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Original Article

Open Repair of Ruptured Abdominal Aortic Aneurysm: The Suitability of Endovascular Aneurysm Repair Does Not Influence Operative Mortality

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Purpose: We analyze the outcomes of open repair (OR) in patients with ruptured abdominal aortic aneurysm (RAAA) according to the anatomic suitability for endovascular aneurysm repair (EVAR).

Materials and Methods: We reviewed retrospectively all consecutive RAAA patients who underwent OR from January 2005 to March 2014. All suspected patients underwent preoperative computed tomography (CT). Outcomes were major morbidities and mortality. Multivariate analysis was performed by using logistic regression adjusted by controlled variables; gender, Hardman index, maximal aneurysmal diameter, rupture type, perioperative transfusion requirement, and perioperative urinary output.

Results: Among 54 consecutive patients with RAAA who underwent OR, 45 patients were included after exclusion of 9 patients (7, suprarenal; 1, infected; 1, inflammatory). Preoperative CT showed 27% (12/45) EVAR-suitable patients. Hostile neck anatomy was found in 88% (29/33) among unsuitable anatomy (UA) (n=33). The maximal aneurysmal diameter was statistically larger (83.1±21.0 mm vs. 68.8±12.3 mm, P=0.032) in the UA group. The 30-day mortality was 28.9% (13/45; 33% vs. 17% in UA group vs. suitable anatomy [SA] group, P=0.460; adjusted P=0.445). UA group had more patients with cardiac morbidity (55% vs. 25%, P=0.079; adjusted P=0.032; odds ratio, 12.914; 95% confidence interval, 1.238-134.675). There was no statistical difference in survival rate between SA and UA groups (74.1%, 74.1%, and 74.1% vs. 60.6%, 55.6%, and 32.4% at 1-, 3- and 5-year, respectively; P=0.145).

Conclusion: In this study, relatively unfavorable outcomes were found in the EVAR-unsuitable group after OR in RAAA patients. However, unsuitable anatomy did not influence patient survival after OR by multivariate analysis.

Key Words: Abdominal aortic aneurysm, Ruptured aneurysm, Endovascular procedures

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INTRODUCTION

Endovascular aneurysm repair (EVAR) for the treatment of ruptured abdominal aortic aneurysm (RAAA) was first performed in 1994 [1]. Since then, EVAR of ruptured aneurysms (REVAR) has been widely used in the recent era. Early results of REVAR have been reported to be more favorable than open repair (OR) in patients with RAAA by some investigators [2-4]. They reported that the introduction of EVAR has reduced postoperative mortality and morbidity. Pooled perioperative mortality rate in 46 studies including 1,397 patients who underwent REVAR was 24.3% (95% confidence interval [CI], 20.7-28.3) [4], whereas that of OR in RAAA patients was 48% (95% CI, 46-50) [5]. However, these results might be flawed by selection bias and heterogeneity between the studies. Furthermore it is still questionable whether different factors are influencing the outcomes of RAAA treatment. It is generally accepted that operation of abdominal aortic aneurysms (AAAs) with complex anatomy is more difficult and results in poorer outcomes, especially in RAAAs. Some authors report that a suitable anatomy (SA) for EVAR can lead to favorable results in patients with RAAA [6,7]. However, others report that early and midterm mortality rates of OR in patients with RAAA were not different between EVAR-suitable and EVAR-unsuitable groups [8]. They suggest that the mortality reduction of REVAR is unlikely due to selection bias based on anatomical configuration of AAAs.

Herein we analyzed whether unsuitable anatomy (UA) according to the criteria for EVAR suitability may influence the outcomes of OR in the patients with RAAA.

MATERIALS AND METHODS

We reviewed retrospectively all consecutive RAAA patients who underwent OR from January 2005 to March 2014 from prospectively collected data. All suspected patients underwent preoperative computed tomography (CT) in this period. The patients diagnosed with degenerative AAA were included after exclusion of suprarenal AAA. Rupture of an aneurysm was defined by the presence of blood outside the true arterial wall either on preoperative CT or on intraoperative findings.

EVAR suitability criteria consisted of aortic neck length ≥15 mm, aortic neck diameter ≤32 mm, aortic neck angulation ≤60°, no conical-shaped aortic neck, thrombus <50% of circumference of the aortic neck and bilateral iliac artery diameter ≥6 mm without severe tortuosity which was based on the generally accepted criteria. If conventional EVAR was not able to be performed due to unilateral access vessel problems, an aorto-uni-iliac stent graft with a contralateral iliac occluder and a femoro-femoral crossover bypass graft (AUIFF) was proposed as an alternative option. However, cases requiring chimney technique, sandwich technique, branched stent graft and embolization of both internal iliac arteries (BIIA) were classified as UA.

Outcomes were major morbidity (cardiac, pulmonary and renal) and 30-day mortality according to anatomic suitability for EVAR. Cardiac morbidity included heart failure, arrhythmia such as atrial fibrillation or ventricular tachycardia, cardiac arrest, stress-induced cardiomyopathy and coronary artery disease. Pulmonary morbidity included pneumonia, pneumothorax, atelectasis and pleural effusion. Renal morbidity was defined as renal insufficiency with a serum-creatinine >190 μmoL/L in the postoperative period. Survival data such as mortality, cause of death and loss to follow-up were collected by reviewing the medical records and asking the close relatives of the patient by phone call.

Descriptive statistics were calculated for all variables. Kolmogorov-Smirnov test was performed to confirm normal distribution in the continuous data. The independent t-test was used for continuous data which were reported as mean±standard deviation. Chi-squared and Fishers exact tests were used for categorical data which were reported as percentages. Survival analysis was performed using a Kaplan-Meier survival curve with log rank test. Multivariate analysis was performed by using logistic regression adjusted by controlled variables consisting of gender (male), Hardman index (age >76, loss of consciousness, hemoglobin <9.0 g/dL, serum-creatinine >190 μmoL/L and ischemic electrocardiographic signs), maximal aneurysmal diameter, rupture type (contained rupture, fistula to vena cava, fistula to bowel, and free rupture), perioperative transfusion requirement (units of packed red blood cell, from admission to postoperative 24-hour), and perioperative urinary output (mL/hour, from admission to postoperative 24-hour). There was no multicollinearity among the variables. Odds ratio (OR), hazard ratio and 95% CI were calculated. Statistical significance was defined as P-value ≤0.05. All analyses were performed using IBM SPSS Statistics for Windows ver. 20.0 (IBM Co., Armonk, NY, USA).

RESULTS

Among 54 consecutive patients with RAAA who underwent OR, 45 patients were included after exclusion of 9 patients (7, suprarenal; 1, infected; 1, inflammatory). Preoperative CT showed 26.7% (12/45) EVAR-suitable patients (11, conventional EVAR; 1, AUIFF). AUIFF was due to narrow access vessel.

The reasons for UA group (n=33) are shown in Table 1. Hostile neck anatomy was found in 87.9% (n=29) including short length (n=16), severe angulation (n=16), conical shape (n=1) and thrombus (n=3). Access vessel problem was found in 27.3% (n=9) including tortuosity (n=3) and narrow diameter (n=6). Anatomy requiring the embolization of BIIA was present in 39.4% (n=13).

Baseline characteristics of the SA group (n=12) and

UA group (n=33) are shown in Table 2. The maximal aneurysmal diameter was statistically larger (83.1±21.0 mm vs. 68.8±12.3 mm, P=0.032) in UA group. There were no statistical differences in the other variables; gender, Hardman index, diabetes mellitus, rupture type (contained rupture, fistula to vena cava, fistula to bowel, and free rupture), perioperative transfusion requirement (units of packed red blood cell, from admission to postoperative 24-hour), and perioperative urinary output (mL/hour, from admission to postoperative 24-hour).

Major morbidities and 30-day mortality are shown in Table 3. The 30-day mortality of OR in patients with RAAA was 28.9% (13/45; 8, hypovolemic shock from ongoing bleeding due to coagulopathy; 3, heart failure; 1, myocardial infarction; 1, cerebral infarction); 33% vs. 17%

Table 1. Reasons for unsuitable anatomy group (n=32) in patients with ruptured abdominal aortic aneurysm who underwent open repair, according to the criteria for endovascular aneurysm repair suitability

Reasons for unsuitability	n (%)
Aortic neck	29 (87.9)
Length <15 mm	16 (48.5)
Angulation >60°	16 (48.5)
Conical shape	1 (3.0)
Thrombus ≥50 % of circumference	3 (9.0)
Access vessels	9 (27.3)
Tortuosity	3 (9.0)
Diameter <6 mm	6 (18.2)
Requiring embolization of both internal iliac arteries	13 (39.4)
Total	33 (100)

Table 3. Major morbidities and 30-day mortality of the patients with ruptured abdominal aortic aneurysm who underwent open repair, according to the anatomic suitability criteria for endovascular aneurysm repair

	Suitable anatomy (n=12)	Unsuitable anatomy (n=33)	P-value
Morbidity			
Cardiac[a]	3 (25.0)	18 (54.5)	0.079
Pulmonary[b]	5 (41.7)	10 (30.3)	0.496
Renal[c]	5 (41.7)	11 (33.3)	0.728
30-day mortality	2 (16.7)	11 (33.3)	0.460

Values are presented as number (%).
[a]Including heart failure (n=8), arrhythmia (n=8) such as atrial fibrillation or ventricular tachycardia, cardiac arrest (n=5), stress-induced cardiomyopathy (n=2) and coronary artery disease (n=2). [b]Including pneumonia (n=13), pneumothorax (n=2), atelectasis (n=1) and pleural effusion (n=1). [c]Serum-creatinine >190 μmol/L.

Table 2. Baseline characteristics of the patients with ruptured abdominal aortic aneurysm who underwent open repair, according to the anatomic suitability criteria for endovascular aneurysm repair

	Suitable anatomy group (n=12)	Unsuitable anatomy group (n=33)	P-value
Gender (male)	12 (100)	24 (72.7)	0.086
Hardman index[a]			
Age >76 years	5 (41.7)	10 (30.3)	0.496
Loss of consciousness	3 (25.0)	6 (18.2)	0.682
Hemoglobin <9.0 g/dL	0	9 (27.3)	0.086
Serum-creatinine >190 μmol/L	2 (16.7)	6 (18.2)	1.000
Ischemic electrocardiographic signs	4 (33.3)	4 (12.1)	0.181
Total sum	1.17±1.03	1.06±1.00	0.756
Diabetes mellitus	1 (8.3)	6 (18.2)	0.655
Maximal aneurysmal diameter (mm)	68.8±12.3	83.1±21.0	0.032
Ruptured type			0.896
Contained rupture	10 (83.3)	26 (78.8)	
Fistula to vena cava	0	2 (6.1)	
Fistula to bowel	1 (8.3)	1 (3.0)	
Free rupture	1 (8.3)	4 (12.1)	
Transfusion requirement (units of P-RBC)[b]	12.0±13.1	11.1±9.0	0.804
Urinary output (mL/hour)[b]	193.4±260.5	105.3±78.9	0.085

Values are presented as number (%) or mean±standard deviation.
P-RBC, packed red blood cell.
[a]Sum from the variables when supposing that each variable is worth one point. [b]Perioperative (from admission to postoperative 24-hour).

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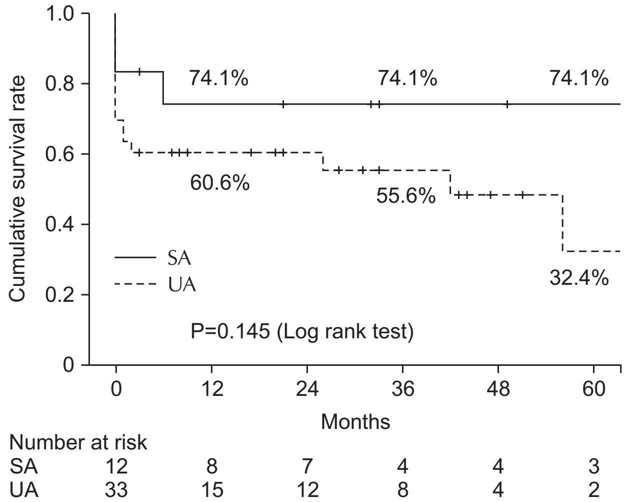

Fig. 1. Kaplan-Meier survival analysis of the patients with ruptured abdominal aortic aneurysm who underwent open repair, according to the anatomic suitability criteria for endovascular aneurysm repair. SA, suitable anatomy; UA, unsuitable anatomy.

in UA group vs. SA group, respectively (P=0.460). UA group tended to have more patients with cardiac morbidity (55% vs. 25%, P=0.079). There was no statistical difference in all other variables between the two groups.

Long-term cause of death was sepsis due to pneumonia (1 at month), aspiration pneumonia (1 at 2 months), graft infection (1 at 26 months), lung cancer (1 at 56 months), and unknown cause (2 at 6 and 42 months).

Kaplan-Meier survival analysis is shown in Fig. 1. The mean follow-up duration was 24.2±27.4 months. One patient was lost to follow-up. There was no statistical difference in survival rate between SA and UA groups (74.1%, 74.1%, and 74.1% vs. 60.6%, 55.6%, and 32.4% at 1-year, 3-year and 5-year, respectively; p=0.145).

Multivariate analysis for major morbidities and 30-day mortality according to unsuitable anatomy was analyzed by using logistic regression that was adjusted for variables as mentioned above. Unsuitable anatomy was associated with cardiac morbidity (OR, 12.914; 95% CI, 1.238-134.675; P=0.032), and not associated with other outcomes, such as pulmonary morbidity (P=0.218), renal morbidity (P=0.429), or 30-day mortality (P=0.445). Instead of anatomic suitability, when analyzed with aortic neck length ≥15 mm, there was no statistical significance. The same was true for aortic neck angulation ≤60°.

DISCUSSION

The present study suggests that unsuitable anatomy has no adverse effect on survival outcomes of OR in RAAA patients by multivariate analysis.

Richards et al. [9] reported that unsuitable anatomy was associated with graft-related mortality in RAAA patients who underwent REVAR. However there is a controversy about whether the unsuitable anatomy influences the outcomes of OR in the patients with RAAA. Perrott et al. [10] reported that there was a trend towards reduction in 30-day mortality for RAAA patients suitable for EVAR (6.9% in suitable patients versus 30.4% in unsuitable patients; P=0.066). A limitation of their study was that only 41% of the patients treated with OR received preoperative CT. On the other hand, Ten Bosch et al. [8] reported that anatomic suitability was not associated with the mortality of OR in RAAA patients. A limitation of their study was that only an univariate analysis and unadjusted for gender difference between the two groups was performed, although all patients did undergo preoperative CT. Female gender is known to be associated with an increased risk for death [11,12]. Our study overcomes these limitations by multivariate analysis and routine preoperative CT.

The 30-day mortality of OR in RAAA patients is reported to be nearly 50% [5,13,14], but that of our study was 28.9%. In the United States data, the proportion of EVAR is increasing each year, from 6% in 2001 to 17% in 2005 [15]. Many studies have reported that the introduction of REVAR has reduced the 30-day mortality in the treatment of RAAA [2-4]. However, in a prospective randomized study, Hinchliffe et al. [16] reported that there was no difference in early mortality rate, complication and length of hospital stay of OR versus REVAR in RAAA patients. In a recent observational study, Sarac et al. [17] reported a 30-day mortality of 31% for OR versus 32% for REVAR in RAAA patients. Additionally, REVAR did not improve long-term survival [18].

Some investigators argue that more stable or anatomically less challenging patients may be treated by REVAR compared to OR and favorable early results of REVAR may be flawed by selection bias. In observational studies, REVAR tends to be performed in more hemodynamically stable patients compared to OR [19,20]. However, this selection bias is not the only reason for favorable early results of REVAR. Ten Bosch et al. [6] reported that the 30-day mortality of REVAR was better than that of OR in EVAR-suitable RAAA patients (20.0% versus 45.5%; P=0.043). Mayer et al. [21] argued that the 30-day mortality was 24% in the EVAR-only period from 2009 to 2011 including the patients with unsuitable anatomy and hemodynamic instability. In their study, modern techniques such as chimney technique, embolization technique and open iliac debranching were used in 24%.

In the present study, the suitability rate was 27% and hostile neck anatomy was found in 88% of unsuitable anatomy patients according to the generally accepted EVAR suitability criteria. In the literature, the suitability rate is reported to be 20%-67% [2,3,10,22], and hostile neck anatomy is reported to be 76% [22]. Keefer et al. [23] reported that patients with large aneurysmal diameter had more unsuitable anatomy. Because RAAAs have shorter or wider aortic neck, they have more hostile neck anatomy and less suitability rate for EVAR [24-26]. In these situations, because it is hard to do aortic cross-cramping and it takes more time to do so, morbidity and mortality may increase. Therefore, in the present study, these reasons may cause unfavorable results in the unsuitable anatomy group; including cardiac morbidity (55% vs. 25%, P=0.079; adjusted P=0.032) and 30-day mortality (33% vs. 17%, P=0.460; adjusted P=0.445). However these findings may have limitations because of small sample size of the present study.

Mehta et al. [27] suggested that the EVAR suitability criteria from the indications for use of stent graft devices approved by the United States Food and Drug Administration should be expanded for RAAA. According to the expanding criteria such as aortic neck length ≥10 or 5 mm, aortic neck angulation ≤75° or 90°, iliac artery diameter ≥5 mm and AUIFF, EVAR suitability rate will be increased in the treatment of RAAAs. Sweet et al. [28] reported that female gender patients had shorter aortic neck length, more angulated aortic neck and smaller iliac artery diameter in non-ruptured AAA (12% of female versus 32% of male for suitability rate). Because Asian patients have shorter aortic neck length [29] and smaller iliac artery diameter [30] than other races, care should be taken when analyzing and comparing the suitability rate.

CONCLUSION

In this study, relatively unfavorable outcomes are found in the EVAR-unsuitable group after OR in RAAA patients. However, unsuitable anatomy did not influence patient survival after OR by multivariate analysis. In the EVAR era, RAAA patients who underwent OR may have more unsuitable anatomy and less hemodynamic stability. These changes should be considered when analyzing and comparing the results of OR in RAAA patients.

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