

Quantified Aortic Luminal Irregularity as a Predictor of Complications and Prognosis After Endovascular Aneurysm Repair

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Abstract: Atheromatous degeneration of the aorta is considered to be a risk factor for postoperative embolic complications after endovascular treatment, and is associated with a high incidence of vascular events in the long term. We devised a method to quantify the shagginess of the aorta using contrast-enhanced computed tomography (CT) images. This study examined the method's validity and prognostic usefulness in patients undergoing elective endovascular abdominal aortic aneurysm repair (EVAR).

We retrospectively investigated 427 patients who underwent elective EVAR between 2007 and 2013. Preoperative contrast-enhanced CT images with a slice thickness of 1 mm were analyzed using a workstation, and the degree of aortic luminal irregularity from the level of the left subclavian artery ostium to that of the celiac artery ostium was quantified by computing a shagginess score. We compared the computed scores with subjective visual assessments of aortic shagginess. Subsequently, we evaluated the relationship between the computed scores and postoperative prognosis.

The shagginess scores were significantly correlated with the visual assessments of the aortic lumen, which were performed by 5 experienced vascular surgeons (ρ ranged from 0.564–0.654, all $P < 0.001$). Multiple logistic regression analysis demonstrated that the shagginess score was independently associated with the development of renal impairment within a month after EVAR (odds ratio, 2.78; 95% confidence interval [CI], 1.83–4.22, $P < 0.001$). The shagginess score was significantly higher in patients who suffered postoperative intestinal and peripheral ischemic complications, as compared with those who did not ($P < 0.001$). The mean postoperative follow-up period was 1207 ± 641 days. Cox proportional hazards regression showed that the shagginess score was a significant independent predictor of all-cause and cardiovascular mortality (hazard ratio [HR], 1.37; 95% CI, 1.09–1.72, $P = 0.007$, and HR, 1.51; 95% CI, 1.04–2.18, $P = 0.030$, respectively).

The results suggest that the shagginess score provides a quantitative reflection of aortic luminal irregularity. It may serve as a useful predictive factor for postoperative renal function deterioration, embolic complications, and long-term mortality after elective EVAR.

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Abbreviations: 3D = 3-dimensional, CAD = coronary artery disease, CI = confidence interval, COPD = chronic obstructive pulmonary disease, CT = computed tomography, CVD = cerebrovascular disease, EVAR = endovascular abdominal aortic aneurysm repair, HR = hazard ratio, MPR = multiplanar reconstruction, MRI = magnetic resonance imaging, PET = positron emission tomography, SD = standard deviation, TEE = transesophageal echocardiography.

INTRODUCTION

Endovascular aneurysm repair (EVAR) has been established as an effective alternative in the treatment of abdominal aortic and iliac aneurysms. However, EVAR remains challenging in patients with a shaggy aorta, which is an aorta that has extensive atheromatous degeneration with diffuse ulcerations and unstable plaques.¹ EVAR is difficult in these cases because it entails a high risk of perioperative embolic complications triggered by endoluminal wire and catheter manipulation, which can sometimes lead to fatal conditions.^{2–6}

Although it is commonly recognized that patients with a shaggy aorta face high morbidity after endovascular treatment, the embolic potential of aortic atheroma has mainly been evaluated subjectively based on preoperative imaging tests. Few studies have investigated methods of more reliable evaluations of embolic potential by using quantitative and objective assessments of aortic plaque instability. We devised a method to semi-automatically quantify the degree of aortic shagginess on the basis of contrast-enhanced computed tomography (CT) using a 3-dimensional (3D) image analysis workstation. In the present study, we examined the method's validity and evaluated its usefulness as a predictive factor for morbidity and mortality after EVAR.

METHODS

Patient Population

The study protocol was approved by the ethics committee of Morinomiya Hospital. Between October 2007 and March 2013, 700 consecutive patients underwent EVAR using a stent graft main body at the Department of Cardiovascular Surgery, Morinomiya Hospital. We excluded patients who had a history of graft replacement or endovascular repair of the aortic arch or descending aorta, those who had a dissected thoracic aorta with a patent false lumen, those who were treated for ruptured or infected aneurysms, and those who did not have preoperative contrast-enhanced CT of the whole aorta performed at our institution and stored in the hospital archive. After making these exclusions, there were 536 remaining patients, each of

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TABLE 1. Clinical Characteristics of the Patients

Age, years (mean \pm standard deviation)	74.9 \pm 8.2
Sex (male/female)	343/84
Comorbidity, n (%)	
Hypertension	322 (75.6)
Hypercholesterolemia	101 (23.7)
Diabetes mellitus	37 (8.7)
Coronary artery disease	94 (22.0)
Cerebrovascular disease	71 (16.6)
Chronic obstructive pulmonary disease	123 (29.6)
History of smoking, n (%)	345 (81.0)
History of malignancy, n (%)	111 (26.0)
Statin use, n (%)	186 (43.7)
Antiplatelet use, n (%)	184 (43.2)
Stent graft used in the treatment (n)	
Excluder	277
Powerlink	3
Zenith	110
Endurant	30
Incraft	7

whom had analyzable preoperative contrast-enhanced CT data and underwent elective EVAR during the study period. We additionally excluded 26 patients who were treated with a fenestrated endovascular graft, 6 patients who were treated with adjunctive bypass grafting to the abdominal aortic branches concurrently with or before EVAR, 61 patients who underwent concomitant renal artery stenting or coverage, and 16 patients with chronic renal failure on maintenance hemodialysis. After these exclusions, 427 patients (343 men and 84 women) were included in the present analysis.

The clinical characteristics of the patients are summarized in Table 1. Patients were assumed to have hypertension or diabetes mellitus if they were taking corresponding medication. Hypercholesterolemia was defined as serum level of total cholesterol ≥ 220 mg/dl or that of low-density lipoprotein cholesterol ≥ 140 mg/dl. Coronary artery disease (CAD) was defined as having a history of interventional or surgical treatment of the disease, and cerebrovascular disease (CVD) was diagnosed from a history of stroke. The diagnosis of chronic obstructive pulmonary disease (COPD) was confirmed by respiratory function tests showing that forced expiratory volume in 1 second was less than 70% of forced vital capacity.

Dual-phase contrast-enhanced CT and/or ultrasonography (in color-flow and pulse-wave modes, without contrast enhancement) were routinely performed within a week postoperatively to evaluate endoleaks and other procedure-related complications.

Definition of the Shaginess Score

All patients included in the present study underwent preoperative contrast-enhanced CT of the whole aorta using a 64-detector row CT scanner (Brilliance 64, Philips Medical Systems, Best, The Netherlands). A bolus-tracking technique was used by placing a circular region of interest within the descending aorta at the level of the tracheal bifurcation, following intravenous administration of 50 to 75 ml contrast agent at 3 to 4 ml/second. The data of CT images of the early arterial phase with a slice thickness of 1 mm were transferred to a 3D image analysis workstation (SYNAPSE VINCENT, Version 4.1, Fujifilm Co., Tokyo, Japan) for evaluation. A central

luminal line of the aorta was automatically defined, and multi-planar reconstruction (MPR) images were obtained perpendicularly to the centerline with a regular slice thickness of 1.2 to 1.7 mm from the level of the left subclavian artery to that of the celiac artery. In each MPR image, the contour of the aortic lumen was automatically recognized and traced, and its length (A) was calculated; simultaneously, diameters of the aortic luminal contour through the central luminal line were also measured automatically for every degree, and the mean value of 180 measurements was calculated (B). Then, the ratio of A to the circumference of a perfect circle with a diameter of B was determined [$C = A/(3.14 \cdot B)$] (Figure 1). A is mainly determined by the diameter and irregularity of the aortic lumen. By dividing A by the circumference of a circle with a diameter equal to the average diameter of the lumen (B), we quantified the deviation of the luminal contour from that of a perfect circle. Accordingly, we regarded this ratio (C) as a potential indicator of the degree of luminal irregularity and shaginess.

The shaginess score was then defined as the mean value of $(C - 1) \times 100$ from the level just distal to the left subclavian artery ostium to that just above the celiac artery ostium. In practice, the process of calculating the score required a few minutes.

Shaginess Score and Grading of Aortic Shaginess by Visual Assessment

Among the study population, 54 patients underwent EVAR during the period between January and December 2011, and their preoperative axial CT images were reviewed independently by 5 experienced vascular surgeons. The observers visually graded the irregularity of the aortic luminal surface of each patient on a scale of 1 to 10 (1 = clean and not atheromatous, 10 = most severely shaggy) after being given reference sample images. The correlations between the visual scales and shaginess scores were evaluated.

Postoperative Renal Dysfunction, Ischemic Events, and All-Cause and Cardiovascular Mortality

The relationships between the pre- and intraoperative risk factors (including the shaginess score) and postoperative renal dysfunction, ischemic complications, and long-term mortality were evaluated. Data on the serum creatinine levels of each patient were collected before surgery, throughout the perioperative period, and at a 1-month follow-up. Postoperative renal impairment was defined as an absolute increase in serum creatinine of ≥ 0.3 mg/dl or a percentage increase in serum creatinine of $\geq 50\%$ within a month after surgery, as compared with the preoperative level.⁷ The diagnosis of bowel ischemia was established using colonic endoscopy and/or contrast-enhanced CT performed following characteristic clinical presentations, such as abdominal pain and melena. Blue toe syndrome was diagnosed from the clinical findings. Deaths and causes of mortality were identified by chart review and by direct contact with patients and their families, if necessary.

Statistical Analysis

Continuous data are presented as means \pm standard deviations (SDs). The Mann-Whitney *U* test was used for comparisons between groups of patients, and relationships between categorical variables were compared using Chi-squared test. Correlation analyses were performed using the Spearman rank test. Multiple logistic regression analysis was performed to

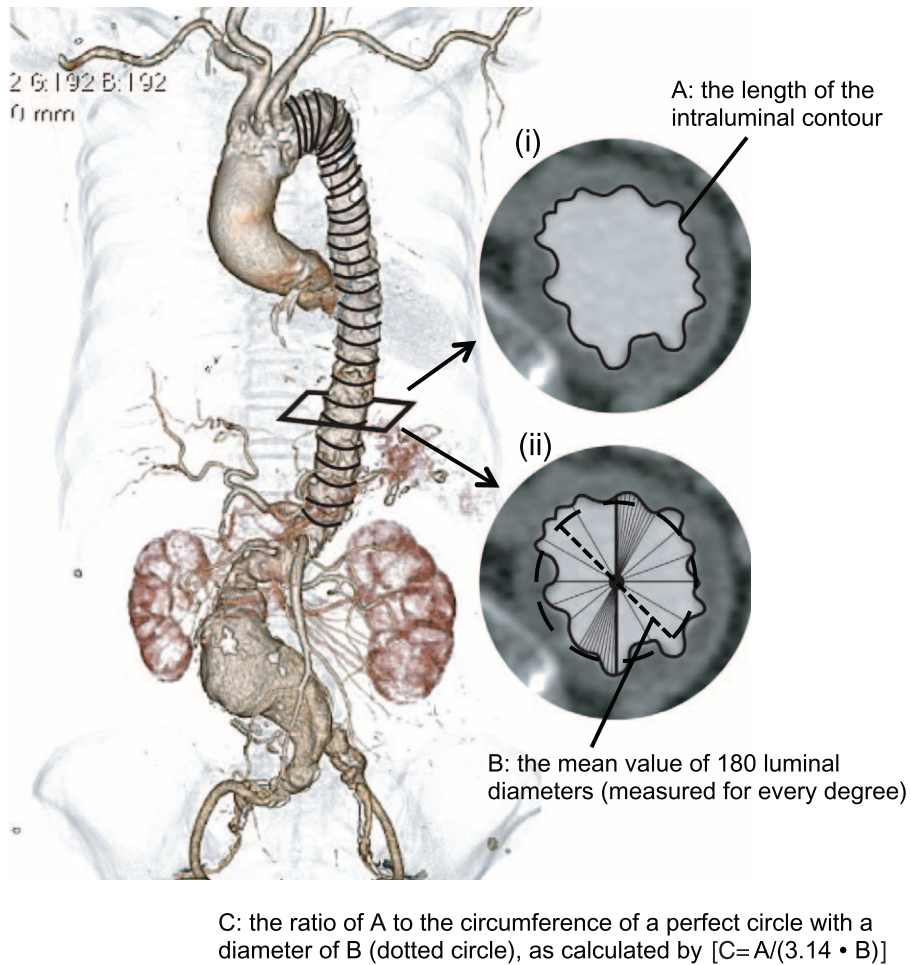


FIGURE 1. In each multiplanar reconstruction image perpendicular to the automatically defined aortic centerline with a regular slice thickness of 1.2 to 1.7 mm, the contour of the aortic lumen was recognized and traced (i), and its length (A) was calculated. Simultaneously, diameters of the aortic luminal contour through the central luminal line were measured automatically for each individual degree (ii), and the mean value of 180 measurements of the diameters was computed (B, dotted line). Then, the ratio of A to the circumference of a perfect circle with a diameter of B (dotted circle) was determined [$C = A / (3.14 \cdot B)$]. The mean value of $(C - 1) \times 100$ from the left subclavian artery ostium to the celiac artery ostium was calculated and defined as the shagginess score.

determine the relative contributions of variables associated with postoperative renal impairment. Cox proportional hazards analyses were used to examine factors related to all-cause and cardiovascular mortality. Each multivariate analysis included all variables that were significant in univariate analyses at the P values < 0.1 level. All analyses were performed using PASW Statistics 18 (SPSS, Inc., Chicago, IL). P values less than 0.05 were regarded as indicating statistical significance.

RESULTS

Profiles of the Shagginess Score

The primary technical success rate was 94.8%; minor type I or III endoleaks were observed in 22 patients at completion angiography. In 20 of these patients, the endoleaks had resolved by the time of the follow-up CT and/or duplex echography that were performed 4 to 6 days after EVAR. Postoperative 30-day mortality was 0.2%. The mean shagginess score was 8.254 ± 0.665 , with a range of 7.013 to 12.441. The shagginess

score was significantly higher in patients with hypertension, CAD, and COPD ($P < 0.001$, 0.036, and 0.028, respectively), but did not differ significantly according to sex, or between patients with and without a history of hypercholesterolemia, diabetes, CVD, or smoking (Table 2). The shagginess score did not show correlations with age or preoperative serum creatinine level ($\rho = 0.236$ and 0.194, respectively, both $P < 0.001$).

The CT images and shagginess scores of several patients are shown in Figure 2. The shagginess score showed a significant correlation with the visual assessments of the aortic lumen, which were made on a 10-point scale by 5 observers ($\rho = 0.564$, 0.595, 0.601, 0.627, and 0.654, respectively, all $P < 0.001$).

Shagginess Score, Postoperative Renal Impairment, and Ischemic Events

We evaluated the relationships between the pre- and intraoperative conditions and change in renal function within the first postoperative month. Seven patients were excluded

TABLE 2. Shagginess Score and Preoperative Risk Factors for Atherosclerosis

	Present	Absent	P
Male gender	8.261 ± 0.661	8.226 ± 0.684	0.89
Hypertension	8.321 ± 0.713	8.047 ± 0.433	<0.001
Hypercholesterolemia	8.198 ± 0.544	8.272 ± 0.698	0.51
Diabetes mellitus	8.338 ± 0.604	8.246 ± 0.671	0.26
Coronary artery disease	8.343 ± 0.704	8.229 ± 0.652	0.036
Cerebrovascular disease	8.292 ± 0.682	8.247 ± 0.662	0.72
Chronic obstructive pulmonary disease	8.369 ± 0.722	8.215 ± 0.644	0.028
History of smoking	8.282 ± 0.693	8.136 ± 0.522	0.11

Results are presented as mean ± standard deviation.

from the analysis because of a lack of data. Postoperative renal impairment was observed in 70 patients. Univariate analyses demonstrated that the shagginess score, the preoperative level of serum creatinine, and the amount of contrast medium used during the operation were significantly higher in patients who suffered postoperative renal impairment, as compared with those who did not. Patients with postoperative renal impairment were significantly older and more likely to have hypertension. A multiple logistic regression analysis showed that the shagginess score, the preoperative serum creatinine level, and the amount of contrast medium used intraoperatively were independently associated with the development of renal impairment after EVAR (Table 3).

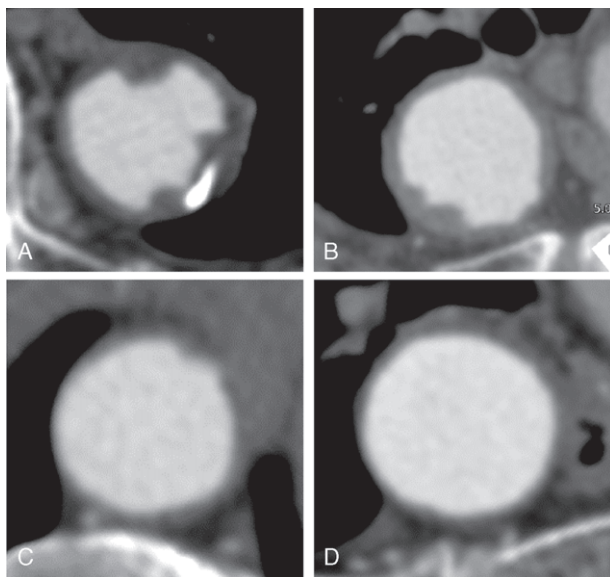


FIGURE 2. Examples of multiplanar reconstruction computed tomography images perpendicular to the aortic centerline. (A) A patient with both hypertension and coronary artery disease (CAD) (shagginess score, 12.434). (B) A patient with CAD and without hypertension (shagginess score, 8.538). (C) A patient with hypertension and without CAD (shagginess score, 8.133). (D) A patient without hypertension or CAD (shagginess score, 7.705).

Two patients developed postoperative bowel ischemia, 3 developed blue toe syndrome, and 1 developed both; 4 of these 6 patients' cases were also complicated by postoperative renal impairment. The shagginess score was significantly higher in patients with bowel ischemia and/or blue toe syndrome after EVAR, as compared with those who did not develop these complications ($P < 0.001$).

Shagginess Score, All-Cause Mortality, and Cardiovascular Mortality

The mean follow-up period was 1207 ± 641 days, with a range of 3 to 2570 days. Ninety-one patients died during the study period, of whom 26 died of a cardiovascular cause. A Cox proportional hazards model demonstrated that the shagginess score was a significant independent predictor of all-cause mortality (hazard ratio [HR], 1.37; 95% confidence interval [CI], 1.09–1.72, $P = 0.007$), as were age at operation (HR, 1.09; 95% CI, 1.05–1.12, $P < 0.001$) and history of malignancy (HR, 2.48; 95% CI, 1.59–3.86, $P < 0.001$) (Table 4). With respect to cardiovascular mortality, the independent predictive factors with statistical significance were shagginess score (HR, 1.51; 95% CI, 1.04–2.18, $P = 0.030$), age at operation (HR, 1.09; 95% CI, 1.03–1.15, $P = 0.004$), and preoperative level of serum creatinine (HR, 6.35; 95% CI, 1.17–34.54, $P = 0.032$) (Table 5).

DISCUSSION

The shagginess score is an assessment of aortic shagginess that can be calculated semi-automatically from the contrast-enhanced CT images within a processing time of a few minutes. The results of the present study demonstrated that the shagginess score corresponded well with the visual assessment of aortic luminal irregularity. The score showed significant association with the occurrence of postoperative renal, mesenteric, and peripheral arterial complications mostly attributable to atheroembolism. Further, our results suggest that the score may have a prognostic value in predicting long-term mortality, indicating its potential usefulness in determining treatment strategies for EVAR candidates. To the best of our knowledge, this is the first attempt to quantitatively characterize the shagginess of the aorta and to evaluate the clinical value of the proposed index.

Vulnerable plaques are widely recognized to play important roles in the development of cardiovascular events. Efforts have been made to identify these lesions in the coronary and carotid arteries, and to quantify their instability using various imaging modalities, such as ultrasonography, CT, magnetic resonance imaging (MRI), positron emission tomography (PET), and optical coherence tomography.^{8–14} The presence of unstable plaques in the aorta is also considered a risk factor for distal atheroembolism, and previous studies have demonstrated the usefulness of various grading scales of aortic atheroma, as determined using transesophageal echocardiography (TEE), contrast-enhanced CT, and PET.^{5,6,15–20} Among these modalities, TEE is most commonly used in the evaluation of aortic plaques. However, TEE has several limitations—it requires operators with a certain level of skills and sufficient time to examine the whole thoracic aorta. PET can quantify the inflammatory activity of the plaques, but it is less available for routine use as a screening tool. On the other hand, CT provides unbiased information on the whole aorta in a single rapid scan, and its advantages have recently been broadened by the development of the multidetector apparatus and image analysis software.

TABLE 3. Pre- and Intraoperative Conditions and Postoperative Renal Impairment

Variable	Univariate Analysis			Multivariate Analysis		
	With Postoperative Renal Impairment (n = 70)	Without Postoperative Renal Impairment (n = 350)	P	Odds Ratio	95% CI	P
Age	76.8 ± 7.9	74.5 ± 8.2	0.022	1.01	0.97–1.05	0.74
Male gender	57 (81.4%)	280 (80.0%)	0.78	—		
Hypertension	60 (85.7%)	257 (73.6%)	0.032	1.71	0.78–3.73	0.18
Hypercholesterolemia	15 (21.4%)	86 (24.6%)	0.57	—		
DM	8 (11.4%)	29 (8.3%)	0.40	—		
CAD	16 (22.9%)	78 (22.3%)	0.92	—		
CVD	14 (20.0%)	53 (15.1%)	0.31	—		
COPD	20 (29.4%)	102 (29.7%)	0.97	—		
History of smoking	56 (80.0%)	285 (81.7%)	0.74	—		
Stent graft with suprarenal fixation	30 (42.9%)	114 (32.6%)	0.098	0.98	0.54–1.81	0.96
Shagginess score	8.767 ± 1.073	8.150 ± 0.484	<0.001	2.78	1.83–4.22	<0.001
Preoperative serum creatinine, mg/dl	1.02 ± 0.23	0.87 ± 0.20	<0.001	20.52	5.17–81.43	<0.001
Amount of contrast medium, ml	120 ± 54	104 ± 39	0.026	1.01	1.01–1.02	<0.001

CAD = coronary artery disease, CI = confidence interval, COPD = chronic obstructive pulmonary disease, CVD = cerebrovascular disease, DM = diabetes mellitus.

Previously suggested methods of assessing aortic shagginess have used either TEE or contrast-enhanced CT, and have mainly focused on thickness and degree of ulceration, protrusion, and mobility of the atheroma.^{5,6,15–19} Katsanos et al¹⁸ defined complex atheromatous plaques as present if the lesions evaluated by TEE were >4 mm thick, ulcerated, or had mobile components. In a meta-analysis, they reported that the presence of complex plaques in the descending aorta can be a risk factor for stroke. Ko et al¹⁹ defined high-risk aortic atherosclerotic disease as the presence of aortic plaque in the ascending aorta and aortic arch that had a thickness of ≥4 mm, was ulcerated, or was hypoattenuated on contrast-enhanced CT. They

demonstrated that high-risk disease was prevalent in patients with embolic stroke. Several studies have investigated the impact of aortic shagginess on the occurrence of embolic complications associated with EVAR. Patel et al⁵ graded the degree of aortic luminal irregularity on a scale of 0 to 3, while Toya et al⁶ defined a shaggy aorta as the presence of a fragile atheroma >4 mm thick; both of these definitions were based on CT images reviewed by experts. Both studies showed that aortic shagginess was a significant predictor of postoperative ischemic events. Although these classifications of aortic plaques have proven significance, they mainly depend on the experts' visual assessments of images acquired by TEE or CT. This entails the

TABLE 4. Preoperative Conditions and All-Cause Mortality

Variable	Univariate Analysis			Multivariate Analysis		
	Hazard Ratio	95% CI	P	Hazard Ratio	95% CI	P
Age	1.09	1.06–1.12	<0.001	1.09	1.05–1.12	<0.001
Male gender	1.05	0.63–1.77	0.84	—		
Hypertension	1.02	0.63–1.63	0.95	—		
Hypercholesterolemia	0.95	0.59–1.52	0.83	—		
DM	0.97	0.45–2.10	0.94	—		
CAD	0.67	0.39–1.17	0.16	—		
CVD	1.36	0.81–2.28	0.24	—		
COPD	1.50	0.97–2.31	0.067	1.12	0.72–1.75	0.60
History of smoking	1.03	0.62–1.73	0.90	—		
History of malignancy	2.35	1.54–3.59	<0.001	2.48	1.59–3.86	<0.001
Statin use	0.60	0.38–0.94	0.025	0.77	0.49–1.23	0.27
Antiplatelet use	0.99	0.65–1.50	0.96	—		
Shagginess score	1.56	1.26–1.92	<0.001	1.37	1.09–1.72	0.007
Preoperative serum creatinine, mg/dl	4.38	1.73–11.10	0.002	1.52	0.54–4.27	0.43

CAD = coronary artery disease, CI = confidence interval, COPD = chronic obstructive pulmonary disease, CVD = cerebrovascular disease, DM = diabetes mellitus.

TABLE 5. Preoperative Conditions and Cardiovascular Mortality

Variable	Univariate Analysis			Multivariate Analysis		
	Hazard Ratio	95% CI	P	Hazard Ratio	95% CI	P
Age	1.10	1.04–1.16	0.001	1.09	1.03–1.15	0.004
Male gender	1.09	0.41–2.89	0.87			
Hypertension	1.90	0.65–5.53	0.24	—		
Hypercholesterolemia	1.18	0.51–2.73	0.70	—		
DM	0.48	0.07–3.53	0.47	—		
CAD	0.63	0.22–1.82	0.39	—		
CVD	1.33	0.50–3.54	0.56	—		
COPD	1.38	0.61–3.13	0.44	—		
History of smoking	0.87	0.35–2.16	0.76	—		
Statin use	0.51	0.21–1.21	0.13	—		
Antiplatelet use	0.90	0.41–1.98	0.79	—		
Shagginess score	1.76	1.26–2.47	0.001	1.51	1.04–2.18	0.030
Preoperative serum creatinine, mg/dl	12.71	2.61–61.95	0.002	6.35	1.17–34.54	0.032

CAD=coronary artery disease, CI=confidence interval, COPD=chronic obstructive pulmonary disease, CVD=cerebrovascular disease, DM=diabetes mellitus.

potential for variation that result from the inherently subjective nature of the evaluations. In addition, any detailed visual evaluation of the acquired images requires considerable time.

We considered that the ulcerated or protruding fragile aortic atheroma results in the elongation of the luminal contour of the aorta, as assessed in a cross-sectional CT image orthogonal to the central luminal line. Further, we considered that the difference between its length and a corresponding perfect circle might reflect the morphological irregularity of the aortic surface. The shagginess score can be calculated semi-automatically within a few minutes by manually determining the proximal and distal ends of the target artery. Our automated method using a standard contrast-enhanced CT could objectively quantify the degree of aortic shagginess, considering the close correlation with the visual assessment.

Postoperative renal impairment following EVAR is multifactorial, and previous studies have indicated potential contributing factors that include preexisting renal insufficiency, fixation level of the stent graft, nephrotoxicity of contrast medium, and procedure-related microembolism.^{21–26} In concordance with previous reports,²¹ the results of the present study demonstrated that preexistent renal dysfunction was a significant risk factor. The impact of fixation type on renal function remains controversial^{22–26}; we found that the use of a device with suprarenal fixation was not independently associated with the deteriorated renal function after EVAR in the short term. Nephrotoxicity of contrast medium is considered to play a certain role, but there is little information on the precise relationship between the volume of contrast medium that is used during EVAR and postoperative kidney function. Our study showed that this volume was an independent risk factor, as previously indicated in coronary interventions.²⁷ Microembolism caused by dislodged thrombus from the proximal aortic surface during the procedure has been suggested as an important etiologic factor.^{22,24,25} The shagginess score was significantly associated with the postoperative renal impairment and other ischemic complications in the present study, which might indicate that it reflects the instability of aortic plaque and

predisposition to embolic events. The score can potentially be a useful diagnostic index to evaluate the risk of postoperative atheroembolic complications in patients undergoing EVAR.

Previous studies have suggested that the severity of atheromatous degeneration of the thoracic aorta could be predictive of future vascular events.^{15–17} Sen et al¹⁶ demonstrated that patients with atheroma progression in the aortic arch had a high risk of recurrent vascular events. Izumi et al¹⁷ reported that those with severe atheromatous plaques in the thoracic aorta had a lower survival rate and higher embolic event rate, as compared with those without these plaques. Complex plaques in the aorta can be considered a marker of systemic atherosclerotic disease, reflecting high cardiovascular risk.¹⁸ The present study demonstrated that the shagginess score was an independent risk factor for all-cause and cardiovascular mortality after EVAR, over a mean follow-up period of 3.3 years. These findings suggest that the score might be representative of systemic atherosclerotic burden and be indicative of long-term prognosis. It would be interesting to elucidate its clinical significance in a broader population with a various degree of risks for atherosclerosis in the longer term.

The present study has some limitations. Because of its retrospective design, all patients were not systematically followed up (although most of them were on a uniform postoperative follow-up protocol). Further, unmeasured confounding factors might have affected the results of the study. In addition, patient selection bias might exist, since this was a single-center study. Additional studies are necessary to delineate the clinical usefulness of the shagginess score.

CONCLUSIONS

The shagginess score appears to quantitatively characterize aortic luminal irregularity. It could serve as a useful diagnostic parameter for predicting treatment-associated atheroembolic complications and long-term prognosis in patients undergoing EVAR. Larger and longer-term studies are necessary in order to further clarify the clinical value of the score.

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