Radiology

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Management of Renal Arteries in Conjunction with Thoracic Endovascular Aortic Repair for Complicated Stanford Type B Aortic Dissection: The Japanese Multicenter Study (J-Predictive Study)

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Conflicts of interest are listed at the end of this article.

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Background: Management of abdominal branches associated with Stanford type B aortic dissection is controversial without definite criteria for therapy after thoracic endovascular aortic repair (TEVAR). This is in part due to lack of data on natural history related to branch vessels and their relationship with the dissection flap, true lumen, and false lumen.

Purpose: To investigate the natural history of abdominal branches after TEVAR for type B aortic dissection and the relationship between renal artery anatomy and renal volume as a surrogate measure of perfusion.

Materials and Methods: This study included patients who underwent TEVAR for complicated type B dissection from January 2012 to March 2017 at 20 centers. Abdominal aortic branches were classified with following features: patency, branch vessel origin, and presence of extension of the aortic dissection into a branch (pattern 1, supplied by the true lumen without branch dissection; pattern 2, supplied by the true lumen with branch dissection, etc). The branch artery patterns before TEVAR were compared with those of the last follow-up CT (mean interval, 19.7 months) for spontaneous healing. Patients with one kidney supplied by pattern 1 and the other kidney by a different pattern were identified, and kidney volumes over the course were compared by using a simple linear regression model.

Results: Two hundred nine patients (mean age ± standard deviation, 66 years ± 13; 165 men and 44 women; median follow-up, 18 months) were included. Four hundred fifty-nine abdominal branches at the last follow-up were evaluable. Spontaneous healing of the dissected branch occurred in 63% (64 of 102) of pattern 2 branches. Regarding the other patterns, 6.5% (six of 93) of branches achieved spontaneous healing. In 79 patients, renal volumes decreased in kidneys with pattern 2 branches with more than 50% stenosis and branches supplied by the aortic false lumen (patterns 3 and 4) compared with contralateral kidneys supplied by pattern 1 (pattern 2 vs pattern 1: −16% ± 16 vs 0.10% ± 11, $P = .002$; patterns 3 and 4 vs pattern 1: −13% ± 14 vs 8.5% ± 14, $P = .004$).

Conclusion: Spontaneous healing occurs more frequently in dissected branches arising from the true lumen than in other branch patterns. Renal artery branches supplied by the aortic false lumen or a persistently dissected artery with greater than 50% stenosis are associated with significantly greater kidney volume loss.

Online supplemental material is available for this article.

An earlier incorrect version of this article appeared online. This article was corrected on March 20, 2020.

Abbreviation

TEVAR = thoracic endovascular aortic repair

Summary

Renal arteries supplied by the aortic false lumen or a persistently dissected artery with more than 50% stenosis at CT after treatment are associated with renal mass volume loss, suggesting reduced branch perfusion.

Key Results

- In the morphologic analysis of the abdominal aortic branches, the last follow-up CT showed spontaneous healing of a dissected branch in 63% of branches arising from the true lumen. However, it was rarely achieved in other branch patterns (supplied by the aortic false lumen or both lumens) (6.5% at postoperative CT and 6.5% at last follow-up CT).
- CT kidney volumes decreased in dissected branches arising from the true lumen with more than 50% diameter stenosis (pattern 2) and branches supplied by the aortic false lumen (irrespective of whether the branch was dissected, patterns 3 and 4) at postoperative CT, compared with contralateral kidneys supplied by the true lumen without dissection of the branch (pattern 1) (pattern 2 vs pattern 1: −16% ± 16 vs 0.10% ± 11, *P* = .002; patterns 3 and 4 vs pattern 1: −13% ± 14 vs 8.5% ± 14, *P* = .004).

Since the initial performance of thoracic endovascular aortic repair (TEVAR) for Stanford type B aortic dissection (1), TEVAR has been used for complicated Stanford type B aortic dissection (2). The strategy for management of abdominal branches in complicated type B dissection has been described and includes branch vessel stent placement in cases with direct extension of the aortic dissection into a branch (static obstruction). However, to our knowledge, the threshold of branch stenosis associated with clinically critically decreased perfusion has never been described in detail. Additionally, the chronic effect on organ perfusion by branches supplied by the aortic false lumen after TEVAR has not been well documented.

For type B dissection, TEVAR is performed to close the entry tear, which subsequently increases the flow in the aortic true lumen and decreases the flow in the aortic false lumen. Therefore, TEVAR may reduce the branch vessel perfusion in arteries supplied by the aortic false lumen. Despite these potential concerns, there is a lack of evidence documenting the fate of abdominal aortic branch vessel flow after TEVAR.

Consequently, we conducted a multicenter study to investigate the rate of spontaneous healing and impact of branch vessel morphology on renal perfusion, using changes in kidney volumes over time as a surrogate measure for renal perfusion. Kidney volume is easily measurable at noncontrast CT and comparing bilateral kidneys with different renal artery morphology in the same patients helps to minimize any other confounding factors and to isolate the impact of branch morphology to kidney volume change.

The results of this study may help to inform management of renal artery involvement or visceral arteries in association with TEVAR for type B dissection.

Materials and Methods

Study Design, Inclusion Criteria, and Exclusion Criteria

The J-Predictive study was a retrospective multicenter study involving 20 institutions. Institutional review board approval for retrospective chart review was obtained for each center. Inclusion criteria were as follows: consecutive patients with Stanford type B aortic dissection treated with TEVAR at participating institutions from January 2012 to March 2017, Stanford type B aortic dissection with complications (rupture, malperfusion, uncontrollable pain, uncontrollable hypertension, and rapid enlargement of aorta), and duration between type B aortic dissection onset and TEVAR within 1 year. Exclusion criteria included type B aortic dissection without complications, duration between type B aortic dissection onset and TEVAR of more than 1 year, and patients who were treated with homemade device. Additionally, branches that underwent stent placement during the study period were excluded from branch analysis, but the patient was included if they had other branch vessels to evaluate. For the analysis of renal volume change, patients who had accessory renal arteries or only one renal artery due to a previous nephrectomy were excluded. Patients with one kidney supplied by pattern 1 and the other supplied by another pattern (discussed next) were extracted to compare the kidney volume change based on both observed branch patterns.

Definition and Branch Analysis

The J-Predictive study included an independent core laboratory consisting of three radiologists (R.T., M.Y., and S.I., with more than 10 years of experience with aortic interventions and interpretation of radiograms and CT images). The dissection pattern for an individual branch (celiac artery, superior mesenteric artery, both renal arteries, and accessory renal arteries [if recognized]) was classified according to the following criteria: vessel patent or occluded; branch blood flow supplied by aortic true lumen, false lumen, or both lumens; and branch artery with or without dissection. Therefore, there are seven anatomic branch vessel supply patterns (Fig 1) (pattern 1, supplied by true lumen without branch dissection; pattern 2, supplied by true lumen with branch dissection; pattern 3, supplied by false lumen without branch dissection; pattern 4, supplied by false lumen with branch dissection; pattern 5, supplied by both lumens without branch dissection; pattern 6, supplied by both lumens with branch dissection; and pattern 7, occlusion of the branch).

Illustrative examples of each pattern are detailed in Figure 2. Preoperative, postoperative, and the last follow-up CT images were evaluated by the core laboratory, and abdominal branches were classified as one of the seven patterns. The lumen directly communicating with the nondiseased ascending aorta was defined as the aortic true lumen. We defined the continuous linear shadow in the branch as branch dissection. The degree of stenosis was assessed in branches with patterns 2 and 4 by measuring the diameter from arterial wall to wall. During evaluation of the change in branch morphology, the phenomenon of the branch pattern changing to pattern 1 from another pattern without stent placement was defined as spontaneous branch healing (Fig E1 [online]).

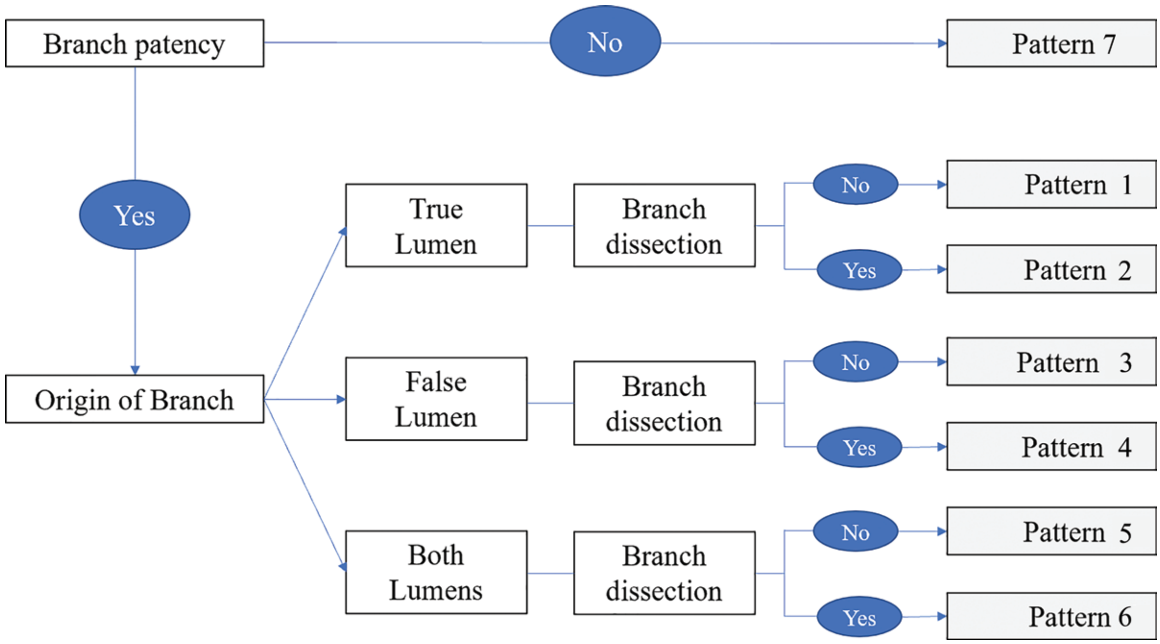

Figure 1: Flowchart shows classification of abdominal branches (celiac artery, superior mesenteric artery, both renal arteries, and accessory renal arteries [if recognized]). First, evaluation of branch patency was performed. If branch was patent, then subsequent assessment of origin of branch and presence of extension into branch was performed.

In this J-Predictive study, kidney volumes were assessed by using CT during follow-up to investigate the chronic effect of renal artery blood flow. The assessment was performed by two radiologists (T.N., with 5 years of experience with aortic intervention and interpreting CT images and S.I., with more than 10 years of experience with aortic interpretation and 10 years of experience interpreting CT images) and one radiology technologist (T.I., with more than 10 years of experience interpreting CT images) by using Synapse Vincent software (version 5.3; Fujifilm, Tokyo, Japan). They independently measured kidney volumes from three projections of CT data from the preoperative and final images (Fig E2 [online]). If there was a discrepancy between observers, then a discussion to reach a consensus was performed. Kidney volume was defined as the combined volume of the renal medulla and renal cortex, without any renal cyst or the renal pelvis. The relative change in kidney volume was described as the difference between the follow-up volume and the preoperative kidney volume relative to the preoperative kidney volume. The ratio of kidney volume change was used rather than kidney volume change because a ratio can evaluate the impact of preoperative kidney condition. The correlation between the change in the estimated glomerular filtration rate and bilateral kidney volume changes was evaluated.

Average kidney volume change ratios for each branch pattern were investigated. In addition, patients with one kidney supplied by pattern 1 and the other supplied by another pattern were extracted. Comparisons between the bilateral kidney volume change ratios were performed. These analyses used the branch morphologic pattern based on the postoperative CT image. The comparison of the bilateral kidneys in the same patients can help to minimize any other confounding factors and to isolate the impact of branch morphology to kidney volume change.

Data Collection

Each institution completed an approved clinical report. The data collected were patient demographics (age, sex, dates of type B aortic dissection onset and TEVAR, and indication for TEVAR), procedural data (device used, additional procedure such as debranching, chimney- and procedure-related complications), follow-up data (survival, dates of most recent follow-up and secondary procedures), and laboratory data (blood urea nitrogen level, creatinine level, estimated glomerular filtration rate). These data and CT data were anonymized at each institution and sent to the principal institution.

Statistical Analysis

Continuous variables were summarized with means and standard deviations. The change in the total volume of bilateral kidney from preoperative CT to the last follow-up CT was measured. The correlation between the changes in bilateral kidney volume and the change in estimated glomerular filtration rate was estimated by using Pearson correlation.

Differences in kidney volume between healthy and diseased kidneys were assessed by using a paired *t* test and a simple linear regression model. The volume change ratios of healthy and diseased kidneys were fit by using a simple linear regression model with days of follow-up as the predictor variable. In addition, the differences in the volume change ratios between healthy and diseased kidneys were also fit by using a simple linear regression model with days of follow-up as the predictor variable. The coefficient was assessed, which clarifies the impact of renal artery morphology to kidney volume change over the course of the

Figure 2: Images show examples of each pattern of branch supply after aortic dissection. *A,* Pattern 1: right renal artery originates from true lumen without extension of dissection flap into renal artery. *B,* Pattern 2 with less than 50% stenosis: superior mesenteric artery originates from true lumen. Dissection flap is seen in branch artery lumen with less than 50% stenosis. *C,* Pattern 2 with more than 50% stenosis: true lumen is collapsed and false lumen is not yet opacified with contrast medium. Lumen of celiac artery filled with contrast medium shows severe stenosis due to extension of dissection flap into artery. *D,* Pattern 3: right renal artery originating from false lumen is patent. Left renal artery originating from true lumen is patent. *E,* Pattern 4: left renal artery is supplied by aortic false lumen and presence of extension of aortic dissection into branch was recognized as linear line. *F,* Pattern 5: celiac artery is supplied by both true and false lumens without branch dissection. *G,* Pattern 6: left renal artery is supplied by both true and false lumens with clear evidence of branch dissection. *H,* Pattern 7: left renal artery is occluded. Aortic true lumen is collapsed. Arrow indicates the branch. F = aortic false lumen, T = aortic true lumen.

study. $P < .05$ was considered to indicate statistical significance. Statistical analyses were performed with the open source R suite environment (version 3.4.1; R Foundation for Statistical Computing, Vienna, Austria).

Results

Patient Demographics and Branch Morphology Change

A total of 209 patients (165 men and 44 women) with an average age of 66.1 years ± 12.5 (standard deviation) were included. The indications for TEVAR are described in Table 1. Overall, 29 patients had multiple indications, 19 had two indications, and 10 had three indications for TEVAR. A total of 14 branch stents or covered branch stents were used along with TEVAR. Six superior mesenteric artery stents were deployed, seven renal stents were placed, and one covered stent was used in a celiac artery. The summary of stents used is detailed in Table E1 (online). These branches with stents were excluded from branch morphologic evaluation. Consequently, 736 branches were analyzed with CT preoperatively and postoperatively (Fig E3 [online]). The average interval from TEVAR to postoperative CT was 6.9 days ± 7.7.

Table 1: Summary of Enrolled Patients (*n* = 209)

Variable	Value
Age (y)*	66.1 ± 12.5
Sex	
Male	165
Female	44
Average duration from onset to TEVAR (d)*	39.2 ± 68.1
Indication for TEVAR	
Rupture	41 (19.7)
Celiac malperfusion	12 (5.8)
Superior mesenteric artery malperfusion	28 (13.5)
Renal artery malperfusion	35 (16.7)
Lower extremity malperfusion	45 (21.5)
Uncontrollable pain	13 (6.3)
Uncontrollable hypertension	6 (2.9)
Rapid enlargement of aorta	68 (32.7)

Note.—Unless otherwise specified, data are numbers, with percentages in parentheses. Some patients had multiple indications. TEVAR = thoracic endovascular aortic repair.
* Data are means ± standard deviation.

Table 2: Branches Categorized for Each Pattern in the Celiac Artery, SMA, and Bilateral Renal Arteries Assessed at CT Angiography

Variable	1	2	3	4	5	6	7	Total
Preoperative celiac artery	126	25	16	1	7	8	2	185
Postoperative celiac artery	130	24	14	1	7	7	2	185
Last follow-up celiac artery	82	9	13	1	6	3	1	115
Preoperative SMA	110	52	3	2	3	10	0	180
Postoperative SMA	120	44	4	1	4	7	0	180
Last follow-up SMA	83	16	4	0	3	5	0	111
Preoperative right renal artery	140	18	16	1	3	4	1	183
Postoperative right renal artery	143	13	17	0	4	5	1	183
Last follow-up right renal artery	87	4	15	0	2	4	2	114
Preoperative left renal artery	123	30	19	4	1	8	4	189
Postoperative left renal artery	128	28	16	3	1	10	2	188
Last follow-up left renal artery	81	15	14	1	1	6	1	119

Note.—The average interval from thoracic endovascular aortic repair (TEVAR) to postoperative CT was 6.9 days ± 7.7 (standard deviation). The average interval from TEVAR to the last follow-up CT was 19.7 months ± 14.8. SMA = superior mesenteric artery.

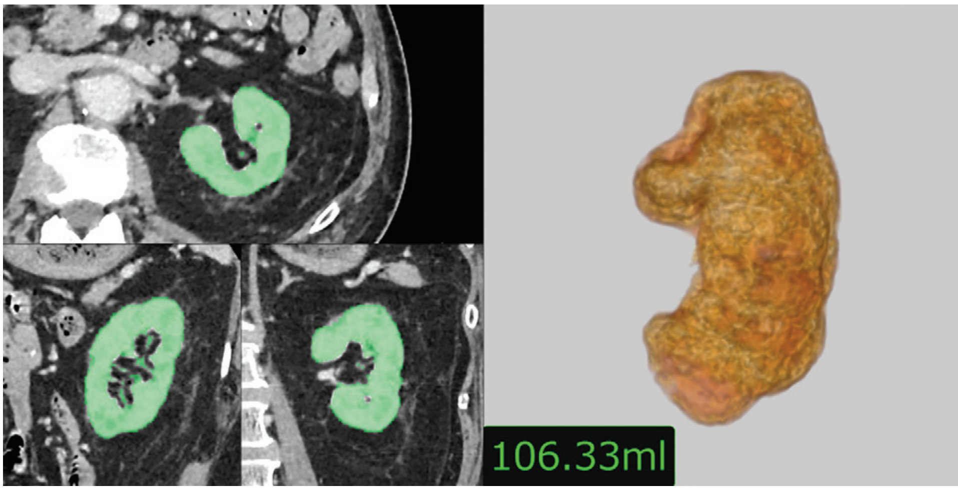

Figure 3: Images show axial, sagittal, and frontal rendering of CT data used to determine kidney volume (left). Volume of green highlighted area was measured as kidney volume. Volume rendering of kidney (right) shows estimated volume in left corner.

Table 3: Summary of the Kidney Volume Change Ratio

		Average Kidney Volume Change Ratio (%)		
Patient Group	No. of Patients	Kidney Concerned*	Contralateral Kidney†	*P* Value
Pattern 1 vs 2	30	−12 ± 16	−1.1 ± 11	<.001
Pattern 1 vs 2 (<50% stenosis)	11	−4.6 ± 14	−3.19 ± 12	.59
Pattern 1 vs 2 (≥50% stenosis)	19	−16 ± 14	−3.0 ± 12	<.001
Pattern 1 vs 3 and 4	30	−13 ± 14	8.5 ± 14	<.001
Pattern 1 vs 5 and 6	16	−6.2 ± 15	−2.9 ± 12	.31

Note.—Unless otherwise specified, data are means ± standard deviation. In patients with one kidney supplied by pattern 1 and the other supplied by another pattern, the kidney volume change of healthy and diseased kidney from preoperative to the last follow-up CT were assessed. The kidney volume supplied by pattern 2 with more than 50% stenosis or pattern 3 and 4 decreased compared with the contralateral kidney supplied by pattern 1.

* Supplied by another pattern.

† Supplied by pattern 1.

Branch artery involvement was categorized based on CT findings before TEVAR as pattern 1 (*n* = 499, 67.8%), pattern 2 (*n* = 126, 17.1%), pattern 3 (*n* = 53, 7.2%), pattern 4 (*n* = 8, 1.1%), pattern 5 (*n* = 15, 2.0%), pattern 6 (*n* = 28, 3.8%), or pattern 7 (*n* = 7, 1.0%). On the other hand, branches were categorized based on CT findings after TEVAR as pattern 1 (*n* = 521, 70.8%), pattern 2 (*n* = 109, 14.8%), pattern 3 (*n* = 51, 6.9%), pattern 4 (*n* = 5, 0.7%), pattern 5 (*n* = 16, 2.2%), pattern 6 (*n* = 29, 3.9%), or pattern 7 (*n* = 5, 0.7%) (Table 2). De novo occlusion of an abdominal branch following TEVAR was not recognized. A total of 14 branch stents or covered branch stents were used with TEVAR. Six superior mesenteric artery stents were deployed, seven renal stents were placed, and one covered stent was used in a celiac artery (Table E1 [online]).

Regarding pattern 2 branches (*n* = 126), 21 branches (16.7%) showed spontaneous branch healing at postoperative CT. Fifty-eight pattern 2 branches had more than 50% stenosis at preoperative CT; of these, 28 branches had less than 50% stenosis observed and eight branches had spontaneous branch healing at postoperative CT. As a result, 62.1% (36 of 58) of pattern 2 branches associated with severe stenosis improved to mild stenosis (less than 50% stenosis) or spontaneous healing with TEVAR exclusively.

In the group with pattern 3 and pattern 4 branches, only one branch (1.6%) showed spontaneous branch healing at postoperative CT. In the group with pattern 5 and pattern 6 branches, no branch showed spontaneous healing at postoperative CT. As a result,

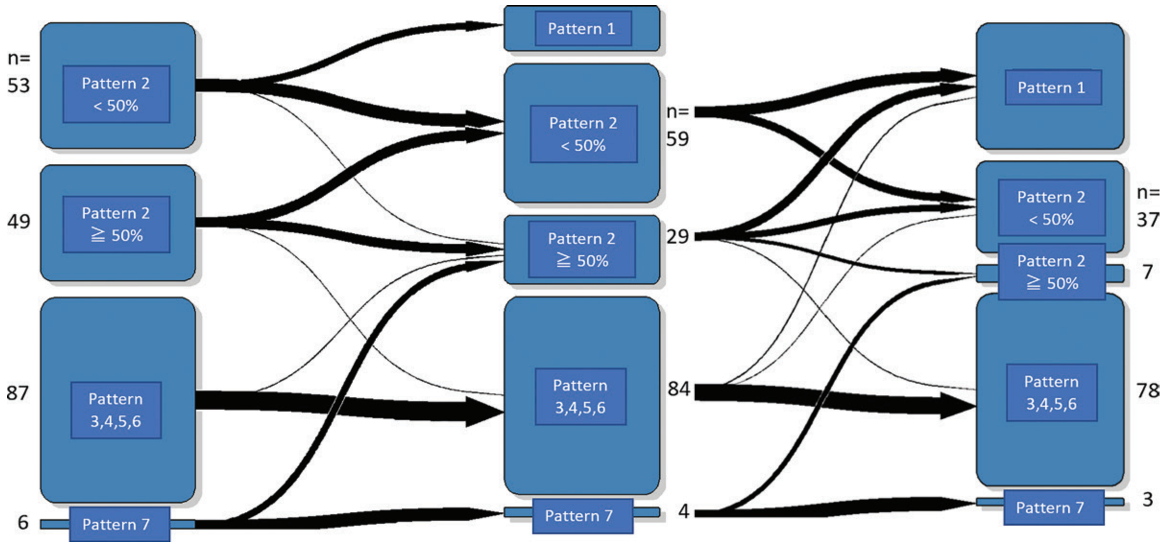

Figure 4: Image shows preoperative to postoperative transition of abdominal branches and last follow-up. Total of 470 branches were analyzed. Almost half of these branches with pattern 2 changed to pattern 1. Branches with other patterns predominantly remained the same during follow-up period.

branches supplied by the aortic false lumen or both lumens rarely healed (1.0%; one of 104) after TEVAR alone.

Seven branches were occluded before TEVAR and two of them (28.6%) recanalized after TEVAR only. However, the two treated exclusively with TEVAR without branch stent placement had a residual stenosis diameter of more than 50%.

At the time of the last follow-up CT, 69 patients had undergone only noncontrast CT. Therefore, the abdominal branch pattern at the last follow-up was analyzed for 117 cases (459 branches, including accessary renal arteries). The average interval from TEVAR to the last follow-up CT was 19.7 months ± 14.8. The transition of branches is detailed in Figure 3. Sixty-four pattern 2 branches (62.7%, 64 of 102) spontaneously healed during the follow-up period. Regarding the other patterns, six branches achieved spontaneous healing (6.5%, six of 93). De novo occlusion of an abdominal branch during follow-up was not recognized.

Kidney Volume Changes

Seven patients had accessory renal arteries and one patient had only one renal artery due to a previous nephrectomy. These eight patients were excluded. Kidney volumes were assessed for 178 cases and evaluated with CT preoperatively and at the last follow-up. The average kidney volumes according to preoperative CT and at the last follow-up were 169.2 mL ± 47.2 and 158.9 mL ± 52.5, respectively. The average kidney volume change was –10.3 mL ± 33.4 (–5.6% ± 19.6). The average kidney volume change and change ratio for each branch pattern are detailed in Table E2 (online).

The relationship between kidney volume and renal function was assessed. There was a positive correlation (r = 0.514; $P <$ .001) between the ratio of the kidney volume change (x-axis) and the change in estimated glomerular filtration rate (y-axis). The linear regression for x and y was estimated as $y = 0.656x$ (Fig E4 [online]).

Seventy-nine patients met inclusion criteria for the renal volumetric change analysis with one renal artery supplied by pattern 1 and the other renal artery supplied by another pattern (pattern 1 vs pattern 2, n = 30; pattern 1 vs pattern 3, n = 27; pattern 1 vs pattern 4, n = 3; pattern 1 vs pattern 5, n = 4; pattern 1 vs pattern 6, n = 12; pattern 1 vs pattern 7, n = 3). For these 79 patients, there were no branches with stents. These branch patterns were re-evaluated at postoperative CT. Because of the small number of patients in the cohort with different patterns of branch supply to the kidneys (pattern 1 vs pattern 4, pattern 1 vs pattern 5, and pattern 1 vs pattern 7), patients with patterns of 1 versus 3, 1 versus 4, 1 versus 5, and 1 versus 6 were combined for analysis. No analysis was performed for patients with pattern 1 versus pattern 7. Furthermore, patients with pattern 1 versus pattern 2 were divided into two groups according to stenosis diameter (pattern 1 vs pattern 2 with <50% stenosis and pattern 1 vs pattern 2 with ≥50% stenosis). Patients with branch pattern 2 with more than 50% stenosis were described as pattern 2 (≥50% stenosis).

The average kidney volume change ratios are detailed in Table 3. The relationships between time and the ratio of the kidney volume change are plotted in Figure 4.

In patient cohorts with different renal supply patterns, simple linear regression models were performed to determine the differences in kidney volume change rates between the normal and diseased kidneys (Table 4, Fig 5).

In the cohorts of patients with pattern 1 versus 2, pattern 1 versus 2 (≥ 50% stenosis), pattern 1 versus 3, and pattern 1 versus 4, the slope coefficient (ie, change rate) of the linear trend line was $P <$ .05. Therefore, the renal volumes decreased over time in the kidneys and were associated with the true lumen supply with branch vessel dissection with more than 50% stenosis and in kidneys supplied by aortic false lumen perfusion patterns compared with contralateral kidneys supplied by arteries with pattern 1 branch anatomy.

Discussion

We surveyed the natural history of abdominal branch morphology and stenosis following thoracic endovascular aortic

Table 4: Summary of the Linear Regression Coefficient

Patient Group	No. of Patients	Follow-up Period (mo)*	Linear Regression Coefficient	*P* Value
Pattern 1 vs 2	30	19 ± 16	−0.02	.004
Pattern 1 vs 2 (<50% stenosis)	11	19 ± 16	−0.01	.06
Pattern 1 vs 2 (≥50% stenosis)	19	19 ± 15	−0.03	.002
Pattern 1 vs 3 and 4	30	19 ± 15	−0.02	.004
Pattern 1 vs 5 and 6	16	21 ± 17	−0.002	.71

Note.—In patients with one kidney supplied by pattern 1 and the other supplied by another pattern, the difference of kidney volume change of healthy and diseased kidney from preoperative to the last follow-up CT was assessed by using a simple linear regression model. The kidney volume supplied by pattern 2 with more than 50% stenosis or pattern 3 and 4 decreased compared with the contralateral kidney supplied by pattern 1.

* Data are means ± standard deviation.

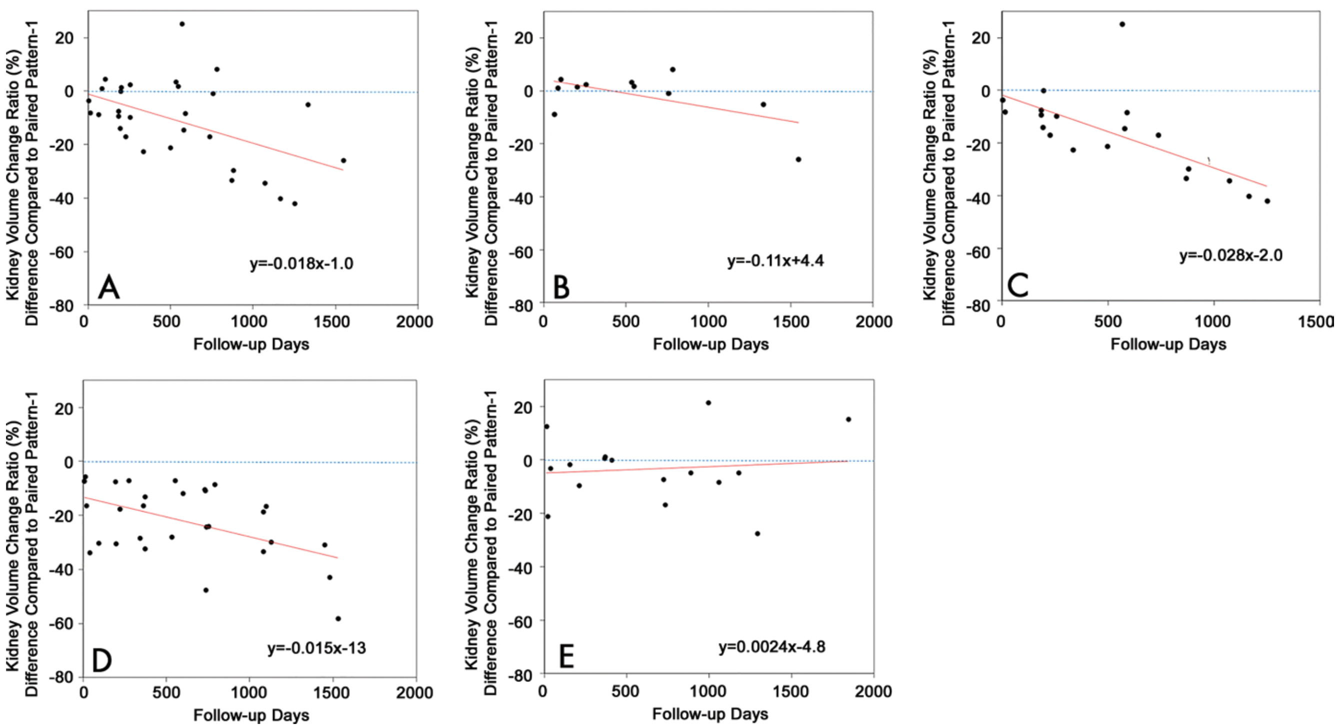

Figure 5: Plots show relationship between length of follow-up in days (x-axis) and difference between bilateral kidney volume change rates (y-axis). Each black dot describes reduction in kidney volume change ratio for both kidneys. *A,* Pattern 1 versus 2: line decreases over time. *B,* Pattern 1 versus 2 (<50% stenosis): line slightly decreases over time but is not statistically significant. *C,* Pattern 1 versus 2 (≥50% stenosis): line significantly decreases over time. *D,* Pattern 1 versus 3 and 4: line decreases over time. *E,* Pattern 1 versus 5 and 6: line slightly increases over time but is not statistically significant.

repair (TEVAR) and the impact on end-organ perfusion using renal volume change over time as a model of perfusion. The branch pattern analysis found that 62.5% of the dissected abdominal branches arising from the true lumen healed spontaneously, whereas only 6.5% of the abdominal branches supplied from false or both lumens exhibited dissection healing. Kidney volume analysis demonstrated that decreased kidney volume was associated with worsening of kidney function and that renal arteries supplied by the aortic false lumen or a persistently dissected artery with greater than 50% stenosis are associated with renal volume loss, suggesting reduced branch perfusion.

The typical categorization of branch vessel morphology in aortic dissection simply describes the origin of the branch as being true lumen, false lumen, and both aortic lumens (3,4). Our categorization added the presence of dissection extending into a branch. Because severe stenosis in a branch can cause malperfusion, characterization of the severity of associated stenosis may be prognostically important.

There were four reasons for focusing on kidney perfusion only and not on other visceral organs. First, the celiac artery and superior mesenteric artery are commonly connected anatomically, with potential cross-perfusion through rich collateral flow. Therefore, the individual branch pattern of dissection involvement is not the only factor that determines the branch blood flow. Yet, the kidney is an end organ and the renal artery is a telangion (with some small collateral sources, which are negligible). Consequently, the renal artery pattern is directly associated with renal blood flow. Second, there is no clear surrogate marker of blood flow in the celiac artery or

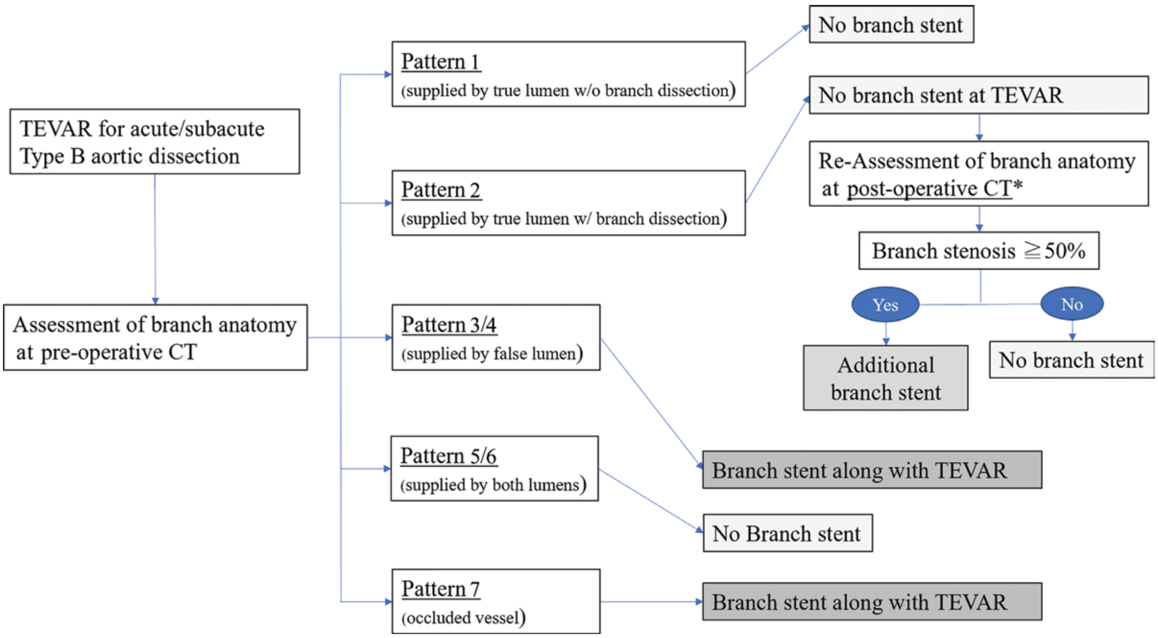

Figure 6: Flowchart shows management strategy for abdominal branches in conjunction with thoracic endovascular aortic repair (TEVAR) for type B aortic dissection. * = We recommend that CT should be performed within 1 week after TEVAR.

superior mesenteric artery. Decreased renal artery perfusion reportedly causes worsening of kidney function and kidney shrinkage (5,6). Therefore, the kidney volume change can be a surrogate marker of renal artery perfusion. Third, for patients with superior mesenteric artery malperfusion, stents were likely to be deployed because of the acute and severe consequences of mesenteric ischemia. However, for patients with renal malperfusion, stents were less likely to be deployed unless there was evidence of obvious critical ischemia. This difference in interventional approaches provided an opportunity to follow the natural course of the change in renal blood flow after TEVAR exclusively. The final reason was the ease of assessment when determining chronic renal malperfusion. Even in patients who underwent only noncontrast CT for disease surveillance, kidney volume change was easily measurable at noncontrast CT.

Our results suggest that branch pattern should be taken into consideration when considering stent placement. We propose a potential management strategy for renal arteries based on branch patterns and degree of stenosis (Fig 6).

If the branch is supplied by pattern 2 anatomy, then we do not recommend branch stent placement during TEVAR. This is because 62.1% (36 of 58) of branches with pattern 2 anatomy with greater than 50% stenosis at preoperative CT evolved to less than 50% stenosis or pattern 1 after TEVAR. Our data would suggest that TEVAR without branch stent placement is associated with a level of improvement of branch status in patients with pattern 2 supply. However, if residual stenosis greater than 50% is diagnosed at postoperative CT, then a branch vessel stent should be considered.

If the branch is supplied by pattern 3 or 4, then a stent or covered branch stent along with TEVAR may be advisable as an initial treatment to maintain organ perfusion. These morphologic patterns rarely resulted in branch healing for patients and were associated with decreased renal perfusion. If the branch is supplied by pattern 5 or 6, then any adjunctive branch procedure is not necessary at the same time as or after TEVAR because these branches are not associated with reduced renal perfusion. If a branch is occluded at the time of diagnosis, then a branch stent or covered stent along with TEVAR is advisable to restore branch perfusion. Only two of seven (28.6%) initially occluded branches achieved spontaneous recanalization after TEVAR exclusively, but were found to be pattern 2 with greater than 50% stenosis at postoperative CT. Therefore, all occluded branches treated by using TEVAR exclusively led to unfavorable results, suggesting branch stent placement for an occluded branch may be performed in conjunction with TEVAR.

It is important to recognize that interventional management of acute complicated type B aortic dissection involves multiple considerations and treating physicians should modify any management strategy according to the clinical circumstances. Additionally, arteriography of the branch, the use of intravascular US, and measurements of arterial blood pressure may help physicians when deciding whether to perform branch stent placement. The relative value of branch morphologic pattern and estimated stenosis versus use of pressure gradients across branches was not tested in our study.

Our study had limitations. First, this was a retrospective study. Second, there were a limited number of patients with renal artery anatomy corresponding to patterns 4, 5, and 7 after dissection. Therefore, it is difficult to draw meaningful conclusions from an analysis of their outcomes. Additionally, we do not use intravascular US and pressure gradient measurements were not obtained; instead, percent stenosis and morphologic appearance of dissection were classified. Finally, we did not determine the actual effectiveness of stent placement on outcomes such as renal volume loss. We only make suggestions about the potential utility based on our data.

In conclusion, for type B aortic dissection, the abdominal branch supply pattern and presence of stenosis after thoracic endovascular aortic repair (TEVAR) determined by using CT is a critical determinant of long-term organ perfusion. Individuals with renal arteries supplied by the aortic false lumen or dissected branches with residual stenosis after TEVAR experience kidney volume loss during follow-up. Consequently, branch stent placement may be beneficial for patients with these branch supply patterns when clinically appropriate.

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Letters to the Editor

Erratum

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Management of Renal Arteries in Conjunction with Thoracic Endovascular Aortic Repair for Complicated Stanford Type B Aortic Dissection: The Japanese Multicenter Study (J-Predictive Study)

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Page 458, figure 2 legend should read: Images show examples of each pattern of branch supply after aortic dissection. *A*, Pattern 1: right renal artery originates from true lumen without extension of dissection flap into renal artery. *B*, Pattern 2 with less than 50% stenosis: superior mesenteric artery originates from true lumen. Dissection flap is seen in branch artery lumen with less than 50% stenosis. *C*, Pattern 2 with more than 50% stenosis: true lumen is collapsed and false lumen is not yet opacified with contrast medium. Lumen of celiac artery filled with contrast medium shows severe stenosis due to extension of dissection flap into artery. *D*, Pattern 3: right renal artery originating from false lumen is patent. Left renal artery originating from true lumen is patent. *E*, Pattern 4: left renal artery is supplied by aortic false lumen and presence of extension of aortic dissection into branch was recognized as linear line. *F*, Pattern 5: celiac artery is supplied by both true and false lumens without branch dissection. *G*, Pattern 6: left renal artery is supplied by both true and false lumens with clear evidence of branch dissection. *H*, Pattern 7: left renal artery **is** occluded. Aortic true lumen is collapsed. Arrow indicates the branch. F = aortic false lumen, T = aortic true lumen.