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Influence of measurement and sizing techniques in thoracic endovascular aortic repair on outcome in acute complicated type B aortic dissections

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Key question

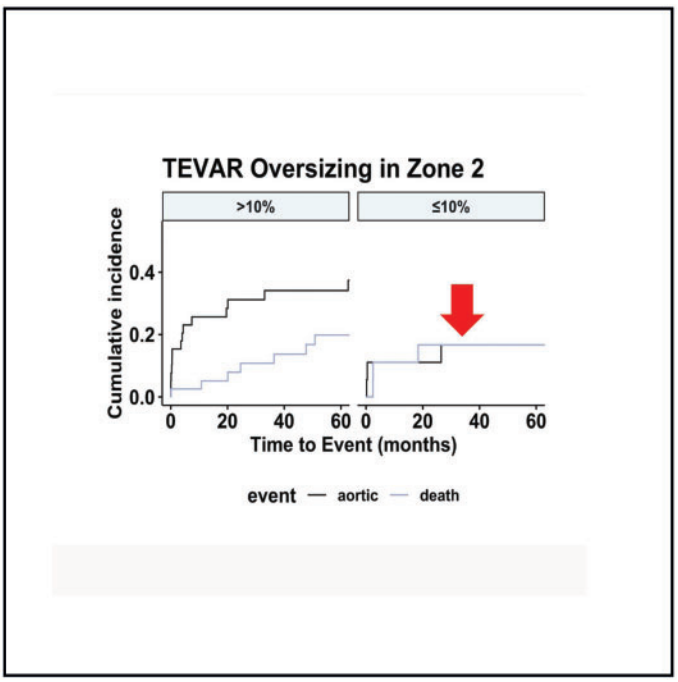
Do different measurement and sizing techniques have an influence on event-free survival in acute complicated type B aortic dissections (cTBAD)?

Key finding(s)

TEVAR oversizing ≤10% shows a tendency towards better freedom from aortic events and mortality.

Take-home message

TEVAR oversizing ≤10% in cTBAD shows a tendency towards better long-term results. Measurement techniques vary widely. A consensus on measurement techniques as well as sizing recommendations is urgently needed.



Abstract

OBJECTIVES: Thoracic endovascular aortic repair (TEVAR) is the first-line therapy in acute complicated type B aortic dissections (cTBAD). Nevertheless, no evidence-based consensus on the optimal measurement technique and sizing for TEVAR in cTBAD exists. The aim was to evaluate how different measurement and sizing techniques for TEVAR affect long-term outcomes.

METHODS: Retrospective analysis investigating the association between sizing and postoperative results after TEVAR in patients with cTBAD, treated between January 2003 and December 2020. Diameter measurements were performed perpendicular to a centreline in pre-interventional Computed tomography angiographies. Oversizing was determined by measuring aortic diameter in zone 2 of the aortic arch in relation to the implanted stent graft, and categorized into 2 sizing groups (≤10% and >10%). The primary outcome was freedom

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from aortic-related events. Secondary outcomes included mortality and a comparison of 3 alternative measurement techniques considering the estimated pre-dissection diameter.

RESULTS: Fifty-seven patients (median age 69, interquartile range 59.6–78.2 years) were included. Stent graft oversizing by ≤10% showed a trend towards fewer aortic-related events hazard ratio 0.455 (95% confidence interval 0.128–1.624, $P = 0.225$).

The 3 measurement techniques using the pre-dissection aortic diameter differed by a mean of 1.7–4.0 mm with a variability of up to 8.4 mm. In none of the 57 patients, the same stent graft would have been chosen based on the different measurement techniques using an oversizing ≤10%.

CONCLUSIONS: TEVAR oversizing of ≤10% in patients with cTBAD might reduce aortic-related events up to 50%. Consensus on measurement techniques of the pre-dissection aortic diameter and stent graft sizing is of paramount importance.

Keywords: TEVAR • Type B aortic dissection • Aortic stent graft • Sizing • Morphological assessment

ABBREVIATIONS

AZ2	Aortic arch zone 2 diameter
AZ2-3	Aortic arch zone 2 diameter minus 3 mm
CI	Confidence interval
CTA	Computed tomography angiography
cTBAD	Acute complicated type B aortic dissections
HR	Hazard ratio
IQR	Interquartile range
MTL	Maximum diameter true lumen
p/dSine	Proximal/distal Stent graft-induced new entry tear
TEVAR	Thoracic endovascular aortic repair
TQ	True lumen diameter 1st quartile
TQ8	True lumen diameter 1st quartile plus 8 mm

INTRODUCTION

Thoracic endovascular aortic repair (TEVAR) is the first-line therapy in acute complicated type B aortic dissections (cTBAD) [1]. In order to ensure successful endovascular treatment, correct sizing of the aortic endoprosthesis is essential. No consensus on the optimal stent graft sizing to achieve a secure seal and to avoid further complications in patients with cTBAD exists.

On the one hand, some proximal oversizing is necessary for sufficient stent graft sealing and prevention of graft migration. On the other hand, excessive oversizing can result in progression of the dissection, retrograde dissections [2–4], proximal and distal stent graft-induced new entry tears (p/dSine) [5–9] or secondary aortic expansion and consequent rupture.

Currently, varying recommendations are available depending on the prosthesis manufacturer (without distinction between aortic aneurysm or dissection), expert opinions [1, 10] and case series [3, 8, 11, 12].

The expert recommendation advocates measuring the overall diameter proximal to the dissected segment in the aortic arch. Based on this result, the chosen stent graft should not be oversized by more than 10%. However, studies that support this are not referenced [1, 10].

A more detailed sizing recommendation was presented by Rylski *et al.* [12], which was based on diameter measurements on computed tomography angiography (CTA) before and after the aortic dissection event. They showed that after an aortic dissection, the total diameter of the descending aorta increased by 23%. Therefore, they propose to determine the stent graft size by measuring the aortic diameter proximal to the dissection and oversize with 5–10% [12]. However, there is a paucity of studies on long-term outcomes for patients with cTBAD based on the selected sizing ratios and measurement techniques.

The aim of this study was to retrospectively evaluate the outcome of patients depending on the selected stent graft sizing ratio. In addition, the various measurement techniques and sizing recommendations proposed by Rylski *et al.* were evaluated. Findings of this study might help to define the optimal measurement location and improve the sizing of the stent graft in patients with cTBAD requiring TEVAR and thereby avoid long-term complications.

METHODS

Ethical statement

This study was approved by the local Ethics Committee Zurich, Switzerland (date of approval 23 July 2020, reference number 2020-01585). Written informed consent was obtained from all patients or their enrolment was provided by the Federal Human Research Act.

Study population, design and recorded data

All consecutive patients with aortic dissections who were treated at the University Hospital Zurich (tertiary referral centre) between January 2003 and December 2020 were retrospectively analysed. This included patients with acute TBAD (<14 days after symptom onset) according to the Stanford classification [1, 13] who were treated by TEVAR. TBAD was defined as complicated in cases of organ/limb malperfusion, aortic rupture, an initial aortic diameter of >55 mm or a rapid increase in aortic diameter of more than 4 mm from the first to the second CTA study (early expansion) [1, 13]. Patients who suffered from recurrent pain and therapy refractory hypertension were also considered as complicated [14, 15].

Exclusion criteria were chronic aortic dissection, treatment with parallel grafts (because of the necessary oversizing), type A aortic dissection, non-A non-B aortic dissections, lack of preoperative CTA, insufficient imaging quality and patients who declined further use of their data.

The stent graft size was determined based on CTA measurements after an interdisciplinary consensus of the vascular surgeon

and the interventional radiologist on duty. A control CTA was performed on the first or second postoperative day.

The following clinical data were collected from the patient records: demographics, cardiovascular risk profile, clinical presentation, morphometric variables on preoperative CTA and follow-up data. Regular follow-up examinations including a CTA were performed on a yearly basis. In cases of missing or external examinations, the general practitioners were contacted. Furthermore, the national 'Unique Person Identification' registry was to check for survival status at the study end date (2 December 2020).

Definition of outcomes

The primary outcomes of this study were freedom from aortic-related events including aortic rupture, retrograde dissection, proximal expansion, distal expansion, distal/proximal stent graft-induced new entry tears (p/dSine) and reintervention. Secondary outcomes included mortality and a comparison of alternative measurement techniques given by Rylski *et al.* [12] described in detail under the section 'Image analysis and calculations'.

The outcomes were compared between patients with stent graft oversizing ≤10% vs >10% defined by the different measurement techniques and the implanted stent grafts.

Image analysis and calculations

Image analysis was performed in multiplanar reconstructions, perpendicular to the centreline, using XERO Viewer (Agfa HealthCare N.V., Mortsel, Belgium), see Fig. 1 [16]. A slice thickness of maximum 2 mm was accepted. Measurements were performed according to the current recommendations at the level of 3 predefined measurement points and reported in millimetres [1, 10, 12, 16, 17]:

1. 'Aortic arch zone 2 diameter (AZ2)' measured at the level between the left common carotid artery and left subclavian artery from outer to outer wall [1, 10, 12].
2. 'True lumen diameter 1st quartile descending aorta (TQ)' measured at the 1st quartile level of the descending aorta [12].
3. 'Maximum true lumen diameter (MTL)' measured in the course of the dissection [12].

For the evaluation of the sizing recommendations by Rylski *et al.* [12], the original pre-dissection aortic diameter was estimated by:

a. Subtracting 3 mm from AZ2 diameter (AZ2-3).
b. Adding 8 mm to the TQ diameter (TQ8).
c. Use of the maximum diameter of the true lumen, which most closely resembles the original aortic diameter, which corresponds to the 'MTL' measuring point mentioned above.

The proximal diameter of the implanted stent graft was used to determine stent graft oversizing at the different aforementioned diameter measurements (AZ2, AZ2-3, TQ8 and MTL). Patients were grouped by stent graft oversizing at ≤10% vs >10% at those diameter measurements.

Statistical analyses

Freedom from aortic events (i.e. aortic event free survival) was analysed with mortality as a competing risk using a Cox proportional hazard model with competing risk analysis. The Cox model was adjusted for baseline characteristics sex and age, the cardiovascular risk profile (i.e. arterial hypertension, smoking, dyslipidaemia, body mass index and diabetes) as well as comorbidities (i.e. chronic renal failure, chronic heart disease and chronic obstructive pulmonary disease), see Table 1 Thereafter, a backwards variable selection was performed using the Akaike information criterion. The selected variables were included in 3 separate models for each diameter measurement technic to elaborate the impact of stent graft oversizing on the primary outcome, see Fig. 4, as well as Supplementary Material Figures S2 and S3.

Follow-up information was included up to 2 December 2020. The completeness of follow-up information was measured using the follow-up index [18].

Due to the low number of missing variables, complete case analyses were performed. The proportional hazard assumption was tested using scaled Schoenfeld residuals for each variable in each model. Continuous variables were summarized by mean and standard deviation if normally distributed or by median and

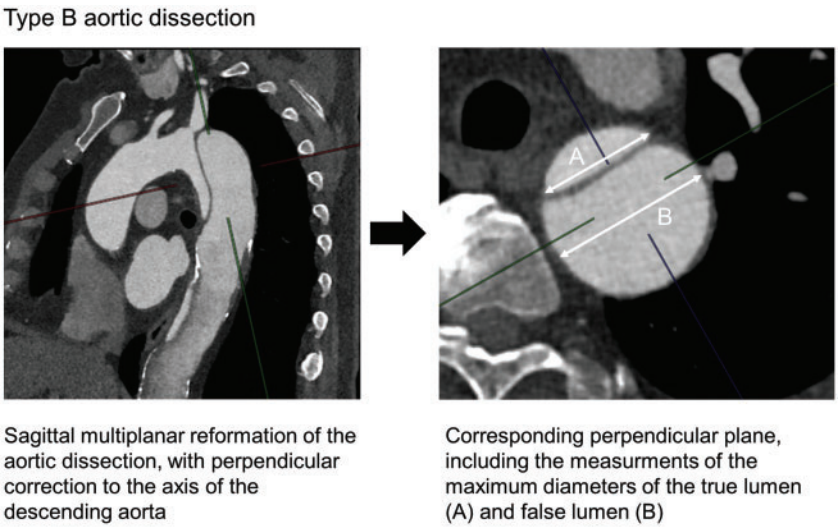

Figure 1: Diameter measurements of the true and false lumen based on multiplanar computed tomography reformations.

Table 1: Competing risk analysis for aortic-related events

	N (%)	HR	95% CI	*P*-value
Female sex	15 (26.3)	0.85	0.28–2.61	0.78
Age, years, median (IQR)	69.0 (59.6–78.2)	1.08	1.01–1.15	0.02
BMI, km/m^2, median (IQR)	25.5 (23.4–29.3)	1.05	0.92–1.20	0.47
Comorbidities				
Hypertension	46 (80.7)	2.70	0.51–14.3	0.24
Chronic renal failure	21 (36.8)	1.45	0.44–4.76	0.54
Smoking	15 (26.3)	7.69	1.82–33.3	0.01
Chronic heart disease	14 (24.6)	0.35	0.08–1.59	0.17
Dyslipidaemia	9 (15.8)	0.77	0.16–3.70	0.75
Diabetes	6 (10.5)	Inf.	0.0 to Inf.	Inf.
COPD	4 (7.0)	1.20	0.21–6.67	0.83

Data were complete. Number of patients in the model $n = 57$, number of aortic events $n = 17$ and number of competing events $n = 17$ (deaths).
95% CI: 95% confidence interval of the hazard ratio; BMI: body mass index; COPD: chronic obstructive pulmonary disease; HR: multivariable hazard ratios; Inf.: infinite (data separation); IQR: interquartile range; TEVAR: thoracic endovascular aortic repair.

interquartile range if skewed. Normality was tested using the Shapiro–Wilk test.

The different measurement techniques proposed by Rylski *et al.* were compared using the Bland–Altman method in the absence of a reference value. This allowed the assessment of the measurement differences between the 3 measuring points and a comparison with each other [19].

All *P*-values are 2-sided with an alpha level of 5%, no adjustment for multiple testing was performed. All analyses were performed with SPSS (Statistical Package for Social Science Chicago, IL, USA, Version 26) and R-Studio, version 3.6.3 [R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, https://www.R-project.org/, on MacOS version 10.15.7].

RESULTS

Study population, indication and treatment received

One hundred and nine patients were treated for cTBAD between January 2003 and December 2020. Of these, 57 [median 69 years, interquartile range (IQR) 59.6–78.2 years] met the inclusion criteria and had a preoperative CTA that was considered sufficient for morphological assessment (see Fig. 2, flowchart). Ninety-three per cent of patients received the same type of stent graft (Gore TAG, W. L. Gore & Associates, Inc., Medical Products, Flagstaff, AZ, USA). The proximal landing zone was in 4 patients in aortic zone 1, in 17 patients in zone 2, in 28 patients in zone 3 and in 8 patients in zone 4, respectively. In 37 (64.9%) of the patients, the proximal landing zone was in a non-dissected segment, in 20 (35.1%), it was in a dissected segment. The median length of stay in hospital was 13 (IQR 9–18) days. Demographics, comorbidities, indications for intervention and details on the treatment are listed in Table 2.

Table 2: Demographics, comorbidities, indication for intervention and treatment ($n = 57$)

Female sex	15 (26.3)
Age, median years (IQR)	69.0 (59.6–78.2)
Comorbidities	
Hypertension	46 (80.7)
Chronic renal failure	21 (36.8)
Smoker	15 (26.3)
Chronic heart disease	14 (24.6)
Hyperlipidaemia	9 (15.8)
Diabetes	6 (10.5)
COPD	4 (7.0)
Indication for intervention (multiple per patient possible)	
Organ/limb malperfusion	23 (42.6)
Aortic rupture	16 (28.1)
Recurrent pain	9 (15.8)
Therapy refractory hypertension	8 (14.0)
Initial aortic diameter >55 mm	8 (14.0)
Early expansion (>4 mm)	2 (3.5)
Treatment	
Stent grafts used	
Gore TAG	53 (93.0)
Jotec E-Vita	2 (3.5)
Cook Zenith Alpha thoracic	1 (1.7)
Medtronic Endurant Cuff	1 (1.7)
Number stent grafts used	
1	43 (75.4)
2	11 (19.3)
3	3 (5.3)
Adjunct procedures	
Supra-aortic debranching LSA	8 (14.0)
Visceral debranching	4 (7.0)
Visceral stenting	3 (5.3)
Infrarenal endovascular aortic repair	2 (3.5)
Iliac stenting	1 (2.0)

Counts are presented with number and (percentage).
COPD: chronic obstructive pulmonary disease; IQR: interquartile range; LSA: left subclavian artery.

Morphological assessment and thoracic endovascular aortic repair sizing ratios

The pre-interventional mean diameters for the different measurement points, their corresponding estimation of the pre-dissecting diameter according to Rylski *et al.* [12] and the resulting median oversizing are listed in Table 3.

Table 3: Morphological assessment

Diameter measured on pre-interventional CTA, mm (SD)	
Aortic arch zone 2 diameter	30.4 (3.7)
Aortic arch zone 2 diameter minus 3 mm	27.4 (3.7)
True lumen diameter first quartile plus 8 mm	29.5 (8.8)
Maximum diameter true lumen	31.3 (4.9)
TEVAR sizing ratios, median % (range)	
Aortic arch zone 2 diameter	17.2 (1.0–64.3)
Aortic arch zone 2 diameter minus 3 mm	30.8 (11.9–84.4)
True lumen diameter first quartile plus 8 mm	23.5 (-23.5 to 196.3)
Maximum diameter true lumen	11.4 (-9.7 to 80.2)

Diameters are presented as mean and (standard deviation) in millimetres. TEVAR sizing ratios are presented as mean percentage with range.
CTA: computed tomography angiography; TEVAR: thoracic endovascular aortic repair.

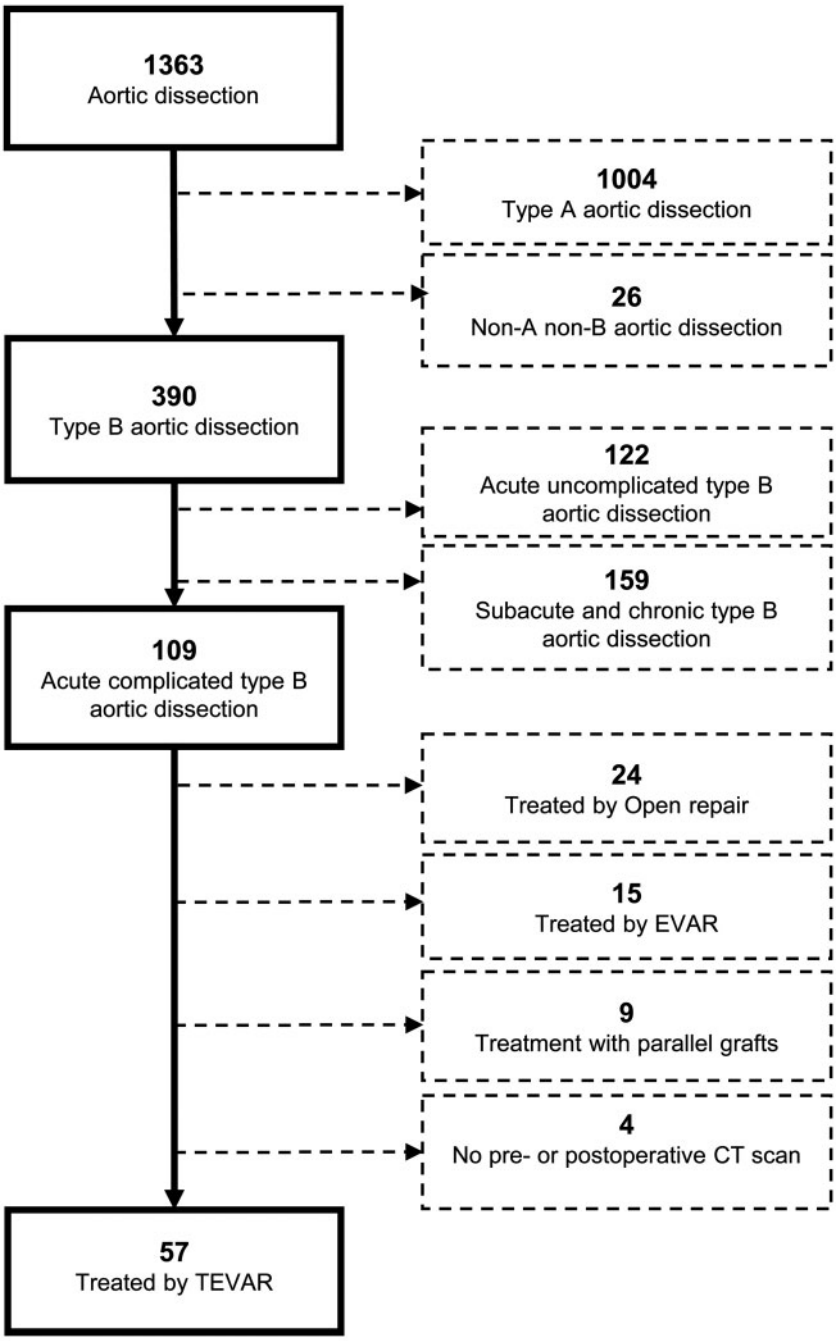

Figure 2: Flowchart of patients treated for aortic dissections between January 2003 to December 2020.

The median oversizing was 17.2% (range 1–64.3%) at the AZ2 diameter. The smallest oversizing was observed for the MTL diameter with a median of 11.4%, range -9.7% to 80.2%. Markedly larger oversizing was observed for the measurement results of TQ8: median 23.5%, range -23.5% to 196.3%; and AZ2-3: median 30.8%, range 11.9–84.4% (Table 3).

Primary outcomes

A total of 17 aortic-related events were observed during the median follow-up time of 47.7 (IQR 7.4–104.6) months. Fourteen of 39 patients (36%) with a stent graft oversizing >10% developed an aortic-related event compared to only 3 of 18 (17%) patients with an oversizing ≤10% measured at the AZ2 diameter. This clinically relevant difference did not reach statistical significance: hazard ratio (HR) 0.455 with 95% confidence interval (CI) from 0.128 to 1.624, $P = 0.225$. Follow-up information at the study end date 2 December 2020 was complete (follow-up index 0.999).

The aortic-related events are summarized in Table 4. Some patients developed more than one complication, in this case, time to first aortic event was used for the analysis. The aortic-related events included 1 (1.8%) aortic rupture diagnosed 10 days post-TEVAR, 7 (12.3%) proximal expansions; 10 (17.5%) distal expansions; 2 pSine (3.8%) diagnosed at 119 and 849 days post-TEVAR, respectively; 1 dSine (1.9%) diagnosed after 602 days; 4

(7.0%) early reinterventions as well as 10 (17.5%) reinterventions during follow-up. No retrograde aortic dissection was observed.

Mortality as a competing risk occurred prior to censoring or an aortic event in 10 of 39 (59%) patients with a stent graft oversizing >10% and in 7 of 18 (41%) patients with an oversizing ≤10% measured at the AZ2 diameter. Of note, this does not reflect overall mortality but mortality as a competing risk. The results of this competing risk analysis are visualized in Fig. 3. The difference in aortic event free survival was observed in the long-term follow-up likewise but was not statistically significant either, $P = 0.15$ (Supplementary Material, Fig. S1).

The final multivariable competing risk Cox model showed that age at diagnosis (HR 1.08 per year, 95% CI 1.01–1.15, $P = 0.034$) and a positive smoking history (HR 3.23, 95% CI 1.01–10, $P = 0.047$) were independently associated with an impaired outcome (Fig. 4). The same analysis was conducted for oversizing using the TQ8 and the MTL aortic diameter measurement technique. Forest plots of those models are available as Supplementary content (Supplementary Material, Figs. S2 and S3).

Table 4: In-hospital and follow-up outcome

	In-hospital ($n = 57$)	Follow-up ($n = 52$)
Aortic-related events (primary outcome)		
Aortic rupture	1 (1.8)	0 (0)
Retrograde dissection	0 (0)	0 (0)
Proximal expansion	4 (7.0)	3 (5.8)
Mean proximal expansion, mm (SD)	0.6 (1.4)	1.6 (3.8)
Distal expansion	4 (7.0)	6 (11.5)
Mean distal expansion, mm (SD)	1.3 (3.9)	3.4 (7.1)
pSine	0 (0)	2 (3.8)
dSine	0 (0)	1 (1.9)
Aortic reinterventions	4 (7.0)	10 (19.2)
Mortality	5 (8.8)	20 (38.5)
Other complications		
Stroke	6 (10.5)	0 (0)
Spinal cord ischaemia	3 (5.3)	0 (0)
Cardiopulmonary resuscitation	1 (1.8)	0 (0)
Graft migration	0 (0)	0 (0)

Counts are presented with number and (percentage). Some patients developed more than one complication and are counted multiple times in different categories.

dSine: distal stent graft-induced new entry tear; mm: millimetre; pSine: proximal stent graft-induced new entry tear; SD: standard deviation.

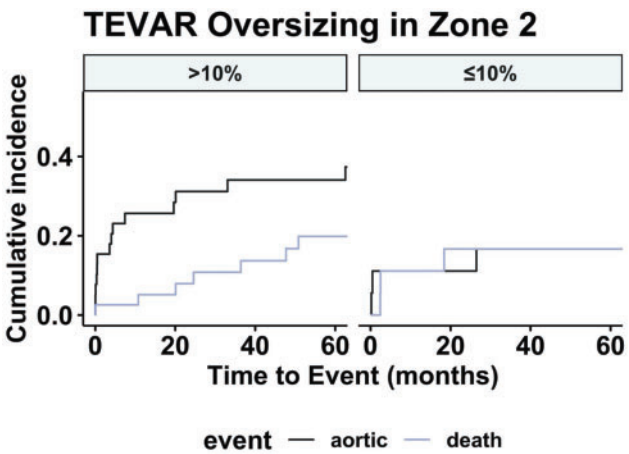

Figure 3: Cumulative incidence of both events (aortic events and mortality) visualizing the competing risk analysis for the measurements in aortic arch zone 2 with an oversizing of >10% vs ≤10%. Death as a competing risk for aortic events occurred throughout the entire study period in both groups.

Secondary outcomes

When freedom from aortic-related events was compared between sizing groups built on MTL measurements, the tendency towards better outcomes with smaller oversizing was statistically significant with an HR of 0.25, 95% CI 0.072–0.891, $P = 0.032$. In other words, the risk for an aortic-related event was 75% smaller in patients with a moderate oversizing of ≤10% compared to patients with an oversizing of more than 10% measured at the maximum true lumen diameter (Supplementary Material, Fig. S3).

Based on the aortic diameter measured with all 4 methods (AZ2, AZ2-3, TQ8 and MTL) the stent graft selection would be non-congruent in each of the 57 cases and most of the patients would receive a different stent graft compared to the prosthesis that was implanted. When comparing the individual measurement techniques with each other, the greatest agreement regarding the stent graft choice was seen for AZ2 and MTL with 35.1% agreement. This was followed by TQ8 and MTL with 21.1% agreement, and AZ2-3 versus MTL with only 14% agreement. Agreement between the other measurement techniques was even lower (AZ2 versus TQ8, 12.3%; AZ2-3 versus TQ8, 12.3%; AZ2 versus AZ2-3, 12.3%), see Fig. 5.

DISCUSSION

To date, there are hardly any guideline-based recommendations on the sizing of thoracic endoprosthesis in cTBAD, especially regarding studies based on long-term results. Experts recommend that no TEVAR oversizing of more than 10% should be performed with respect to the AZ2 diameter [1, 10]. It must be emphasized that the recommendation of ≤10% oversizing was an arbitrary number to date, based only on expert consensus, but to our knowledge has never been studied and has had no evidence to date.

This study shows that a moderate oversizing ≤10% was associated with fewer aortic events. The difference was clinically relevant and consistent throughout several measurement techniques but not statistically significant except for oversizing based on MTL aortic diameter. The multivariable analysis revealed that a positive smoking history and older age at the time of treatment are independently and significantly associated with a worse outcome in terms of aortic-related events.

Generally, there is no agreement on where and how to measure aortic diameters in patients with complicated acute aortic dissections requiring TEVAR. In many studies, the level at which the measurements were taken is not specified. Some state that the measurement should be taken proximal to the dissection (i.e. in aortic arch zone 2) and in a non-dissected segment, respectively [10, 20]. In other cases, only the area of the proximal landing zone is described [9, 21].

Some studies recommend measuring the diameter only in the true lumen perpendicular to a centreline along to the dissecting membrane [22] and others specify that the true lumen diameter should be used [21]. There are also different opinions as to whether the diameter should be measured from adventitia to adventitia (outer to outer wall) [20, 23] or intima to intima [3, 4, 21].

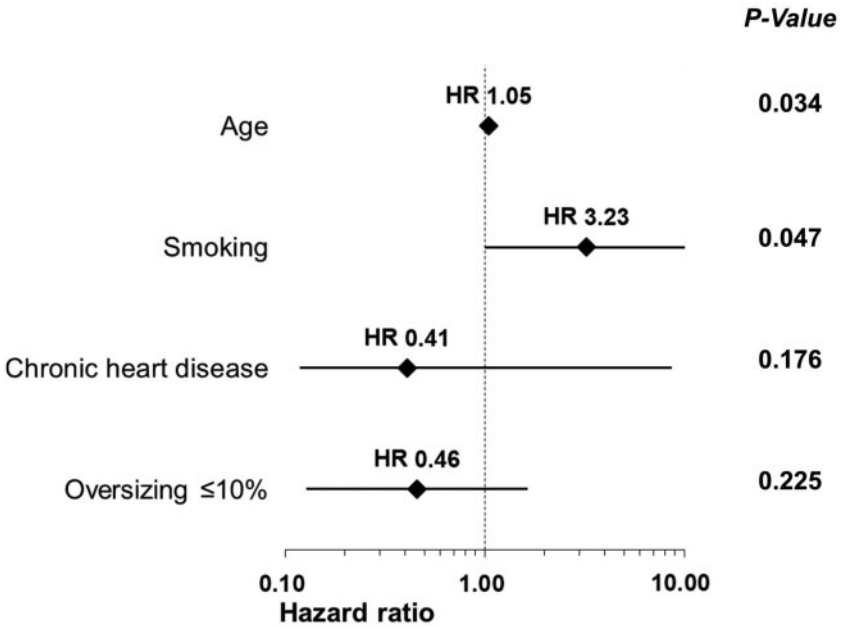

Figure 4: Multivariable Cox proportional hazard model for freedom from aortic events with mortality as a competing risk. Oversizing was measured at aortic arch zone 2 (AZ2). The proportional hazard assumption was tested using scaled Schoenfeld residuals and was satisfied ($P = 0.96$, global test). Not smoking and absence of chronic heart disease served as reference groups for these variables. HR: hazard ratio.

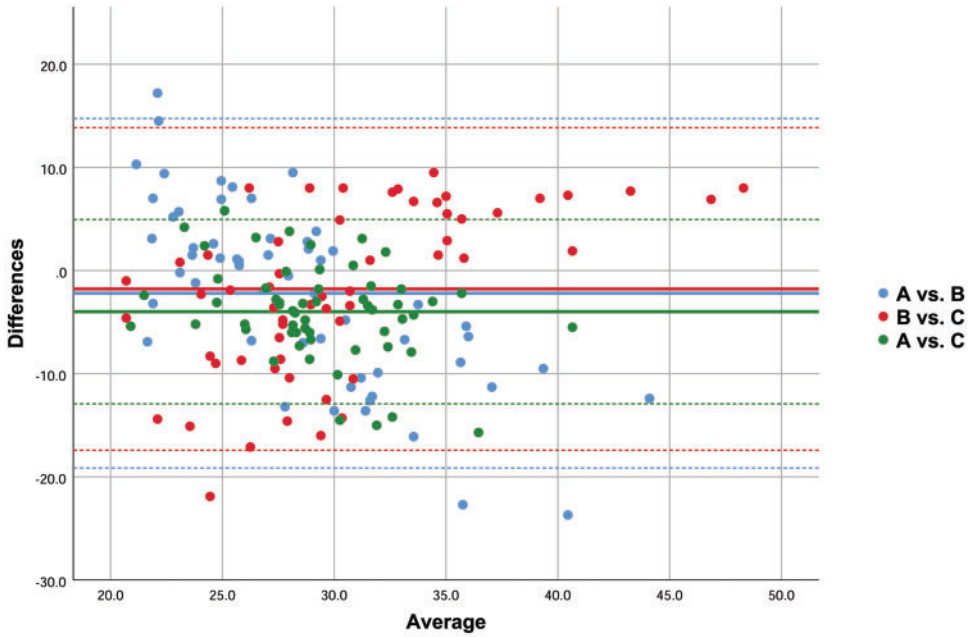

Figure 5: Bland–Altman–Plot comparing diameter measurements according to Rylski *et al.* [12]. (**A**) Aortic arch zone 2 diameter minus 3 mm (AZ2-3). (**B**) True lumen diameter first quartile plus 8 mm (TQ8). (**C**) Maximum diameter true lumen.

The latter is often complicated by plaques or thrombus formation, which should be specified [17].

With regard to the distal landing zone of the stent graft, there are hardly any general recommendations. There are further difficulties at this level, especially in patients with malperfusion and true lumen collapse, in whom the distal true lumen is narrowed markedly.

It could only be shown that excessive oversizing with respect to the true lumen diameter at the distal landing zone can lead to dSine and increased risk of aneurysm formation with subsequent rupture. Since 80% of the cases are treated with a distal landing zone of TEVAR in the dissected aorta [24], the use of tapered stent grafts to avoid excessive oversizing is recommended [6–9, 25].

In emergency situations, such as cTBAD, the appropriate tapered stent grafts are often not available. In this study, tapering was only performed in 15% of cases (mainly by using multiple stent grafts). However, in the entire cohort, only 1 patient with dSine was found, requiring a reintervention more than 1.5 years after the initial intervention. Compared to other cohorts, the

number of dSine is relatively low [5, 8, 9, 25]. In this patient, the stent graft was distally oversized by more than 60% compared with the true lumen. In relation to the total diameter in this area, however, it was only 6%.

In addition to the expert recommendation for measurement and TEVAR sizing based on the diameter in AZ2, more recent measurement techniques according to Rylski *et al.* [12] were evaluated in this study. Through this external validation, a relatively large mean difference (up to 4 mm) and considerable measurement variability between the different measurement methods for determining the pre-dissection aortic diameter were demonstrated. This was reflected in the fact that in no single patient would the same aortic prosthesis has been selected based on all measurement techniques.

Proper stent graft sizing requires the consideration of not just anatomical measurements. Haemodynamic changes also influence aortic diameter. For example, due to shock in the context of an aortic rupture in cTBAD, the diameter may be smaller [23, 26]. Even under physiological conditions, the aortic diameter changes by more than 10% between systole and diastole in the region of the descending aorta [23, 27].

In such cases, intravascular ultrasound-based measurements may be useful in sizing the stent graft. Lortz *et al.* already demonstrated that intravascular ultrasound-based sizing led to a change in stent graft choice in nearly 50% of patients, resulting in better aortic remodelling [23, 28]. Other advantages of intra-interventional intravascular ultrasound measurement include confirmation of correct location in the true lumen, as well as localization of entry tears [23, 29].

Strengths and limitations

A notable strength of the study is that it has a complete follow-up over a very long period (follow-up index 0.999) and it reflects real-world practice outside a prospective study setting where narrow inclusion criteria can make the applicability of findings difficult.

However, this study has several limitations that are inherent to its retrospective nature. Adjustments for potential confounders like the cardiovascular risk profile and baseline characteristics were performed. Still, there might be unmeasured residual confounding that influenced the outcome and biased our findings.

It can be criticized that only one investigator carried out the measurements and no second investigator confirmed those measurements. Singh *et al.* [30] have demonstrated that the intra-observer variability for CTA measurements might be negligible small. Still, an undetected bias due to systematic differences in measurements cannot be ruled out.

Another limitation is the possibility for a change in measurement and sizing behaviour throughout the long study period. This cannot be ruled out since there were no clear measurement guidelines or protocol, and the sizing depended on the experience of the medical team on duty. However, we could not observe any trends in the measurement and sizing behaviour during the inclusions period of this study.

Lastly, to the best of our knowledge, this is the largest series to investigate sizing ratios and long-term results. Still, the cohort is relatively small, and the low number of events limits the generalizability of the results of the study since it was clearly underpowered. The results should therefore be validated in a larger, prospective multicentre study.

CONCLUSIONS

Stent graft oversizing of ≤10% in patients with acute cTBAD requiring TEVAR based on diameter measurements in zone 2 of the aortic arch showed a tendency towards better aortic event free survival compared to patients with bigger oversizing. Up to 50% of aortic-related events might be reduced by a more conservative oversizing.

Different measurement techniques for stent graft sizing showed high variability and little agreement in the choice of stent graft underlining the urgent need for a consensus on measurement technique.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *ICVTS* online.

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Miriam Rychla: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Validation; Visualization; Writing—original draft. **Philip Dueppers:** Methodology; Visualization; Writing—review & editing. **Lorenz Meuli:** Conceptualization; Formal analysis; Methodology; Validation; Writing—review & editing. **Zoran Rancic:** Methodology; Validation; Writing—review & editing. **Anna-Leonie Menges:** Methodology; Validation; Writing—review & editing. **Reinhard Kopp:** Methodology; Validation; Writing—review & editing. **Alexander Zimmermann:** Conceptualization; Investigation; Methodology; Supervision; Validation; Writing—review & editing. **Benedikt Reutersberg:** Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Supervision; Validation; Visualization; Writing—original draft.

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