deficit	323 (9.6)	214 (10.3)	109 (8.5)	.08	187 (9.8)	105 (11.0)	82 (8.6)	.08
Persistent SCD‡	180 (5.4)	118 (5.7)	62 (4.8)	.3	101 (5.3)	54 (5.6)	47 (4.9)	.5
Persistent paraplegia‡	99 (3.0)	68 (3.3)	31 (2.4)	.2	52 (2.7)	33 (3.4)	19 (2.0)	.046
Persistent paraparesis‡	81 (2.4)	50 (2.4)	31 (2.4)	.99	49 (2.6)	21 (2.2)	28 (2.9)	.3
Acute renal dysfunction	409 (12.2)	256 (12.4)	153 (11.9)	.7	231 (12.1)	116 (12.1)	115 (12.0)	.9
Renal failure necessitating dialysis	253 (7.5)	155 (7.5)	98 (7.7)	.9	143 (7.5)	66 (6.9)	77 (8.0)	.3
Persistent dialysis‡	191 (5.7)	114 (5.5)	77 (6.0)	.5	108 (5.6)	50 (5.2)	58 (6.1)	.4
Cardiac complication	873 (26.0)	545 (26.3)	328 (25.6)	.7	494 (25.8)	253 (26.4)	241 (25.2)	.5
Pulmonary complication	1200 (35.8)	680 (32.8)	520 (40.6)	<.001	695 (36.3)	309 (32.3)	386 (40.3)	<.001
Respiratory failure	836 (24.9)	493 (23.8)	343 (26.8)	.05	478 (24.9)	224 (23.4)	254 (26.5)	.1
Necessitating tracheostomy	284 (8.5)	159 (7.7)	125 (9.8)	.04	162 (8.5)	77 (8.0)	85 (8.9)	.5
Left vocal cord paralysis	518 (15.4)	361 (17.4)	157 (12.3)	<.001	274 (14.3)	150 (15.7)	124 (12.9)	.09
Bleeding requiring reoperation	111 (3.3)	68 (3.3)	43 (3.4)	.9	66 (3.4)	34 (3.6)	32 (3.3)	.8
Early survivors of repair§	(n = 3102)	(n = 1922)	(n = 1180)		(n = 1780)	(n = 891)	(n = 889)	
Life-altering complication‡	232 (7.5)	143 (7.4)	89 (7.5)	.96	133 (7.5)	62 (7.0)	71 (8.0)	.4
Length of ICU stay, d	4 [3-7]	4 [3-6]	4 [3-7]	<.001	4 [3-7]	4 [3-6]	4 [3-7]	<.001
Length of overall stay, d	12 [9-17]	11 [9-16]	12 [9-17]	<.001	12 [9-16]	11 [9-15]	12 [9-17]	<.001

Values are n (%) or median [interquartile range]. SCD, Spinal cord deficit; ICU, intensive care unit. *Defined as operative death or persistent (present at hospital discharge) stroke, paraplegia, paraparesis, or renal failure necessitating dialysis. †Present at the time of hospital discharge or early death. ‡Discharged with stroke, paraplegia, paraparesis, or renal failure necessitating dialysis. §Patients surviving the early postoperative period (those without operative death, n = 3102 overall and n = 1780 matched group).

TABLE 4. Relative risk ratio for preoperative and operative predictors of adverse event and operative death after 3353 thoracoabdominal aortic aneurysm repairs

Variable	RRR (CI)	P value
Adverse event		
HCA	3.32 (1.55-7.09)	.002
Rupture	2.57 (1.67-3.96)	<.001
Extent II TAAA repair	1.95 (1.37-2.78)	<.001
Extent III TAAA repair	1.93 (1.34-2.76)	<.001
Extent I TAAA repair	1.62 (1.11-2.38)	.01
Visceral or renal artery stenting	1.39 (0.995-1.95)	.053
Prior myocardial infarction	1.29 (0.995-1.67)	.054
Symptomatic	1.28 (1.003-1.63)	.047
CSFD	1.24 (0.98-1.57)	.07
Increasing patient age at repair, per y	1.04 (1.03-1.05)	<.001
Increasing aortic clamp time, per min	1.02 (1.01-1.02)	<.001
Increasing eGFR, per mL/min/1.73 m ²	0.98 (0.98-0.99)	<.001
Sex (male vs female)	0.97 (0.77-1.22)	.8
Prior aortic operation	0.70 (0.56-0.88)	.002
Elective repair	0.69 (0.52-0.92)	.01
Operative death		
Rupture	2.71 (1.63-4.49)	<.001
HCA	2.52 (1.01-6.28)	.048
Urgent or emergency repair	1.79 (1.26-2.54)	.001
Chronic symptoms	1.63 (1.22-2.17)	.001
Cerebrovascular disease	1.41 (1.01-1.96)	.04
History of COPD/emphysema/bronchitis	1.35 (1.01-1.76)	.04
Increasing patient age at repair, per y	1.04 (1.02-1.06)	<.001
Increasing aortic clamp time, per min	1.02 (1.01-1.02)	<.001
Increasing eGFR, per mL/min/1.73 m ²	0.99 (0.98-0.99)	<.001
Sex (male vs female)	0.98 (0.73-1.32)	.9
Cold renal perfusion	0.72 (0.53-0.98)	.04
Extent IV TAAA repair	0.67 (0.45-0.999)	.049

RRR, Relative risk ratio; CI, confidence interval; HCA, hypothermic circulatory arrest; TAAA, thoracoabdominal aortic aneurysm; CSFD, cerebrospinal fluid drainage; eGFR, estimated glomerular filtration rate; COPD, chronic obstructive pulmonary disease.

identify predictors of adverse event and operative death (Table E6); all variables in the 2 sex-specific separate models were then combined to form a single saturated model (Table 5) so that potentially predictive variables could be evaluated in both men and women. Notably, aortic rupture, increasing patient age at repair, and increasing aortic clamp time were predictive of both adverse event and operative death in men and women. In addition, in both men and women, we found that extent IV TAAA repair reduced the likelihood of an adverse event (relative risk ratio [RRR], 0.54, $P = .001$; RRR, 0.39, $P = .001$, respectively) and cold renal perfusion provided protection against operative mortality (RRR, 0.59, $P = .005$; RRR, 0.60, $P = .03$, respectively). However, there were several factors that were predictive only in men or women.

Late Outcomes

Clinical follow-up data were available for 3051 (98.4%) of the 3102 early survivors (1922 [62%] men, 1180 [38%]

women; median follow-up, 5.8 years [2.8-9.8]). We identified 2069 late deaths but were unable to determine the cause of death. At 15 years after operation, the estimated survival after adjustment for age was similar between men and women ($17.3\% \pm 1.3\%$ vs $18.5\% \pm 1.5\%$, respectively; $P = .6$) (Figure 1, A), including the propensity-matched groups ($20.1\% \pm 1.8\%$ vs $17.9\% \pm 1.6\%$, respectively; $P = .3$) (Figure 2, A). There were 97 survivors with late repair failures; these included graft infection ($n = 6$), fistula ($n = 7$), pseudoaneurysm ($n = 55$), and patch aneurysm ($n = 39$) (10 survivors had 2 types of late repair failures). The rates for freedom from repair failure at 15 years also were comparable for men and women ($94.4\% \pm 1.0\%$ vs $93.6\% \pm 1.2\%$, respectively; $P = .4$) (Figure 1, B), including the propensity-matched groups ($95.4\% \pm 1.3\%$ vs $93.5\% \pm 1.4\%$, respectively; $P = .3$) (Figure 2, B). A combined end point of freedom from death or repair failure demonstrated comparable results for men and women in both the overall and propensity-matched groups (Figures 1, C, and 2, C).

Competing risk analysis of late death and repair failure with adjustment for age (Figure 3 and Table 6) showed that late death was comparable in men and women when the data were adjusted for repair failure (subhazard ratio 1.03, $P = .5$). Likewise, the likelihood of developing late repair failure was comparable when the data were adjusted for late death (subhazard ratio 0.77, $P = .2$).

DISCUSSION

Over the last 2 decades, studies have suggested that women have worse outcomes after CABG procedures,^{2,3,5,7} aortic valve surgery,^{8,9} combined CABG and heart valve surgery,^{10,11} and open AAA repair^{12,13,17,18} than do men. Multiple reasons have been proposed for this discrepancy in cardiovascular surgery outcomes between the sexes: anatomic differences (eg, smaller coronary arteries, native valve orifice area, and aortic diameter in women); age at the time of repair (women are typically older than men at repair); existing comorbidities (women may be sicker than men at the time of repair); delay in referrals (impaired access to treatment for women, who may present more often with later-stage disease, acute symptoms, or rupture); and late complications (women may have increased rates of postoperative infection and readmission).^{3,6,14,15}

However, our study has found that sex itself had little effect on postoperative outcomes after open TAAA repair. Rates of operative mortality and adverse event were similar in the overall group of men and women, as well as in propensity-matched and unmatched groups of men and women. Few studies have been published on the effect of sex on outcomes after open TAAA repair.²⁹⁻³¹ By using data from the American College of Surgeons National Surgery Quality Improvement Program, Flink and colleagues²⁹ stratified early survivors of 17,763 open or endovascular abdominal, thoracic, or TAAA repairs by sex and

TABLE 5. Relative risk ratio for preoperative and operative predictors of adverse event and operative death after 3353 thoracoabdominal aortic aneurysm repairs: A saturated multivariable model stratified by sex

Variables	RRR male (CI)	P value	RRR female (CI)	P value
Adverse event				
HCA	4.95 (2.09-11.70)	<.001	4.42 (1.50-13.00)	.007
Rupture	2.20 (1.28-3.78)	.004	2.98 (1.59-5.56)	.001
Chronic renal insufficiency	2.16 (1.24-3.77)	.007	2.10 (0.76-5.77)	.2
Previous stroke	1.52 (1.02-2.26)	.04	1.21 (0.73-2.02)	.5
Urgent or emergency repair	1.46 (1.03-2.06)	.03	1.26 (0.85-1.88)	.3
Increasing patient age at repair, per y	1.06 (1.05-1.07)	<.001	1.05 (1.03-1.06)	<.001
Increasing aortic clamp time, per min	1.02 (1.01-1.02)	<.001	1.03 (1.02-1.04)	<.001
Prior open aortic repair	0.56 (0.40-0.79)	.001	1.13 (0.69-1.84)	.6
Extent IV TAAA repair	0.54 (0.38-0.78)	.001	0.39 (0.23-0.68)	.001
Previous CABG	0.82 (0.57-1.17)	.3	1.80 (1.11-2.92)	.02
Prior open proximal aortic repair	1.38 (0.88-2.16)	.2	0.48 (0.25-0.91)	.03
Reverse elephant trunk	1.08 (0.44-2.69)	.9	2.41 (1.03-5.671)	.04
Endarterectomy, stenting, or bypass	1.27 (0.95-1.69)	.1	1.43 (0.99-2.06)	.06
Operative death				
HCA	3.94 (1.38-11.28)	.01	2.09 (0.49-8.89)	.3
Urgent or emergency repair	1.85 (1.17-2.92)	.009	0.82 (0.45-1.48)	.5
Chronic renal insufficiency	2.16 (1.10-4.24)	.03	1.04 (0.26-4.22)	.96
Previous stroke	1.85 (1.14-3.03)	.01	0.91 (0.46-1.81)	.8
Increasing patient age at repair, per y	1.07 (1.05-1.09)	<.001	1.03 (1.01-1.05)	.003
Increasing aortic clamp time, per min	1.01 (1.00-1.02)	.004	1.03 (1.02-1.04)	<.001
Cold renal perfusion	0.59 (0.41-0.86)	.005	0.60 (0.37-0.96)	.03
Rupture	1.91 (1.01-3.61)	.045	3.90 (1.82-8.37)	.001
Symptomatic	1.35 (0.90-2.04)	.1	2.47 (1.39-4.37)	.002
Aneurysm without dissection	0.78 (0.52-1.17)	.2	2.21 (1.09-4.48)	.03
Extent II TAAA repair	1.39 (0.92-2.11)	.1	2.26 (1.28-3.99)	.005
Acute symptoms superimposed on chronic symptoms	0.68 (0.25-1.85)	.5	2.451 (1.03-5.85)	.04
Extent III TAAA repair	1.26 (0.76-2.08)	.4	2.24 (1.23-4.08)	.008
Prior open distal aortic repair	0.78 (0.52-1.17)	.2	1.78 (1.03-3.07)	.04
History of COPD/emphysema/bronchitis	1.09 (0.75-1.57)	.7	1.60 (1.02-2.51)	.04

RRR, Relative risk ratio; CI, confidence interval; HCA, hypothermic circulatory arrest; TAAA, thoracoabdominal aortic aneurysm; CABG, coronary artery bypass grafting; COPD, chronic obstructive pulmonary disease.

reported greater rates of major postoperative complications in women than in men (10.8% vs 7.7%, $P < .001$); however, only 292 (1.6%) of these repairs were TAAA repairs (112 women and 180 men). In a mixed series of 675 open descending thoracic or TAAA repairs (278/675 were women), Gaudino and colleagues³¹ found female sex, urgent or emergency repair, and preoperative hemodialysis to be predictive of adverse events (a composite that included operative death). Murana and colleagues³⁰ reported their results from a 20-year, single-center experience in 542 patients (292 men and 250 women) who all underwent open TAAA repair; the unadjusted 30-day mortality differed between men and women (5% and 12%, respectively), and they found that female sex was an independent risk factor for 30-day mortality, along with age and urgent or emergency repair. However, it is difficult to interpret the reports by Gaudino and colleagues³¹ and Murana and colleagues³⁰ in terms of female sex because these reports contain no descriptive information stratified by gender (eg, the average age and the proportion of patients with preoperative renal dialysis

or urgent or emergency repair are not specified for men or women). In contrast, we found in our current study no difference in operative mortality rates between the sexes in overall ($n = 3353$, 7.2% for 2072 men and 7.9% for 1281 women, $P = .5$), propensity-matched ($n = 1916$, 7.0 for 958 men and 7.2% for 958 women, $P = .8$), and unmatched ($n = 1437$, 7.5% for 1114 men and 9.9% for 323 women, $P = .2$) groups after open TAAA repair, and we did not find female sex predictive of operative mortality or adverse event.

However, we did identify several significant differences between men and women in preoperative and intraoperative characteristics in the overall group. Our finding that more men than women underwent repair supports the results of reports of abdominal aortic aneurysm repair.^{12,17,18} One striking difference between the sexes in our study was the significantly higher incidence of chronic dissection in men who underwent TAAA repair than in women. This may be explained by additional factors not included in our study, such as the increased predominance of bicuspid aortic valve disease in men, which predisposes to aortic

FIGURE 1. Age-adjusted estimated survival (A) in 3353 patients (2072 men, 1281 women) after open TAAA repair, freedom from repair failure (B) in 3102 early survivors (1922 men, 1180 women), and age-adjusted freedom from death or repair failure (C) in 3353 patients (2072 men, 1281 women). All data are stratified by sex, and no significant differences between men and women were found.

FIGURE 2. In the propensity-matched group, estimated survival (A) in 958 men and women after open TAAA repair, freedom from repair failure (B) in 1780 early survivors (889 men, 891 women), and freedom from death or repair failure (C) in 958 men and women. All data are stratified by sex, and no significant differences between men and women were found.

FIGURE 3. Competing risk regression models show cumulative incidence of death (A), age-adjusted death (B), repair failure (C), and age-adjusted repair failure (D). The corresponding subhazard ratios, 95% confidence intervals, and *P* values are shown in Table 6.

dissection.³² The presence of a bypass graft to the renal or visceral arteries also was more common in men; this strategy is largely driven by displacement of the arterial branches related to chronic dissection. Men were more likely to have had a previous proximal and distal aortic repair, both open and endovascular. This finding may relate to the higher incidence of chronic aortic dissection of both DeBakey types I and III in men; these types of dissection

often require multiple operations to manage. Accordingly, the rate of failure of previous aortic repair was higher in men because of their likelihood to have had previous aortic repair. Men who underwent open TAAA repair had a slightly larger maximum distal aortic diameter than did women (6.3 [5.6-7.4] cm vs 6.0 [5.5-7.0] cm, *P* < .001, respectively), as expected given their larger body size and baseline aortic diameter.

In the overall group, women were more often symptomatic upon presentation, despite having overall smaller aneurysm size and similar rates of acute or subacute aortic dissection and aortic rupture as men. Also, women more often had aortic aneurysms without dissection, and they were more likely to undergo endarterectomy during TAAA repair, which is typically an indication of severe atherosclerotic disease. The increased prevalence of degenerative, nondissection aortic aneurysms in women undergoing open TAAA repair in this study could be partially explained by the higher current tobacco use in women

TABLE 6. Competing risk analysis of death and repair failure after 3353 thoracoabdominal aortic aneurysm repairs

	Subhazard ratio	95% CI	<i>P</i> value
Death			
Gender (Figure 3, A)	0.91	0.83-0.99	.03
Gender + age (Figure 3, B)	1.03	0.94-1.12	.5
Repair failure			
Gender (Figure 3, C)	0.85	0.57-1.28	.4
Gender + age (Figure 3, D)	0.77	0.51-1.16	.2

See Figure 3 for graphical interpretation. CI, Confidence interval.

compared with men; the association between smoking and AAA is well established for both sexes,³³ and a similar association could exist for thoracoabdominal aneurysms. Moreover, women in this study had more pulmonary complications and respiratory failure necessitating tracheostomy postoperatively, possibly because they were more likely to have pulmonary diseases and to be current smokers.

Our propensity score analysis incorporated more than 50 preoperative and intraoperative variables and resulted in the identification of 958 matched pairs; after this matching process, the median value of maximum distal aortic diameters and of eGFR still showed a small but significant difference between men and women but was considered to be of little clinical importance. There was little difference in early outcomes in the matched groups; pulmonary complications were more common in women, and persistent paraplegia was slightly more common in men. By using National Inpatient Sample data on 9855 open and endovascular repairs of acute distal aortic dissection, Liang and colleagues³⁴ found higher rates of postoperative paraplegia in men than in women after propensity weighting.

In the unmatched group comprising 1114 men and 323 women, our study showed that women were significantly older than men (70 [65-74] years vs 66 [56-72] years, $P < .001$) and had less aortic dissection (10.8% vs 50.4%, $P < .001$) and smaller aneurysms (6.1 [5.5-7.0] cm vs 6.5 [5.6-7.6] cm, $P < .001$). Considering general health in the unmatched group, we found women had fewer cardiovascular comorbidities (ie, lower rates of coronary artery disease and prior myocardial infarction). A review of operative factors showed women were more likely to have urgent or emergency repair (29.1% vs 16.8%, $P < .001$) and endarterectomy (41.8% vs 20.1%, $P < .001$). Despite many differences in the unmatched group, we saw no significant differences in key early postoperative outcomes between men and women: operative death (7.5% vs 9.9%, $P = .2$), persistent stroke (2.9% vs 1.5%, $P = .2$), persistent spinal cord deficit (5.7% vs 4.6%, $P = .4$), and persistent renal failure (5.7% vs 5.9%, $P = .9$), respectively.

In contrast to the findings of Murana and colleagues,³⁰ our overall multivariable analysis did not identify female sex as a predictor of operative death or adverse event after open TAAA repair. Our saturated multivariable analysis (Table 5) revealed both common and sex-specific predictors of adverse event and operative mortality. Supporting our previous results,²⁴ we found that increasing age, increasing aortic clamp time, the use of HCA, and rupture were predictive of adverse events in both men and women. However, we also identified sex-specific predictors of adverse event. Chronic renal insufficiency, previous stroke, urgent or emergency repair, and prior open aortic repair were predictive in men but not in women, whereas previous CABG, prior open proximal aortic repair, and use of a reverse

elephant trunk approach were predictive in women but not in men. We also found increasing age, increasing aortic clamp time, and rupture to be predictive of operative mortality in both men and women. Sex-specific predictors of operative death included urgent or emergency repair, chronic renal insufficiency, and previous stroke in men but not in women, whereas the presence of any symptoms or acute symptoms superimposed on chronic symptoms or having an extent II or III TAAA repair, aneurysm without dissection, prior open distal aortic repair, and a history of chronic obstructive pulmonary disease, emphysema, or bronchitis conferred significant risk in women but not in men.

Most notably, the effect that rupture has on both adverse event and operative mortality was stronger in women than in men: Women were approximately 4 times more likely to die if they had rupture, whereas men were approximately twice as likely to die. This finding supports those of other studies of AAA repair, which have noted that women with rupture typically fare worse than men and have increased rates of operative mortality.^{12,13} Moreover, this finding, coupled with the fact that the presence of acute symptoms superimposed on chronic symptoms was also predictive of operative death in only women, suggests that more vigilant preoperative surveillance may be needed in women.

The large number of late deaths in our study was not entirely unexpected because the median patient age at repair was 67 years for the overall population and 68 years for the matched pairs. Our late survival outcomes were comparable between matched groups after adjusting for age, which was similar to the findings of Murana and colleagues,³⁰ who found that female sex did not affect long-term survival. The available data in our study on late repair failure indicated no differences between men and women.

Study Limitations

Because this is a retrospective study, selection bias was present. Although we aimed to reduce this bias with propensity matching, it may persist in unidentified factors. In addition, data from early in the series were collected retrospectively, which could introduce inconsistency in data collection and impedes the study of era effects. Moreover, our data come from a single practice, and our experience may not be universal. For example, unlike other centers, we use HCA only for highly complex aortic repairs. Thus, although HCA emerged as a predictor of adverse event in both sexes, in other centers where HCA is used routinely in TAAA repairs, it may not be a predictor of negative outcomes. We did not include eGFR, aortic diameter, and body mass index in the propensity-matching analysis. However, these values all have a size component, and men and women have well-established inherent size differences; therefore, we believe this omission would not

substantially change our findings. Because we were unable to determine the causes of late death, some may be related to unreported repair failure; thus, we may have under-reported the number of late repair failures. Also, the large number of late deaths may have affected our finding of a smaller number of repair failures. Finally, we may have failed to adequately capture all late deaths, especially from patients unlikely to be recorded in the Social Security Death Index, such as recent domestic deaths not yet recorded, deaths involving an international patient (which are not captured in the index), and domestic deaths not recorded because of shifting concerns of privacy regarding federal reporting of death data under state jurisdiction.³⁵

CONCLUSIONS

We found similar respectable early outcomes in men and women after open TAAA repair in both the overall cohort and the propensity-matched cohort. This finding may help better clarify the risks women face after TAAA repair, which could help them seek treatment earlier, before symptoms develop or rupture occurs. In addition, we found similar rates of late postoperative estimated survival, freedom from repair failure, and freedom from death or repair failure between the propensity-matched sexes. However, important differences were seen between men and women in several preoperative and intraoperative factors; notably, the disease process leading to open TAAA repair appeared to differ between the sexes. Nevertheless, the implications of differing predictors for men and women for both adverse event and operative death are incompletely understood. Enhanced awareness of sex-specific differences may help improve preoperative surveillance, surgical care, and outcomes after open TAAA repair.

Webcast

You can watch a Webcast of this AATS meeting presentation by going to: http://webcast.aats.org/2016/Video/Tuesday/05-17-16_Ballroom_I_1619_Spiliotopoulos-800.mp4.

Conflict of Interest Statement

O.P. consults for and participates in clinical trials for Medtronic, Inc. J.S.C. participates in clinical research trials conducted by GlaxoSmithKline and Bolton Medical; consults for, receives royalties from, has a departmental educational

grant from, and participates in clinical trials for Vascutek Terumo; and consults and participates in clinical trials for Medtronic, Inc, and WL Gore & Associates. S.A.L. has served as a consultant for Medtronic, Inc, and Vascutek Terumo; has served as an Advisory Board Member for Baxter Healthcare; has served as a principal investigator for clinical studies sponsored by Vascutek Terumo and Baxter Healthcare; and has served as a co-investigator for clinical studies sponsored by Medtronic, Inc, WL Gore & Associates, GlaxoSmithKline, Cook, Inc, and Cytosorbants, Inc. All other authors have nothing to disclose with regard to commercial support.

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Key Words: aneurysm (aorta), aortic dissection, aortic operation, outcomes, thoracoabdominal, sex

Discussion

Dr Wei-Guo Ma (Beijing, China). I congratulate Dr Coselli on his outstanding surgical outcomes in this large series of patients with TAAA. This article contains an enormous amount of data that were rigorously analyzed and could not be presented within the allotted time.

My first question is regarding the overall implication of this study and the clinical recommendations. In your study, you have found no difference between men and women with regard to the early and late outcomes after TAAA repair. What does this mean to clinicians? What is the take-home message? Will this finding change anything in the approach to men or women compared with what was previously accepted?

Dr K. Spiliotopoulos (Houston, Tex). Before we embarked in finding out whether there are any differences between sexes after TAAA repair, we did not know what the outcomes would be. After we reviewed the results, we found that the outcomes are similar between men and women. The strategies

that we apply in this procedure have been similar in both men and women. Now that we know the outcomes are similar, we can say that we do not need to differentiate our strategies in 1 of the 2 sexes, men or women.

Now, another possible implication could be that when we counsel patients who come for this operation, we can answer more positively; for example, if a woman has some concern that she could fare worse because she has heard in certain other procedures that women do worse, we can tell her that we have comparable outcomes in men and women.

Dr Ma. You mentioned in the article that women always do worse than men in aortic valve surgery, mitral valve surgery, and coronary surgery. Can you speculate why this difference was not observed in this series of patients with TAAA repair?

Dr Spiliotopoulos. Many studies show a difference in other cardiovascular operations. Our speculation would be, for example, in CABG there may be some technical difficulties if women have smaller coronary arteries or lower use of arterial grafts, which has been shown for women in relevant articles. In aortic valve surgery, women may have smaller body surface areas and smaller valves, and they may be more prone to patient–prosthesis mismatch. So there are possible explanations for the gender differences in these other procedures.

For open thoracoabdominal repair, we speculate that because the surgery involves larger vessels than in CABG, these larger aortic operations do not cause more technical difficulties in women than men. So that could be an explanation for why we don't see these differences in thoracoabdominal aortic repairs.

TABLE E1. Variables from preoperative characteristics (Table 1) and operative details (Table 2) used in propensity-matching analysis

Preoperative variables	Intraoperative variables
Male sex	Elective repair
Age, y	Urgent repair
Age ≤50 y	Extent I repair
Aortic aneurysm without dissection	Extent II repair
Acute dissection	Extent III repair
Chronic dissection	Redo thoracotomy and/or laparotomy
DeBakey type I	Reverse elephant trunk
DeBakey type III	Clamping proximal to left subclavian artery
DeBakey type IIb	Intercostal/lumbar artery reattachment
Connective tissue disorder	Aortic clamp time, min
Marfan syndrome	Bypass graft of visceral or renal artery
Diameter >7.5 cm	Endarterectomy of visceral or renal artery
Hypertension	Stenting of visceral or renal artery
Hyperlipidemia	CSFD
Diabetes	HCA
Coronary artery disease	LHB
Prior CABG	Cold renal perfusion
Prior MI	Selective perfusion of visceral arteries
Cerebrovascular disease	Any bypass, endarterectomy, or stenting of
Prior stroke	Visceral or renal artery
Chronic renal insufficiency	
Pulmonary disease	
History of COPD/emphysema/bronchitis	
Current tobacco use	
Peripheral vascular disease	
Symptomatic	
Acute symptoms	
Acute symptoms superimposed on chronic symptoms	
Chronic symptoms	
Rupture	
Prior aortic repair	
Prior open aortic repair	
Prior proximal open aortic repair	
Prior distal open aortic repair	
Prior distal aortic repair	
Prior distal endovascular repair	
Failure of prior aortic repair	
Repair failure	

Diameter >7.5 had $P < .1$ in the univariate comparisons but were excluded because of missing ~10% of values. CABG, Coronary artery bypass grafting; MI, myocardial infarction; COPD, chronic obstructive pulmonary disease; CSFD, cerebrospinal fluid drainage; HCA, hypothermic circulatory arrest; LHB, left heart bypass.

TABLE E2. Preoperative characteristics of unmatched group

Variable	All unmatched (n = 1437)	Unmatched men (n = 1114)	Unmatched women (n = 323)	P value
Age, y	67 [58-73]	66 [56-72]	70 [65-74]	<.001
Age ≤50 y	196 (13.6)	178 (16.0)	18 (5.6)	<.001
Connective tissue disorder	106 (7.4)	80 (7.2)	26 (8.0)	.6
Marfan syndrome	100 (7.0)	76 (6.8)	24 (7.4)	.7
Aortic aneurysm without dissection	841 (58.5)	553 (49.6)	288 (89.2)	<.001
Aortic dissection	596 (41.5)	561 (50.4)	35 (10.8)	<.001
Acute or subacute	60 (4.2)	46 (4.1)	14 (4.3)	.9
Chronic	536 (37.3)	515 (46.2)	21 (6.5)	<.001
DeBakey type I	235 (16.4)	233 (20.9)	2 (0.6)	<.001
DeBakey type III	345 (24.0)	313 (28.1)	32 (9.9)	<.001
DeBakey type IIIa	36 (2.5)	23 (2.1)	13 (4.0)	.047
DeBakey type IIIb	309 (21.5)	290 (26.0)	19 (5.9)	<.001
Localized dissection	14 (1.0)	13 (1.2)	1 (0.3)	.2
Maximum distal aortic diameter, cm	6.4 [5.6-7.3]	6.5 [5.6-7.6]	6.1 [5.5-7.0]	<.001
Diameter >7.5 cm	279 (19.4)	251 (22.5)	28 (8.7)	<.001
Hypertension	1246 (86.7)	979 (87.9)	267 (82.7)	.02
Hyperlipidemia	455 (31.7)	378 (33.9)	77 (23.8)	<.001
Diabetes	121 (8.4)	108 (9.7)	13 (4.0)	.001
Coronary artery disease	548 (38.1)	493 (44.3)	55 (17.0)	<.001
Prior CABG	274 (19.1)	261 (23.4)	13 (4.0)	<.001
Prior MI	325 (22.6)	296 (26.6)	29 (9.0)	<.001
Cerebrovascular disease	267 (18.6)	202 (18.1)	65 (20.1)	.4
Prior stroke	156 (10.9)	113 (10.1)	43 (13.3)	.1
eGFR	64 [47-82]	64 [47-83]	60 [45-78]	.03
Chronic renal insufficiency	58 (4.0)	56 (5.0)	2 (0.6)	<.001
History of renal failure requiring dialysis*	31 (2.2)	30 (2.7)	1 (0.3)	.009
Body mass index	26.4 [23.1-29.6]	27.4 [24.4-30.4]	22.5 [19.6-25.8]	<.001
Pulmonary disease	532 (37.0)	358 (32.1)	174 (53.9)	<.001
History of COPD/emphysema/bronchitis	497 (34.6)	336 (30.2)	161 (49.8)	<.001
Current tobacco use	390 (27.1)	258 (23.2)	132 (40.9)	<.001
Asymptomatic	551 (38.2)	856 (76.8)	81 (25.1)	<.001
Symptomatic	886 (61.7)	644 (57.8)	242 (74.9)	<.001
Acute	213 (14.8)	152 (14.2)	61 (18.9)	.02
Both acute and chronic	37 (2.6)	17 (1.5)	20 (6.2)	<.001
Chronic	710 (49.4)	509 (45.7)	201 (62.2)	<.001
Peripheral vascular disease	377 (26.2)	278 (25.0)	99 (30.7)	.04
Rupture	69 (4.8)	50 (4.5)	19 (5.9)	.3
Prior aortic repair†	734 (51.0)	666 (59.8)	68 (21.1)	<.001
Prior open aortic repair	673 (46.8)	607 (54.5)	66 (20.4)	<.001
Proximal	349 (24.3)	295 (26.5)	54 (16.7)	<.001
Distal	396 (27.6)	371 (33.3)	25 (7.7)	<.001
Prior distal aortic repair	405 (28.2)	380 (34.1)	25 (7.7)	<.001
Prior endovascular	39 (2.7)	37 (3.3)	2 (0.6)	.009
Failure of prior distal aortic repair‡	63 (4.4)	60 (5.4)	3 (0.9)	.001

Data are presented as n (%) or median [interquartile range]. CABG, Coronary artery bypass grafting; MI, myocardial infarction; eGFR, estimated glomerular filtration rate; COPD, chronic obstructive pulmonary disease. *Serum creatinine level 3.0 mg/dL or dialysis. †Prior open or endovascular aortic repair. ‡Failure of prior distal open or endovascular aortic repair necessitating in-window repair.

TABLE E3. Preoperative characteristics, operative details, and early outcomes in 1083 extent II thoracoabdominal aortic aneurysm repairs performed on 702 men and 381 women

Variable	All (n = 1083)	Men (n = 702)	Women (n = 381)	P value
Preoperative characteristics				
Patient age at repair, y	66 [56-72]	65 [55-72]	67 [58-72]	.04
Connective tissue disorder	175 (16.2)	105 (15.0)	70 (18.4)	.1
Aneurysm without dissection	544 (13.3)	298 (42.5)	246 (64.6)	<.001
Acute or subacute dissection	59 (5.4)	41 (5.8)	18 (4.7)	.4
Chronic dissection	480 (44.3)	363 (51.7)	117 (30.7)	<.001
DeBakey type I	220 (20.3)	169 (24.1)	51 (13.4)	<.001
DeBakey type III	309 (28.5)	228 (32.5)	81 (21.3)	<.001
Maximum distal aortic diameter, cm	6.3 [5.7-7.2]	6.5 [5.8-7.4]	6.1 [5.5-7.0]	<.001
Hyperlipidemia	271 (25.0)	186 (26.5)	85 (22.3)	.1
Coronary artery disease	313 (28.9)	224 (31.9)	89 (23.4)	.003
Prior CABG	140 (12.9)	107 (15.2)	33 (8.7)	.002
Prior MI	183 (16.9)	134 (19.1)	49 (12.9)	.009
Cerebrovascular disease	187 (17.3)	117 (16.7)	70 (18.4)	.5
Chronic renal insufficiency	28 (2.6)	23 (3.3)	5 (1.3)	.05
Pulmonary disease	368 (34.0)	202 (28.8)	166 (43.6)	<.001
Current tobacco use	324 (30.0)	173 (24.6)	151 (39.6)	<.001
Symptomatic	678 (62.6)	429 (61.1)	249 (65.4)	.2
Rupture	32 (3.0)	21 (3.0)	11 (2.9)	.9
Prior open aortic repair	502 (46.4)	372 (53.0)	130 (34.1)	<.001
Operative details				
Urgent or emergency repair	202 (18.7)	123 (17.5)	79 (20.7)	.2
Redo thoracotomy and/or laparotomy	125 (11.5)	104 (14.8)	21 (5.5)	<.001
Clamping proximal to LSCA	249 (23.0)	181 (25.8)	68 (17.9)	.003
Intercostal/lumbar artery reattachment	935 (86.3)	634 (90.3)	301 (79.0)	<.001
Management of visceral/renal arteries				
Bypass graft	343 (31.7)	236 (33.6)	107 (28.1)	.06
Endarterectomy	280 (25.9)	153 (21.8)	127 (33.3)	<.001
Stenting	90 (8.3)	54 (7.7)	36 (9.5)	.3
Endarterectomy, stenting, or bypass	308 (28.4)	174 (24.8)	134 (35.2)	<.001
Adjuncts				
CSFD	673 (62.1)	447 (63.7)	226 (59.3)	.2
LHB	892 (82.4)	589 (83.9)	303 (79.5)	.07
HCA	18 (1.7)	10 (1.4)	8 (2.1)	.4
Cold renal perfusion	717 (66.2)	465 (66.2)	252 (66.1)	.97
Selective perfusion of visceral arteries	689 (63.6)	460 (65.5)	229 (60.1)	.08
Early outcomes				
Adverse event*	204 (18.8)	129 (18.4)	75 (19.7)	.6
Operative death	101 (9.3)	59 (8.4)	42 (11.0)	.2
In-hospital	97 (9.0)	55 (7.8)	42 (11.0)	.08
30-d	68 (6.3)	40 (5.7)	28 (7.4)	.3
Stroke	48 (4.4)	35 (5.0)	13 (3.4)	.2
Persistent stroke†	37 (3.4)	26 (3.7)	11 (2.9)	.5
Spinal cord deficit	149 (13.8)	103 (14.7)	46 (12.1)	.2
Persistent SCD†	86 (7.9)	60 (8.6)	26 (6.8)	.3
Persistent paraplegia†	51 (4.7)	38 (5.4)	13 (3.4)	.1
Persistent paraparesis†	35 (3.2)	22 (3.1)	13 (3.4)	.8
Acute renal dysfunction	172 (15.9)	103 (14.7)	69 (18.1)	.1
Renal failure necessitating dialysis	104 (9.6)	64 (9.1)	40 (10.5)	.5
Persistent renal failure‡	79 (7.3)	48 (6.8)	31 (8.1)	.4
Cardiac complication	342 (31.6)	230 (32.8)	112 (29.4)	.3
Pulmonary complication	460 (42.5)	277 (39.5)	183 (48.0)	.006
Respiratory failure	332 (30.7)	203 (28.9)	129 (33.9)	.09
Necessitating tracheostomy	132 (12.2)	74 (10.5)	58 (15.2)	.02

(Continued)

TABLE E3. Continued

Variable	All (n = 1083)	Men (n = 702)	Women (n = 381)	P value
Left vocal cord paralysis	253 (23.4)	187 (26.6)	66 (17.3)	<.001
Bleeding requiring reoperation	40 (3.7)	21 (3.0)	19 (5.0)	.10
Early survivors: length of ICU stay, d	5 [3-8] (n = 946)	4 [3-8] (n = 614)	5 [3-8.5] (n = 332)	.3
Early survivors: length of hospital stay, d	13 [10-21] (n = 977)	12 [10-21] (n = 638)	13 [10-21] (n = 339)	.4

Data presented as no. (%) or median [interquartile range]. CABG, Coronary artery bypass grafting; MI, myocardial infarction; LSCA, left subclavian artery; CSFD, cerebrospinal fluid drainage; LHB, left heart bypass; HCA, hypothermic circulatory arrest; SCD, spinal cord deficit; ICU, intensive care unit. *Defined as operative death or persistent (present at hospital discharge) stroke, paraplegia, paraparesis, or renal failure necessitating dialysis. †Present at the time of hospital discharge or early death. ‡Discharged with stroke, paraplegia, paraparesis, or renal failure necessitating dialysis.

TABLE E4. Operative details of unmatched group

Variable	All unmatched (n = 1437)	Unmatched men (n = 1114)	Unmatched women (n = 323)	P value
Urgency of operation				
Elective	1156 (80.4)	927 (83.2)	229 (70.9)	<.001
Urgent or emergency	281 (19.6)	187 (16.8)	94 (29.1)	<.001
Extent of TAAA repair				
Extent I	350 (24.4)	240 (21.5)	110 (34.1)	<.001
Extent II	512 (35.6)	413 (37.1)	99 (30.7)	.03
Extent III	249 (17.3)	164 (14.7)	85 (26.3)	<.001
Extent IV	326 (22.7)	297 (26.7)	29 (9.0)	<.001
Redo thoracotomy or laparotomy	295 (20.5)	274 (24.6)	21 (6.5)	<.001
Reverse elephant trunk	40 (2.8)	29 (2.6)	11 (3.4)	.4
Elephant trunk completion repair	66 (4.6)	51 (4.6)	15 (4.6)	.96
Clamping proximal to left subclavian artery	252 (17.5)	217 (19.5)	35 (10.8)	<.001
Intercostal/lumbar artery reattachment	703 (48.9)	591 (53.1)	112 (34.7)	<.001
Aortic clamp time, min	53 [40-71]	58 [48-75]	41 [30-51]	<.001
Management of visceral/renal arteries				
Bypass graft	397 (27.6)	339 (30.4)	58 (18.0)	<.001
Endarterectomy	359 (25.0)	224 (20.1)	135 (41.8)	<.001
Stenting	120 (8.4)	88 (7.9)	32 (9.9)	.3
Endarterectomy, stenting, or bypass	605 (42.1)	441 (39.6)	137 (42.4)	<.001
Adjuncts				
CSFD	658 (45.8)	503 (45.2)	155 (48.0)	.4
LHB	681 (47.4)	543 (48.7)	138 (42.7)	.06
HCA	21 (1.5)	18 (1.6)	3 (0.9)	.4
Cold renal perfusion	887 (61.7)	719 (64.5)	168 (52.0)	<.001
Selective perfusion of visceral arteries	387 (26.9)	316 (28.4)	71 (22.0)	.02

Data presented as n (%) or median [interquartile range]. TAAA, Thoracoabdominal aortic aneurysm; CSFD, cerebrospinal fluid drainage; LHB, left heart bypass; HCA, hypothermic circulatory arrest.

TABLE E5. Early outcomes of unmatched group

Variable	All unmatched (n = 1437)	Unmatched men (n = 1114)	Unmatched women (n = 323)	P value
Adverse event*	214 (14.9)	164 (14.7)	50 (15.5)	.7
Operative death	115 (8.0)	83 (7.5)	32 (9.9)	.2
In-hospital	108 (7.5)	78 (7.0)	30 (9.3)	.2
30-d	76 (5.3)	57 (5.1)	19 (5.9)	.6
Stroke	48 (3.3)	42 (3.8)	6 (1.9)	.09
Persistent stroke†	37 (2.6)	32 (2.9)	5 (1.5)	.2
Spinal cord deficit	136 (9.5)	109 (9.8)	27 (8.4)	.4
Persistent SCD‡	79 (5.5)	64 (5.7)	15 (4.6)	.4
Persistent paraplegia†	47 (3.3)	35 (3.1)	12 (3.7)	.6
Persistent paraparesis†	32 (2.2)	29 (2.6)	3 (0.9)	.07
Acute renal dysfunction	178 (12.4)	140 (12.6)	38 (11.8)	.7
Renal failure necessitating dialysis	110 (7.7)	89 (8.0)	21 (6.5)	.4
Persistent dialysis‡	83 (5.8)	64 (5.7)	19 (5.9)	.9
Cardiac complication	379 (26.4)	292 (26.4)	87 (26.9)	.8
Pulmonary complication	505 (35.1)	371 (33.3)	134 (41.5)	.007
Respiratory failure	358 (24.9)	269 (24.1)	89 (27.6)	.2
Necessitating tracheostomy	122 (8.5)	82 (7.4)	40 (12.4)	.004
Left vocal cord paralysis	244 (17.0)	211 (18.9)	33 (10.2)	<.001
Bleeding requiring reoperation	45 (3.1)	34 (2.4)	11 (3.4)	.7
Early survivors	(n = 1322)	(n = 1031)	(n = 291)	
Life-altering complication‡	99 (7.5)	81 (7.9)	18 (6.2)	.4
Length of ICU stay, d	4 [3-6]	4 [3-6]	4 [3-7]	.04
Length of overall stay, d	12 [9-17]	11 [9-17]	13 [9-18]	.01

Values are n (%) or median [interquartile range]. SCD, Spinal cord deficit; ICU, intensive care unit. *Defined as operative death or persistent (present at hospital discharge) stroke, paraplegia, paraparesis, or renal failure necessitating dialysis. †Present at the time of hospital discharge or early death. ‡Discharged with stroke, paraplegia, paraparesis, or renal failure necessitating dialysis. §Patients surviving the early postoperative period (those without operative death, n = 3102 overall and n = 1780 matched group).

TABLE E6. Relative risk ratio for preoperative and operative predictors of adverse event and operative death after thoracoabdominal aortic aneurysm repairs: Separate models for 2072 men and 1281 women

Variables	RRR (CI)	P value
Adverse event in men (n = 2072)		
HCA	4.98 (2.11-11.75)	<.001
Chronic renal insufficiency	2.23 (1.29-3.87)	.004
Rupture	2.23 (1.30-3.81)	.003
Previous stroke	1.48 (0.99-2.20)	.05
Urgent or emergency repair	1.47 (1.40-2.07)	.03
Increasing patient age at repair, y	1.06 (1.04-1.07)	<.001
Increasing aortic clamp time, min	1.02 (1.01-1.02)	<.001
Prior open aortic repair	0.64 (0.49-0.85)	.002
Extent IV TAAA repair	0.56 (0.40-0.80)	.001
Adverse event in women (n = 1281)		
HCA	4.67 (1.59-13.71)	.005
Rupture	3.60 (2.06-6.29)	<.001
Reverse elephant trunk	2.43 (1.03-5.72)	.04
Previous CABG	1.85 (1.14-2.99)	.01
Endarterectomy, stenting, or bypass	1.49 (1.04-2.15)	.03
Increasing patient age at repair, y	1.05 (1.3-1.07)	<.001
Increasing aortic clamp time, min	1.03 (1.02-1.04)	<.001
Prior open proximal aortic repair	0.52 (0.32-0.86)	.01
Extent IV TAAA repair	0.40 (0.23-0.69)	.001
Operative death in men (n = 2072)		
HCA	3.78 (1.33-10.76)	.01
Urgent or emergency repair	2.41 (1.67-3.48)	<.001
Chronic renal insufficiency	2.18 (1.12-4.22)	.02
Previous stroke	1.80 (1.11-2.91)	.02
Increasing patient age at repair, y	1.06 (1.04-1.08)	<.001
Increasing aortic clamp time, min	1.01 (1.01-1.02)	<.001
Cold renal perfusion	0.59 (0.41-0.84)	.003
Operative death in women (n = 1281)		
Rupture	3.56 (1.81-7.01)	<.001
Symptomatic	2.58 (1.44-4.64)	.002
Aneurysm without dissection	2.24 (1.11-4.49)	.02
Extent II TAAA repair	2.21 (1.25-3.90)	.006
Acute symptoms superimposed on chronic symptoms	2.07 (0.91-4.67)	.08
Extent III TAAA repair	1.91 (1.08-3.40)	.03
Prior open distal aortic repair	1.72 (1.01-2.95)	.05
History of COPD/emphysema/bronchitis	1.57 (1.00-2.45)	.05
Increasing patient age at repair, y	1.04 (1.01-1.06)	.006
Increasing aortic clamp time, min	1.03 (1.02-1.04)	<.001

RRR, Relative risk ratio; CI, confidence interval; TAAA, thoracoabdominal aortic aneurysm; CABG, coronary artery bypass grafting; HCA, hypothermic circulatory arrest; COPD, chronic obstructive pulmonary disease.