Factors predictive of distal stent graft-induced new entry after hybrid arch elephant trunk repair with stainless steel-based device in aortic dissection

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Objectives: Stent graft-induced new entry (SINE) has been increasingly observed after thoracic endovascular aortic repair of aortic dissection. We illustrate the possible mechanism by exploring predictive factors of late distal SINE after hybrid arch elephant trunk repair for aortic dissection.

Methods: From November 2006, to May 2011, 20 of 99 patients underwent hybrid arch repair using the elephant trunk graft as the proximal landing zone. After a mean follow-up period of 27.9 ± 12.0 months, 12 patients had late distal SINE events and the others were free of events. False lumen remodeling level was observed and maximal longitudinal diameter, average of longitudinal and transverse maximal diameter, circumference, and area of true lumen were analyzed for precise size selection of stent graft before and after the procedure. Taper ratio, true lumen:aorta ratio, pre-stent grafting oversizing ratio, post-stent grafting oversizing ratio, and expansion mismatch ratio of distal true lumen were proposed and calculated for further evaluation of the mechanism of late distal SINE.

Results: Only the area oversizing ratio between true lumen and the distal selected stent graft at the presumed distal end of stent grafting was found as a significant predictive factor of SINE before procedure (4.00 ± 2.96 vs 1.98 ± 0.66 for SINE vs non-SINE, respectively; $P = .031$). The significant difference of the expansion mismatch ratio of true lumen between the 2 groups was found not only in the size measurement of mean diameter (1.48 ± 0.29 vs 1.22 ± 0.15 ; $P = .039$), but also in the area (2.39 ± 0.85 vs 1.58 ± 0.42 ; $P = .031$) and circumference (1.43 ± 0.27 vs 1.18 ± 0.14 ; $P = .016$) after stent grafting.

Conclusions: We found that taper ratio is not an optimal criteria for stent graft size selection and distal oversizing calculated by true-lumen area is a significant factor causing delayed distal SINE. Use of the pre-stenting area oversizing ratio should be limited. (J Thorac Cardiovasc Surg 2013;146:623-30)

Traditional surgical approaches for aortic arch repair, including hypothermic circulatory arrest, have been challenged by the hybrid elephant trunk procedure with the emergence of thoracic stent graft technology, which involves combining the advantages of open surgery with the less-invasive principles of endovascular implantation.¹ Because the elephant trunk technique allows repair of concomitant aortic arch and proximal descending aortic aneurysms in a single stage operation² and endografting for arch repair,³ the use of the elephant trunk as the proximal landing zone has not only changed the risk profile of the second stage operation but also provided the proper and secure proximal fixation zone for stent graft landing that avoids the diseased

and weakened dissected aorta. However, the distal landing zone of stent grafting is still located at the true lumen of the dissected descending aorta with a high incidence of late distal intimomedial injury induced by stent graft after implantation, as described in our previous work.^{3,4} Stent graft-induced new entry (SINE) has been increasingly observed after thoracic endovascular aortic repair (TEVAR) for Stanford type B dissection²⁻⁵ and distal SINE appears to be noticeably life threatening. Factors predictive of late distal SINE and preventions of SINE after hybrid arch repair using elephant trunk graft as proximal landing zone for aortic dissection were investigated.

MATERIALS AND METHODS

Patients

Between November 2006, and May 2011, 201 patients underwent TEVAR in our institute, the Taipei Veterans General Hospital. Ninety-nine patients had aortic dissection, including chronic type B and residual type A. Chronic aortic dissection type B is defined as event after 2 weeks. Residual type A is a condition in which dissection of the arch and descending aorta remains following aorta open repair of acute aortic dissection type A. The surgical indications are aneurysm rupture, intractable pain, refractory hypertension, ischemia of visceral or lower limb, and a maximal diameter of aneurysm >60 mm. Twenty patients (22%) who underwent hybrid arch repair using elephant trunk as proximal landing zone for stent

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Abbreviations and Acronyms

CT	= computed tomography
SINE	= stent graft-induced new entry
TEVAR	= thoracic endovascular aortic repair

graft enrolled in our study. This retrospective study was approved by the institutional review board at our institution.

Stent Graft System

Only the stainless steel-based stent graft (Zenith TX2, Cook Inc, Bloomington, Ind) was available before June 2010. That device is composed of stainless-steel Gianturco modified Z-stents covered with a polyester (Dacron) graft. The proximal element presents a proximal covered end with protruding barbs to secure it to the aortic wall and the distal end of the proximal component is fully covered. The distal component includes a covered proximal portion and a distal bare stent with barbs. Radial force over both ends of the covered segments facilitates landing zone seal and fixation.

Hybrid Arch Repair With the Elephant Trunk Technique

For patients with residual type A dissection or type B aortic dissection aneurysm, the hybrid arch elephant trunk procedure was performed through median sternotomy and under hypothermic cardiopulmonary extracorporeal support (23°C core temperature) as well as short temporary low circulatory arrest. Several types of adjunctive procedures were performed before thoracic stent graft implantation, according to different proximal landing zones. These procedures included carotid-to-left subclavian artery bypass, supra-aortic debranching, and arch and ascending aortic replacement.

The proximal stent graft size was selected according to the elephant trunk graft diameter with 20% to 30% oversizing. Taper devices were selected with a maximum 8 mm tapering, if 2 stent grafts were required.

A sheath of appropriate size was selected and inserted through femoral vascular access. The guide wire and pigtail catheter were advanced into the true lumen in a retrograde manner up to the ascending aorta under fluoroscopic guidance. One or 2 pieces of thoracic stent graft (mostly tapered, some nontapered) were then introduced along with the preset stiff guide wire and into the elephant trunk graft of the proximal landing zone. The proximal end of the stent graft was deployed across the elephant trunk anastomosis, which was securely fixed to minimize the possibility of distal migration in the future. During stent graft deployment, the patient's systolic blood pressure was lowered to <100 mm Hg to prevent both the windsock effect and distal migration. Further balloon molding was prohibited during the TEVAR procedure. Completion digital subtraction angiography aortography was finally performed to assess the correct position of the stent graft, the coverage of whole primary entry along the descending aorta, and the absence of endovascular leaks, as well as to assess the maintained patency of the supra-aortic trunks and the bypass grafts. Coil embolization for proximal left subclavian artery and/or ligation of the proximal left carotid artery were required to prevent type 2 endovascular leaks if the left subclavian artery and/or left carotid artery were covered by a stent graft. After the operation was complete, spinal cerebrospinal fluid drainage was established immediately if there were any symptoms of paraplegia.

Follow-up Imaging Protocols

Computed tomography (CT) was used to inspect the entire thoracic and abdominal aorta, including the bilateral carotid and iliac arteries. Helical 3-dimensional reconstructions were composed to assist graft length measurements and access conduit evaluation (iliofemoral arteries). Postoperative CT was performed 1 to 2 weeks after the procedure, then 3 months, 6 months, and annually after the primary TEVAR. Aortic size, diameter

of the true and false lumens, endoleaks, and characteristics of the stent grafts were evaluated in each patient. The occurrence and progression of new erosion or disruption of the intimal medial membrane of native aorta over the bilateral ends of the stent graft was documented.

The diameter, area, and circumference change of the true lumen of the proximal and distal segments of the descending aorta were measured both in the SINE and the non-SINE group by CT scan image.

The Extent Level of False Lumen Remodeling

The extent level of false lumen thrombosis was classified into no thrombosis (ie, within-stent level), partial thrombosis (ie, level between diaphragm and distal end of stent graft), and complete thrombosis (ie, diaphragm level). The extent of regression level (defined as false lumen obliteration) was also divided into 3 types, as described elsewhere.³

Data Collection and Analysis

CT imaging was performed using a Hi-Speed Advantage scanner (GE Healthcare, Waukesha, Wis) with settings at 5 mm collimation; 10 mm/sec-ond table speed; pitch = 2; and 120 kV, and 230- to 250-mA tube current. The Digital Imaging and Communications in Medicine data was transferred to OsiriX MD (version 1.1; <http://www.osirix-viewer.com>) for measurement and calculation of the true lumen orthogonal diameter, circumference, and area by multiple plane reconstruction technique.^{6,7} Three intervals of CT imaging were collected: CT imaging before and after primary TEVAR, CT imaging with first detection of distal SINE for the SINE group, and the last CT for the non-SINE group. Four proposed equations for precise size selection of stent graft before and after procedure were analyzed at the distal end level of the primary stent graft and at 2 cm away from the stent's distal end. These included measurements of longitudinal maximal diameter of true lumen (Figure 1, B), average of longitudinal and transverse maximal diameter of true lumen (Figure 1, C), circumference of true lumen (Figure 1, D), and area of true lumen (Figure 1, D). The diameter of elephant trunk graft (proximal landing zone) was also measured (Figure 1, A). Although the stent graft is presumably fully expanded, the proposed diameter, circumference, or area of distal end of stent graft was defined as the predicted distal stent size.

To evaluate the predictive factor of the late distal SINE event, 5 equations were proposed (Figures 1, 2, and 3).

$$TR = 1 - \left(\frac{X_A}{X_{Pro}} \right)$$

In this equation, taper ratio (TR)⁸ represents the ratio between the size of the elephant trunk graft (proximal landing zone) and the size of distal true lumen before procedure (Figure 1). X_{Pro} is the diameter of the proximal landing zone before the primary procedure (diameter of the elephant trunk graft, X_{ET} , in this study). X_A is the size of the true lumen at the distal end level of the primary stent graft before primary TEVAR.

$$PRGOR = \left(\frac{X_G}{X_A} \right) - 1$$

In this equation, pre-stent grafting oversizing ratio (PRGOR) represents the ratio between the distal size of the selected stent graft and the true lumen size at the presumed distal end of the stent graft before procedure (Figures 1 and 2). X_G is the distal size of the selected stent graft before the procedure.

$$POGROR = \left(\frac{X'_G}{X_A} \right) - 1$$

In this equation, post-stent grafting oversizing ratio (POGROR) represents the oversizing ratio between the distal size of the limited-expanded stent graft after procedure and the true lumen size at the presumed distal end of the stent graft before procedure. These sizes are measured at the onset

FIGURE 1. A, Sagittal view of preoperative computed tomography scan showing the aortic diameter of the proximal landing zone before primary procedure (X_{Pro}) and presumed level of distal end of stent graft before procedure (X_A). B, Longitudinal maximal diameter of the size of true lumen at X_A . C, Average of longitudinal and transverse maximal diameter of X_A . D, Area and circumference of X_A .

of distal SINE for the SINE group or at the time of the last CT follow-up for the non-SINE group (Figures 1 and 3).

$$EMRDTR = \frac{X'_G}{X'_{A2cm}}$$

In this equation, expansion mismatch ratio of distal true lumen (EMRDTR) represents the expansion mismatch ratio of true lumen between the stent distal end and the noncover segment, 2 cm away from the stent edge after procedure (Figure 3). X'_G is the distal size of the limited-expanded stent graft within true lumen after procedure and X'_{A2cm} is the size of the true lumen (2 cm distal to the distal end of the stent graft after procedure).

Statistical Analysis

Data were analyzed by SPSS statistical software (version 18.0; IBM Corp, Armonk, NY). The continuous variables are expressed as mean $\pm$ standard deviation, and comparison between variables of the SINE and the non-SINE groups were analyzed by Wilcoxon rank-sum test. Categorical variables were analyzed by χ^2 and Fisher exact tests. P values of less than .05 were considered statistically significant.

RESULTS

Stent graft deployment within elephant trunk distal to the true lumen of descending aorta was technically successful in 20 patients, 8 of them with type B aortic dissection and the others with residual type A aortic dissection after emergent

ascending aortic replacement and with existing residual dissection from arch to distal aorta. There were 17 men and 3 women with a mean age of 53.9 ± 14.2 years (range, 32 to 74 years). The mean duration from primary procedure to first postoperative follow-up CT image was 19.7 ± 24.6 days (range, 1 to 115 days). After the mean follow-up interval of 27.9 ± 11.9 months (range, 18 to 44 months), 12 patients experienced late distal SINE events (the SINE group) and the other 8 were free of any events (non-SINE group). Four of the late distal SINE patients received reintervention due to pseudoaneurysm expansion and true lumen compression. All of them were uneventful, except 1 patient died 18 months later due to hepatic cell carcinoma with lung metastasis and pneumonia.⁴ The mean duration from primary procedure to first detection of SINE was 12.6 ± 9.9 months. Other clinical characteristics between groups are summarized in Table 1, and the related hybrid arch repair procedures listed in Table 2 were not significant.

The diameter of the elephant trunk and distal part of implanted stent graft were recorded. The area and circumference were calculated by the formula Area = πr^2 and Circumference = $2\pi r$. Stenting graft oversizing and expansion mismatch ratio were deduced from 5 different

FIGURE 2. The tapered stent graft (4 mm less than proximal diameter).

parameters of size measurement: long diameter, short diameter, mean diameter, area, and circumference.

The extent of false lumen remodeling, taper ratios, and true lumen:aorta ratio (see [Tables 3, 4, and 5](#)) showed no significant differences between the SINE and non-SINE groups. Although no significant differences were found in longitudinal, transverse, mean diameter, or circumference measurements ([Table 5](#)), the graft oversizing by area calculation demonstrated a significant difference between groups ($4.00 \pm 2.96 \text{ cm}^2$ in the SINE group and $1.98 \pm 0.66 \text{ cm}^2$ in non-SINE group; $P = .031$).

No significant difference in diameter and circumference measurements between groups was found for poststent graft oversizing ([Table 5](#)). However, graft oversizing by area calculation tended to be more severe in the SINE group ($3.02 \pm 2.42 \text{ cm}^2$) compared with the non-SINE group ($1.50 \pm 0.62 \text{ cm}^2$) ($P = .082$) after the procedure.

On the other hand, in expansion mismatch of distal true lumen (listed in [Table 5](#)), there were significant differences between groups not only by area calculation (area ratio, $2.39 \pm 0.85 \text{ cm}^2$ in SINE vs 1.58 ± 0.42 in non-SINE; $P = .031$) but also by mean diameter (mean diameter ratio, $1.48 \pm 0.29 \text{ cm}$ in SINE vs $1.22 \pm 0.1 \text{ cm}$ in non-SINE; $P = .039$) and circumference measurements (circumference ratio, 1.43 ± 0.27 in SINE vs and 1.18 ± 0.14 in non-SINE; $P = .016$).

DISCUSSION

Stent graft technique is frequently performed in all kinds of thoracic aorta disease. It is considered a better option than conventional surgery for thoracic endovascular aneurysm repair, especially due to the associated lower morbidity and mortality compared with conventional surgery.³⁻⁵ The benefits of stent graft include its feasibility, safety, effectiveness, and reduction of physiologic stress because of the avoidance of exploratory surgery in lieu of emergent surgery.⁹ After stenting, the remodeling of the false lumen would lead to partial or complete false lumen thrombosis and even complete regression later.^{4,10,11} However, other studies^{2,4} showed that SINE was a new intimal-medial tear occurring at the distal end of the stent graft without disease progression or iatrogenic damage during manipulation of endovascular performance. Although SINE is not emergent, sometimes it may be life threatening, thus necessitating reintervention.

Moreover, the strategy of stent grafting between aortic dissection and atherosclerotic aneurysm is markedly different. In atherosclerotic aneurysm, both the proximal and the distal neck could tolerate the strong radial force of the stent graft without touching the diseased intima of the aneurysm. On the contrary, the whole diseased intima is compressed by the strong radial force of the device at the descending aortic true lumen. Therefore, the new entry tear usually occurs at the margin of the proximal and the distal ends of the device.^{3,5,12} As with other studies,^{13,14} we found that a new ulcer-like projection is detected in about 19% of patients receiving fabric-covered stent graft for thoracic aortic aneurysms during a 6- to 12-months follow-up period. In our study, the first CT image of SINE was detected at a mean follow-up time of 12.58 months after primary procedure. Re-endografting with additional stent grafts is an acceptable solution for rupture rescue and malperfusion prevention.^{4,5,15-17}

Selection of Stent Graft

In several previous articles, stent graft size selection was conducted only according to the diameter measurement of the aortic aneurysm, and a 10% to 20% oversizing ratio at the landing sites of the stent graft was recommended to prevent endoleak¹⁸ and distal migration. As for dissecting aortic pathology, the oversizing of the stent graft is as minimal as

FIGURE 3. A, Sagittal view of postoperative computed tomography scan showing stent graft-induced new entry (SINE). B, Longitudinal maximal diameter of the distal size of limited-expanded stent graft within true lumen after procedure (X_G'). C, Average of longitudinal and transverse maximal diameter of X_G' . D, Area and circumference of X_G' . E, Longitudinal maximal diameter of the size of the true lumen, 2 cm distal to the distal end of stent landing after procedure ($X_{A\ 2cm}$). F, Average of longitudinal and transverse maximal diameter of $X_{A\ 2cm}$. G, Area and circumference of $X_{A\ 2cm}$.

possible, and selecting appropriate and tapered stent graft is crucial to prevent stent graft-induced intima injury.¹⁹

However, the measurement of diameter in the case of aortic dissection is confusing, because the axial transverse view of the aorta in a CT scan is not circular. The proximal end of a stent graft is constrained in the elephant trunk graft, which maintains the proximal variables of the stent graft constant (24 to 28 mm).

As a consequence, the parameter of the distal part of a stent graft may be a factor to predict the most appropriate stent graft size. This requires advanced calculation methods.

Taper Ratio

According to research conducted by Xu and colleagues²⁰ a diameter taper ratio of 30% can be seen in cases with chronic aortic dissection type B. If a stent graft without taper design is selected, the distal end of the graft will oversize the true lumen of the descending aorta by >60%. The tapered stent graft design is thus important for endovascular repair of aortic dissection.⁸ No significant difference was found for full-expanded stent graft in our SINE group (10.86%) and in our non-SINE group (12.12%) when a 4 mm tapered stent graft was used. Therefore, the SINE is only affected by distal end size profile.

For true lumen, the taper ratio did not show a significant difference between groups. Consequently, the occurrence of distal SINE is independent of taper ratio in the cases with hybrid arch repair.

True Lumen:Aorta Ratio of Distal Stent Edge and the Extent Level of False Lumen Remodeling

These parameters represent false lumen transverse and longitudinal regression, respectively. Statistical insignificant difference between groups implies that false lumen remodeling is not the major factor in late distal SINE occurrence after hybrid arch elephant trunk repair for aortic dissection.

Prestenting Graft Oversizing

If the stent graft to true lumen is oversized by 30%, a significant amount of circumferential graft deformation may occur and radial force may be reduced, as suggested by Kratzberg and colleagues.²¹ No obvious torsion, folding, or deformity and migration were found during the 1-year follow-up period in our study. However, 12 patients encountered SINE events. The diameter of the true lumen was evaluated in 2 directions (ie, longitudinal and short axis). And the mean diameter was calculated because the lumen is elliptic in shape after the stent graft landing.²² Although the mean diameter and circumference of the axial view of the stent graft CT image could not be used to predict SINE before the procedure, the prestenting graft oversizing of area ratio could be used to predict SINE occurrence with a significant difference between groups (4.00 in SINE and 1.98 in non-SINE; $P = .031$). For stent graft selection, this implies that when the prestenting graft oversizing of area ratio is <2.00, the SINE incidence is the lowest

TABLE 1. Demographic characteristics of stent graft-induced new entry (SINE) and non-SINE groups

	SINE (n = 12)	Non-SINE (n = 8)	P value
Etiology of dissection			
Residual type A	8	4	.678
Aortic dissection type B (chronic)	4	4	.678
Patient characteristics			
Age (y)	55.50 ± 13.31	51.50 ± 16.01	.851
Men	10	7	.910
Height (cm)	169.70 ± 9.88	167.93 ± 4.85	.678
Weight (kg)	66.07 ± 10.91	74.94 ± 11.83	.157
Body surface area (m ²)	1.75 ± 0.12	1.83 ± 0.17	.305
Body mass index	23.26 ± 5.30	22.53 ± 3.77	.198
Smoking	3	2	1.000
Hypertension	12	8	1.000
Diabetes mellitus	0	1	.678
Alcohol	0	1	.678
Hyperlipidemia	3	1	.678
CAD	0	0	1.000
CRI	1	0	.792
PAOD	0	0	1.000
Previous stroke	1	0	.792
Heart function	62.17 ± 8.80	57.25 ± 8.61	.305
Medication			
Antiplatelet	4	0	.238
Anticoagulant	0	1	.678
Statin	3	0	.384
β-antagonist	8	8	.238
ACEI	1	0	.792
ARBs	7	7	.305
CCB	8	5	.910
Diuretics	6	4	1.000
Follow-up			
Duration	30.00 ± 13.15	24.75 ± 9.71	.135
Surgery to first computed tomography image (d)	19.08 ± 30.76	20.50 ± 12.24	.270
Surgery to first SINE image (mo)	12.58 ± 9.86	No event	

Data are presented as number or mean ± standard deviation. CAD, Coronary artery disease; CRI, chronic renal insufficiency; PAOD, peripheral artery obstructive disease. ACEI, angiotensin-converting enzyme inhibitors; ARBs, angiotensin II receptor blockers; CCB, calcium channel blocker.

possible. Furthermore, a prestenting graft oversizing of area ratio of >4.00 should be avoided because the stronger mechanical radial force could induce intimomedial membrane disruption and lead to SINE occurrence.

Poststenting Graft Oversizing

After deployment, a stent graft can not be fully expanded immediately due to the constraint of the aortic wall.^{2,8,23} Although no significant difference is revealed in poststenting graft oversizing between groups in this study, the poststenting graft oversizing of area ratio in SINE showed a higher tendency of coherence ($P = .082$). In

TABLE 2. Concomitant procedures with hybrid arch elephant trunk repair

	SINE (n = 12)	Non-SINE (n = 8)	P value
Previous procedure			
AsAo repair	8	4	.678
Current procedure			
Elephant trunk diameter (mm)	26.16 ± 3.6	27.00 ± 1.85	.427
Stent graft proximal diameter (mm)	32.83 ± 3.24	29.00 ± 3.02	.305
Taper stent graft	12	8	1.000
C-S bypass	4	3	.910
C-arm time (min)	44.42 ± 25.80	43.88 ± 26.13	1.000
Contrast medium (mL)	192.82 ± 30.49	210.25 ± 57.82	.305

Data are presented as number or mean ± standard deviation. SINE, Stent graft-induced new entry; AsAo, ascending aorta; C-S, carotid-subclavian.

fact, the poststenting graft oversizing of SINE is the result of a force balance between the partial-expanded stent graft and the dissected wall. Therefore, as the area expansion ratio of the distal stent end during CT follow-up approaches 3.00, there will be a higher predictive power of distal end intima disruption. For this reason, frequent CT image follow-up is recommended to prevent rupture or malperfusion.

Expansion mismatch ratio of true lumen. A shear force between the stent graft and native aortic wall has distinctly different mechanical properties at the site of the transition aortic segment.^{24,25} When SINE occurred, the distal end of the stent graft was overexpanded with a tremendous shear force, which could damage the aortic wall transversely. The transition zone of the true lumen, 2 cm below the distal end of stent graft and which could not be expanded or compressed by the false lumen, may develop a pseudo aneurysm if the new intimomedial

TABLE 3. Comparison of false lumen remodeling level between stent graft-induced new entry (SINE) and non-SINE group using different measurement parameters

	SINE (n = 12)	Non SINE (n = 8)	P value
Thoracic false lumen thrombosis level			
No thrombosis*	2	4	
Partial thrombosis†	3	0	
Complete thrombosis‡	7	4	.147
Thoracic false lumen regression level			
No regression*	11	7	
Partial regression†	0	0	
Complete regression‡	1	1	.761

*Within-stent level. †Level between diaphragm and distal end of stent graft.

‡Diaphragm level.

TABLE 4. Taper ratio of stent graft-induced new entry (SINE) and non-SINE groups

	SINE	Non-SINE	P value
Longitudinal diameter	0.30 ± 0.21	0.40 ± 0.25	.910
Transverse diameter	0.62 ± 0.14	0.59 ± 0.10	.521
Mean diameter	0.32 ± 0.14	0.32 ± 0.16	1.000
Area	0.61 ± 0.17	0.57 ± 0.20	1.000
Circumference	0.26 ± 0.15	0.26 ± 0.18	1.000

Data are presented as mean ± standard deviation.

membrane is disrupted.^{4,24,25} The mismatch ratio indicates disproportionate expansion between the stent-covered and non-stent-covered native aorta wall. The expansion mismatch ratio of true lumen between the SINE and the non-SINE groups is shown significantly not only in the size measurement of mean diameter (1.48 ± 0.29 vs 1.22 ± 0.15 ; $P = .039$), but also in area (2.39 ± 0.85 vs 1.58 ± 0.42 ; $P = .031$) and circumference (1.43 ± 0.27 vs 1.18 ± 0.14 ; $P = .016$) after stent grafting.

Timing of SINE During Follow-Up

After a mean follow-up period of 27.9 ± 12.0 months, 12 patients experienced late distal SINE events. However, the mean duration from primary procedure to first detection of a SINE image was 12.6 ± 9.9 months. The distal SINE is a late manifestation by the expansion force of the distal end of the stent graft, and a longer CT follow-up (>1 year) is thus highly recommended.

In studies by Xu and colleagues^{8,20} the diameter oversizing and taper ratio are applied to evaluate the stent graft before implantation. However, the diameter is frequently affected by a kinking or folding obstruction of the stent graft after the procedure and the accuracy of the calculation is limited.²⁰ The prestenenting graft oversizing

of an area may be a better profile for the evaluation of stent graft selection before implantation.

CONCLUSIONS

Improper stent graft size measurement and selection are possible causes of failure with late distal SINE. For patients undergoing hybrid arch repair, taper ratio is not an optimal criteria for stent graft size selection. Excessive oversizing of the distal stent graft could be a significant factor with regard to late distal SINE. This is highly related to area assessment, but not by traditional diameter measurement.

Prestenting graft oversizing of the expansion area is an important index for preoperative size selection. We recommend that area oversizing >4 times should be avoided preoperatively. On the other hand, SINE is predictable if the poststenenting graft oversizing expansion approaches 3 times, and expansion mismatch ratio of the true lumen at the juxtadistal SINE level is high by mean diameter, circumference, and area assessment, which is an important postoperative predictor factor of distal SINE.

Furthermore, in patients undergoing aortic dissection with high taper ratio, the implantation sequence should be considered with distal small-sized stent graft first to prevent future distal SINE. Blood pressure should be well under control and regular CT follow-ups should be conducted, especially during the first postoperative year.

Although lower rates of mortality and complications are seen after TEVAR for aortic dissection, high incidence of distal SINE still exist—especially when excessive distal oversizing is practiced—after follow-up >12 months. More flexible distal ends and tapering the size of new stent grafts might be considered during the development of future technologies. Without head-to-head comparison, our

TABLE 5. Variable formula comparison between stent graft-induced new entry (SINE) and non-SINE group using different measurement parameters

	Longitudinal diameter	Transverse diameter	Mean diameter	Area	Circumference
True lumen/aorta*					
SINE	0.63 ± 0.12	0.59 ± 0.15	0.61 ± 0.12	0.38 ± 0.14	0.57 ± 0.21
Non-SINE	0.75 ± 0.22	0.73 ± 0.22	0.75 ± 0.20	0.59 ± 0.30	0.75 ± 0.20
P value	.115	.181	.157	.157	.157
Prestenting graft oversizing					
SINE	0.35 ± 0.31	2.74 ± 1.56	0.94 ± 0.47	4.00 ± 2.96	0.77 ± 0.39
Non-SINE	0.16 ± 0.17	1.73 ± 0.51	0.61 ± 0.18	1.98 ± 0.66	0.50 ± 0.19
P value	.208	.082	.115	.031†	.115
Post-stenting graft oversizing					
SINE	0.32 ± 0.25	2.03 ± 1.42	0.74 ± 0.41	3.02 ± 2.42	0.61 ± 0.33
Non-SINE	0.18 ± 0.15	1.26 ± 0.61	0.48 ± 0.16	1.50 ± 0.62	0.39 ± 0.17
P value	.427	.208	.238	.082	.208
Mismatch ratio‡					
SINE	1.29 ± 0.28	1.89 ± 0.54	1.48 ± 0.29	2.39 ± 0.85	1.43 ± 0.27
Non-SINE	1.13 ± 0.17	1.45 ± 0.38	1.22 ± 0.15	1.58 ± 0.42	1.18 ± 0.14
P value	.343	.115	.039†	.031†	.016†

Data are presented as mean ± standard deviation. *In distal edge of stent graft. †Significant difference at $P < .05$. ‡True lumen expansion.

conclusions can only be applied to single centers and a single type of stent graft; they cannot refer to all other devices.

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