Eur J Vasc Endovasc Surg (2015) 50, 754—760

# Aortic Arch Morphology and Aortic Length in Patients with Dissection, Traumatic, and Aneurysmal Disease

**H.B. Alberta [a,*], T. Takayama [a], T.C. Smits [a], B.B. Wendorff [a,b], R.P. Cambria [c], M.A. Farber [d], W.D. Jordan [e], V. Patel [c], A. Azizzadeh [f], J.D. Rovin [g], J.S. Matsumura [a]**

[a] School of Medicine and Public Health, Division of Vascular Surgery, University of Wisconsin, Madison, WI, USA
[b] W. L. Gore & Associates, Flagstaff, AZ, USA
[c] Division of Vascular Surgery and Endovascular Surgery, Harvard Medical School, Boston, Massachusetts, USA
[d] Division of Vascular Surgery, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA
[e] Vascular Surgery and Endovascular Therapy, University of Alabama at Birmingham, Birmingham, AL, USA
[f] Department of Cardiothoracic & Vascular Surgery, University of Texas Houston Medical School, Houston, TX, USA
[g] Morton Plant Hospital Valve and Structural Heart Center, Clearwater, FL, USA

**WHAT THIS PAPER ADDS**

The results of this study are unique because of its large, multicenter sample size, from varying patient populations. This makes the results more generalizable to the broader patient population than those of previous studies. In effect, the application of the results is more substantial and is beneficial for device designs and patient selection, which plays a critical role in patient outcomes.

**Objectives:** To assess aortic arch morphology and aortic length in patients with dissection, traumatic injury, and aneurysm undergoing TEVAR, and to identify characteristics specific to different pathologies.
**Method:** This was a retrospective analysis of the aortic arch morphology and aortic length of dissection, traumatic injury, and aneurysmal patients. Computed tomography imaging was evaluated of 210 patients (49 dissection, 99 traumatic injury, 62 aneurysm) enrolled in three trials that received the conformable GORE TAG thoracic endoprosthesis. The mean age of trauma patients was 43 ± 19.6 years, 57 ± 11.7 years for dissection and 72 ± 9.6 years for aneurysm patients. A standardized protocol was used to measure aortic arch diameter, length, and take-off angle and clockface orientation of branch vessels. Differences in arch anatomy and length were assessed using ANOVA and independent *t* tests.
**Results:** Of the 210 arches evaluated, 22% had arch vessel common trunk configurations. The aortic diameter and the distance from the left main coronary (LMC) to the left common carotid (LCC) were greater in dissection patients than in trauma or aneurysm patients ($p < .001$). Aortic diameter in aneurysm patients was greater compared with trauma patients ($p < .05$). The distances from the branch vessels to the celiac artery (CA) were greater in dissection and aneurysm patients than in trauma patients ($p < .001$). The take-off angle of the innominate (I), LCCA, and left subclavian (LS) were greater, between 19% and 36%, in trauma patients than in dissection and aneurysm patients ($p < .001$). Clockface orientation of the arch vessels varies between pathologies.
**Conclusions:** Arch anatomy has significant morphologic differences when comparing aortic pathologies. Describing these differences in a large sample of patients is beneficial for device designs and patient selection.

Article history: Received 11 February 2015, Accepted 10 August 2015, Available online 11 September 2015
**Keywords:** Aortic arch, Aortic length, Aortic morphology, Dissection, Traumatic injury, Aneurysm

## INTRODUCTION

Thoracic endovascular aortic repair (TEVAR) has proven to be successful in treating patients with dissection, traumatic injury, and aneurysm in the descending thoracic aorta.[1–5] In comparison with open surgical repair, patients undergoing TEVAR for these conditions have shown lower morbidity and mortality.[6–11] The application of stent-graft technology within the aortic arch, however, introduces challenges not encountered in the descending aorta. Noted complications have included stent-graft collapse, endoleak, and stroke.[12,13] It is recognized that an important factor in TEVAR success, specifically in the ascending aorta, is dependent on aortic arch morphology and the ability of the endograft to seal off the area of disease or injury by

---

* Corresponding author. School of Medicine and Public Health, University of Wisconsin, 600 Highland Avenue H4/735, Madison, WI 53792, USA.
*E-mail address:* alberta@surgery.wisc.edu (H.B. Alberta).

http://dx.doi.org/10.1016/j.ejvs.2015.08.005

appropriate fixation at the proximal and distal landing zones in the normal aorta.[14] Defining the aortic morphology differences between various patient population groups is therefore important in the considerations for the device choice and sizing, as well as the introduction of new stent-graft technology. This study hypothesizes that there are inherent differences in the aortic arch morphology and aortic length between patients with dissection, traumatic injury, and aneurysm. The null hypothesis is that there are no differences between the three patient populations. The purpose of this study was to assess the aortic arch morphology and aortic length in patients with dissection, traumatic injury, and aneurysm undergoing TEVAR and identify characteristics specific to the different pathologies.

## MATERIALS AND METHODS

A retrospective analysis of the aortic arch morphology and the aortic length was completed on patients enrolled between October 2009 and November 2013 in three multi-site trials that received the GORE Conformable TAG (CTAG) thoracic device (manufactured by W.L Gore and Associates, Flagstaff, AZ). Inclusion criteria for the studies required: the presence of an acute complicated type B aortic dissection, a descending thoracic aorta (DTA) aneurysm, or traumatic injury of the DTA; a proximal and distal landing zone length $\geq$ 2.0 cm; and proximal and distal landing zone inner diameters between 16 and 42 mm. All three studies excluded patients with known connective tissue disorders and those patients with aneurysmal, dissected, heavily calcified, or heavily thrombosed landing zones. Approximately 71% ($n = 120$) of dissection patients screened for eligibility in the CTAG trial were excluded from study participation, with 29% ($n = 33$) of aneurysm patients and 40% ($n = 40$) of trauma patients being screen failures.

For this study, patients were excluded from the analysis if they were screen failures for the CTAG trial, did not have pre-treatment imaging, and/or had incomplete imaging that did not include the visceral arteries. A total of 210 patients (99 traumatic injury, 49 dissection, 62 aneurysm) were included in this study. The mean age of trauma patients was 43 ± 19.6 years, 57 ± 11.7 years for dissection and 72 ± 9.6 years for aneurysm patients.

A series of measurements were completed on each subject to effectively establish an average morphology among the patient populations and to identify morphologic features that differed significantly among the pathologies. Each measurement was completed according to a standardized measurement technique and dual reads were completed to ensure inter-observer agreement was within 15%. TeraRecon Aquarius iNtuition (TeraRecon, Inc., Foster City, CA) was used to complete all measurements. Using TeraRecon toolboxes, the aorta was segmented, surrounding tissues were excluded, and a center lumen line was introduced into the aorta and great vessels and a greater curve into the aortic arch.

Aortic diameters were measured outer edge to outer edge, perpendicular to the center lumen line at distances 20 mm and 40 mm distal to the left main coronary artery (LMC), and 30 mm distal to the left subclavian artery (LSA) (measurement 1—3, Fig. 1A). Additional diameter

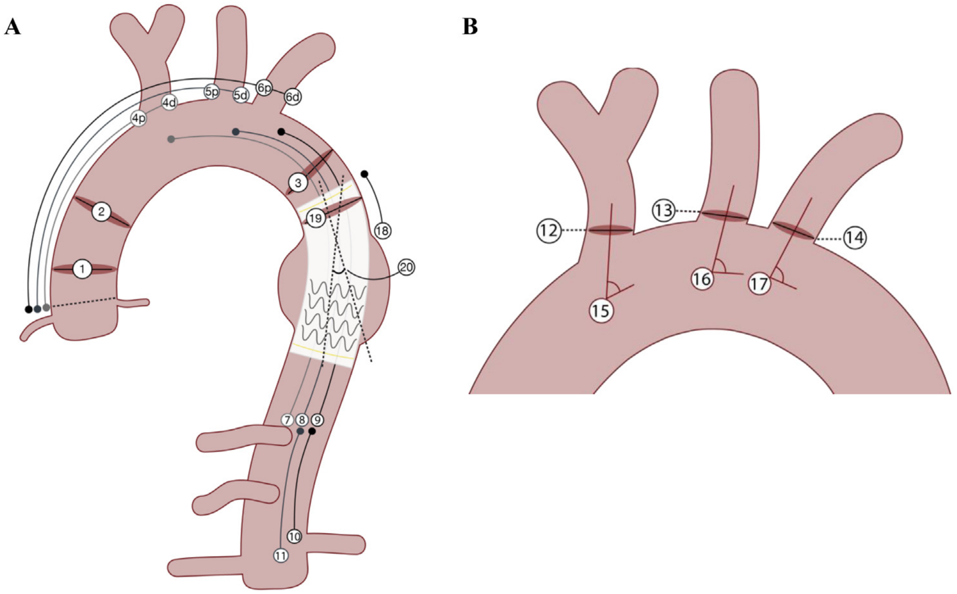

**Figure 1.** Diagram of measurements completed on each subject using both centerline and greater curve. (A) (1) Maximum diameter 20 mm distal to LMC; (2) Maximum diameter 40 mm distal to LMC; (3) Maximum diameter 30 mm distal to LSA; (4p and 4d) Length from LMC to proximal and distal IA; (5p and 5d) Length from LMC to proximal and distal LMC; (6p and 6d) Length from LMC to proximal and distal LSA; (7) Length from IA to CA; (8) Length from LCC to CA; (9) Length from LSA to CA; (10) CA to upper renal; (11) CA to lower renal. (B) (12) Maximum diameter IA; (13) Maximum diameter LCC; (14) Maximum diameter LSA; (15) TOA of IA; (16) TOA of LCC; (17) TOA of LSA; (18) Length of proximal sealing zone; (19) Maximum diameter of proximal sealing zone; (20) Neck angle of proximal sealing zone.

measurements of the supra-aortic branch vessels were captured, along with each ostia diameter (measurement 12—14, Fig. 1B). The supra-aortic branch vessels were further mapped by measuring the distance from the LMC to the proximal and distal edges of the innominate artery (IA), left common carotid artery (LCC), and LSA along the greater curve of the aorta (measurement 4p/4d-6p/6d, Fig. 1A). For patients with a common trunk configuration, the distances from the LMC to the IA and to the LCC were measured as the same distance. The distances from the distal edge of the IA, LCC, and LSA to the proximal edge of the celiac artery (CA) were measured perpendicular to the center lumen line (measurement 7—9, Fig. 1A), in addition to the distances from the proximal edge of the CA to the proximal edges of the upper and lower significant renal arteries (measurement 10—11, Fig. 1A). Each branch vessel's take-off angle (TOA) was measured with respect to the line of flow in the aorta and in the branch vessels using a bifurcated centerline (measurement 15—17, Fig. 1B). The clockface orientation of each branch vessel was captured using the greater curve as a reference point at 12 o'clock. The angle formed by connecting the center of each branch vessel ostia was captured in the 3D view by attaching the angle vectors to each branch vessel centerline. The proximal sealing zone was evaluated by measuring the maximum diameter, length, and angle and by determining if the sealing zone was an inverted-funnel shape (measurement 18—20, Fig. 1A).

The study data were collected and managed using REDCap electronic data capture tools hosted at the University of Wisconsin-Madison School of Medicine and Public Health.[15] The differences in arch morphology and length were assessed using ANOVA and independent *t* tests in Excel. This study was approved by the University of Wisconsin-Madison institutional review board.

## RESULTS

Of the 210 arches evaluated, 22% ($n = 46$) had arch vessel common trunk configurations. There was a significant difference in the diameters at the IA, LCC, and LSA ($p < .05$) between the three patient populations (Fig. 2). The mean diameters of the branch vessels in trauma patients were significantly smaller (IA: 17.7 mm, LCC: 11.7 mm, LSA: 14.1 mm, $p < .05$) compared with dissection and aneurysm patients, while dissection patients were found to have the largest mean diameters (IA: 20.9 mm, LCC: 14.8 mm, LSA: 17.7 mm). In addition, the diameters 20 mm and 40 mm distal to the LMC and 30 mm distal to the LSA in trauma patients were significantly smaller than the diameters of the dissection and aneurysm patients ($p < .05$) (Fig. 2).

The lengths from the LMC to the proximal LCC and distal LSA were significantly shorter in trauma patients than in dissection and aneurysm patients, with dissection patients showing the longest lengths ($p < .05$) (Fig. 3). Trauma patients were also found to have significantly shorter lengths from the IA, LCC, and LSA to the CA compared with dissection and aneurysm patients ($p < .05$) (Fig. 3). Aneurysm patients showed the longest lengths at these locations (Fig. 3). The length from the CA to the upper and lower renal arteries was not significantly different between the three patient populations.

Trauma patients had a significantly larger TOA at the IA (72.5° vs. Dissection: 56.6°, Aneurysm: 53.9°, $p < .05$) and LCC (64.6° vs. Dissection: 51.6°, Aneurysm: 51.4°, $p < .05$) compared with dissection and aneurysm patients (Fig. 4). The TOA of the LSA was significantly different between the three patient populations ($p < .05$). Trauma patients again showed the largest TOA at this location and aneurysm patients the smallest (Fig. 4).

The clock positions of the IA and LCC were significantly less clockwise in dissection patients (IA: 12:11, LCC: 11:47)

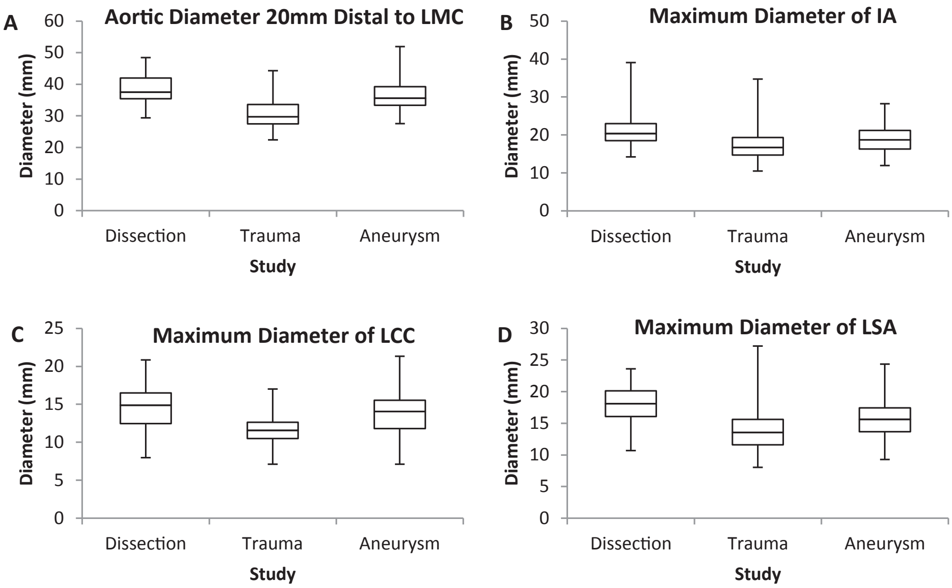

**Figure 2.** Diameter measurements in trauma, dissection, and aneurysm patients. (A) Aortic diameter 20 mm distal to the LMC. (B) Aortic diameter of the IA. (C) Aortic diameter of the LCC. (D) Aortic diameter of the LSA.

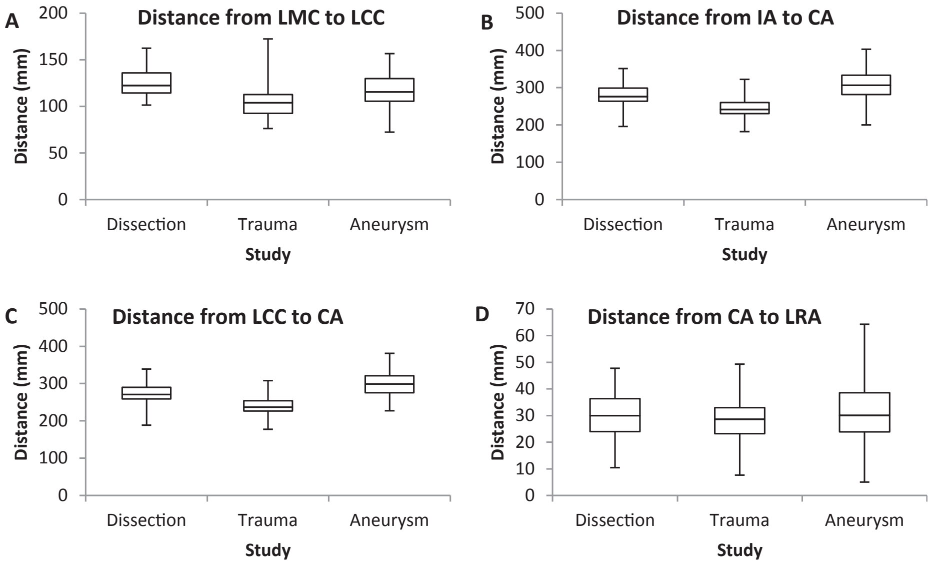

**Figure 3.** Length measurements in trauma, dissection, and aneurysm patients. (A) Distance from the LMC to the LCC. (B) Distance from IA to CA. (C) Distance from the LCC to CA. (D) Distance from CA to LRA.

compared with trauma (IA: 12:38, LCC: 12:04) and aneurysm patients (IA: 12:29, LCC: 11:58) ($p < .05$) (Fig. 5). The most commonly observed clock positions of the IA were at 12:30 and 12:45 in trauma and aneurysm patients and at 12:15 in dissection patients (Fig. 5). All three patient populations showed the most common LCC clock position to be 12 o'clock (Fig. 5). The most common clock position of the LSA in trauma and dissection patients was 12 o'clock and 12:15 in aneurysm patients (Fig. 5). There was no significant difference in the angle between vessels among the three patient populations.

The maximum diameter of the proximal sealing zone was significantly larger in dissection and aneurysm patients than trauma patients ($p < .01$) (Table 1). Aneurysm patients were found to have significantly longer proximal sealing zones than dissection or trauma patients ($p < .01$), with no significant difference in length observed between dissection and trauma patients (Table 1). The neck angle within the sealing zone was significantly larger in dissection and aneurysm patients compared with trauma patients ($p < .01$) (Table 1). There were also significantly more inverted funnel shapes in aneurysm patients than in dissection or trauma patients ($p < .01$) (Table 1).

## DISCUSSION

Characterizing the aortic arch morphology and length of various patient populations is needed for proper device choice and sizing and advances in stent-graft technology. In

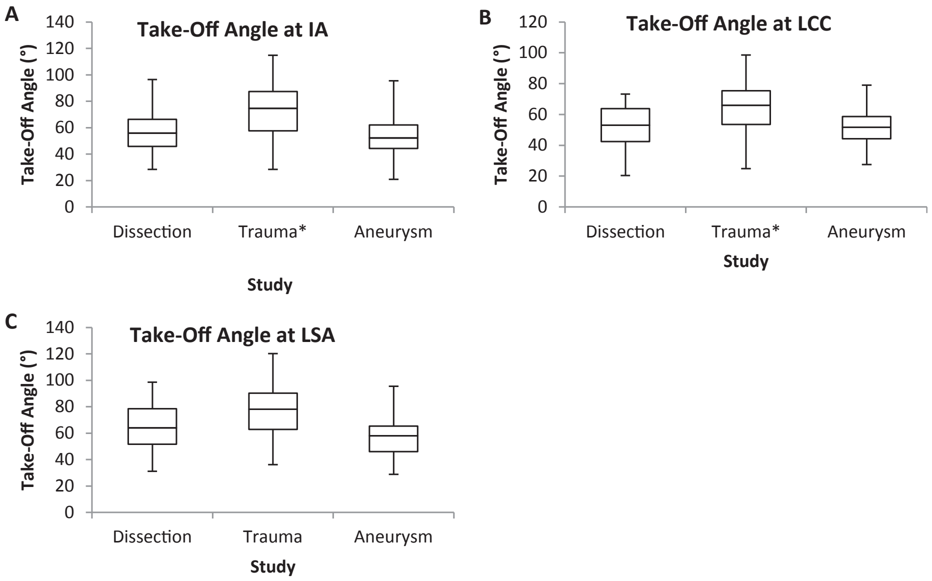

**Figure 4.** Take-off angles of IA, LCC, and LSA in trauma, dissection, and aneurysm patients. (A) Take-off angle of IA. (B) Take-off angle of LCC. (C) Take-off angle of LSA.

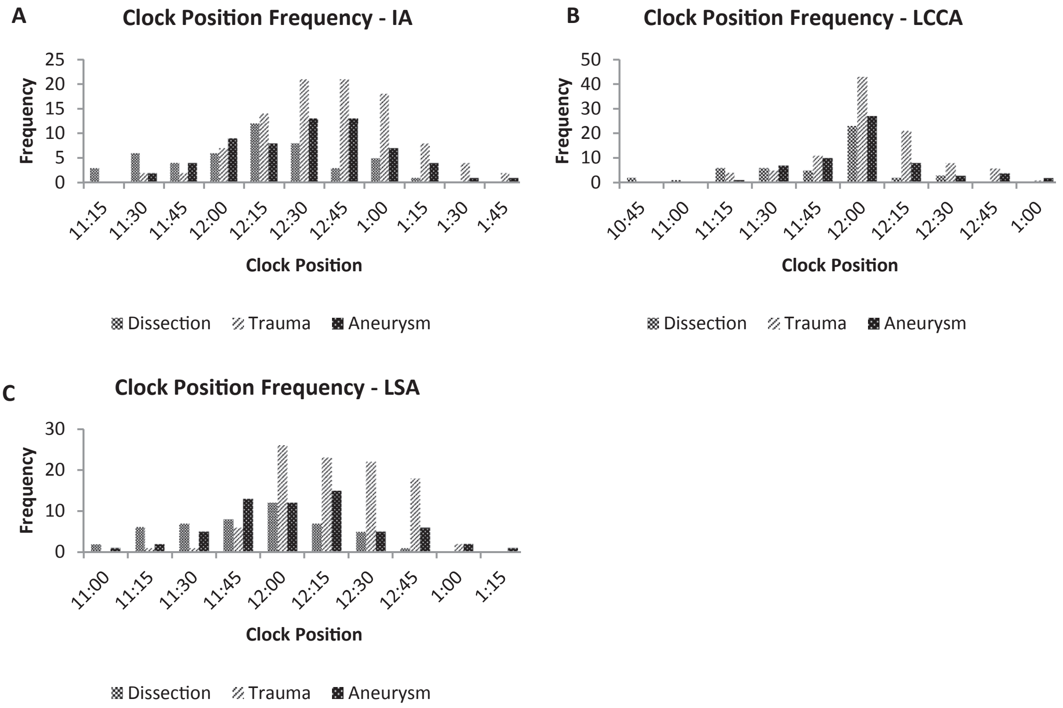

**Figure 5.** Clock position of IA, LCC, and LSA in trauma, dissection, and aneurysm patients. (A) Clock position frequency at IA. (B) Clock position frequency at LCC. (C) Clock position frequency at LSA.

this study, 78% of the patients showed the IA, LCC, and LSA originating independently from the aortic arch, with 22% having common trunk configurations. This finding is similar to that of Alsaif and Ramadan, who found that 75% of 30 adult human preserved cadavers had a common branching pattern.[16] Berko et al. evaluated 1000 adult CT angiograms (CTAs) of the chest and found that 65.9% of the patients had the IA, LCC, and LSA branch independently.[17] Determining the prevalence of aortic arch branching pattern variants is useful for pre-procedure planning and for future stent-graft technology that can accommodate a wide variety of aortic pathologies.

Results of the present study show that trauma patients had smaller aortic and branch vessel diameters compared with those in dissection and aneurysm patients. However, the ranges of measurements did overlap between the patient groups. Prior studies have compared the diameters of the aorta in various population groups. Malkawi et al. found that the mean ostial diameters of the IA, LCC, and LSA were not significantly different between dissection and aneurysm patients.[14] Similar results were observed in this study, with the only significant difference between dissection and aneurysm patients being the diameter of the LSA. In addition, Malkawi et al. showed that the diameter of the aortic arch increased as it approached the aortic root, which is comparable with the measurements obtained in the present study.[14]

In a comparison of patients with aneurysms to patients with normal aortas, Pearce et al. demonstrated that at all levels of the aorta, the aortic diameter is larger in aneurysmal patients compared with normal patients.[18] They also found that the normal aorta enlarges with increasing age, which is analogous with prior studies.[18–20] This is consistent with the present comparison, as the mean age of trauma patients was 14 years and 29 years younger than dissection and aneurysm patients, respectively, and the aortic and branch vessel diameters were smallest in trauma patients. These differences in aortic diameter highlight the need for various device sizes that appropriately accommodate the three patient populations. In addition, longitudinal data that captured the rate of diameter change in the ascending aorta as the patient ages could provide further insight into how well a device is able to maintain a static position in the ascending aorta as the aorta continues to dilate because of high pressures.

Related to aortic length, trauma patients were found to have significantly shorter distances between the LMC and LCC and LSA compared with dissection and aneurysm patients. Malkawi et al. also found no significant differences in the aortic length measurements between dissection and

**Table 1.** Configuration of proximal sealing zone in trauma, dissection, and aneurysm patients.

| | *n* | Max diameter, mm | Sealing length, mm | Neck angle, ° | Inverted funnel shape, % |
|---|---|---|---|---|---|
| Trauma | 94 | 24.51 ± 4.61 | 16.60 ± 8.94 | 21.53 ± 9.19 | 3.19 |
| Dissection | 44 | 31.65 ± 5.06 | 17.98 ± 13.31 | 30.67 ± 8.39 | 2.27 |
| Aneurysm | 57 | 32.20 ± 5.42 | 37.45 ± 19.37 | 28.75 ± 10.58 | 22.81 |

aneurysm patients.[14] The differences between trauma patients and dissection and aneurysm patients could be related to the age of the patient populations. Sugawara et al. observed a positive correlation ($r = 0.72$) between the ascending aortic length and patient age and found that this correlation increased significantly with aging patients.[21] A possible explanation for this relationship could be associated with the proximal aorta exerting more fatigue as the patient ages.[22] In this study, no significant difference was found in the lengths between the CA and renal arteries, which is consistent with Sugawara et al. finding a weak correlation ($r = 0.13$) between the lengths of the descending aorta and patient age.[21]

The correlation between age of the patient and TOA of the branch vessels also has been evaluated.[23,24] Zamir et al. found the mean TOA of the IA, LCC, and LSA to be 56.4°, 58.4°, and 66.5°, respectively, with no correlation observed between TOA and patient age.[24] This is in contrast with the significantly positive correlation found between the TOA of the LCC and LSA and patient age by Demertzis et al.[23] In the present comparison, trauma patients were observed to have a significantly larger TOA of the IA and LCC than dissection or aneurysm patients. With the mean age of the trauma patients being younger than dissection or aneurysm patients, this finding does not support the results from Demertzis et al.[23] The mean age of the 92 patients evaluated by Demertzis et al. was 69.4 years, 26 years older than the mean age of the trauma population, and this difference in the age groups evaluated could account for the inconsistent results. The TOA measurements of the IA and LCC were similar to the dissection and aneurysm patients evaluated by Malkawi et al., which found the mean TOA of the IA and LCC to be $49^\circ \pm 11^\circ$ and $48^\circ \pm 10^\circ$, respectively.[14] The varying TOAs between the patient populations illustrate the need for branched devices that can be utilized in differing pathologies.

There are limitations with this study. The authors were masked to individual patient identifying information, including unique gender and age data. Given that CTAG studies are currently still in progress, there was no access to patient clinical information. In addition, only those patients deemed candidates for the CTAG device were studied.

## CONCLUSION

In conclusion, significant morphologic differences were found in the arch anatomy of trauma, dissection, and aneurysm patients. Trauma patients were observed to have significantly smaller aortic and branch vessel diameters, significantly shorter aortic lengths, and larger TOA at the IA and LCC when compared with dissection and aneurysm patients. In general, dissection and aneurysm patients were found to exhibit similar aortic arch morphologies. Describing these differences in a large sample of patients, from varying patient populations, is beneficial for device designs and patient selection, which plays a critical role in patient outcomes.

## CONFLICT OF INTEREST

BW: Quality engineer at W.L Gore. He started this position in August 2014, several months after the study and manuscript were completed. RC: Research support from W.L. Gore. MF: Consults for W. L. Gore, Cook, Bolton, and Endologix and has research grants with Cook. WJ: Consults for W. L. Gore, Medtronic, Endologix, Aptus, and Lombard and has research grants with W.L. Gore, Medtronic, Endologix, Lombard, Cordis, Aptus, and Trivascular. AA: Consults for W. L. Gore and Medtronic. JR: Consults for W.L. Gore. JM: Research grants with Abbott, Covidien, Cook, Endologix, W. L. Gore and NIH.

## FUNDING

None.

## REFERENCES

1 Bell RE, Taylor PR, Aukett M, Sabharwal T, Reidy JF. Mid-term results for second-generation thoracic stent grafts. *Br J Surg* 2003;**90**:811—7.

2 Cambria RP, Crawford RS, Cho JS, Bavaria J, Farber M, Lee WA, et al. A multicenter clinical trial of endovascular stent graft repair of acute catastrophes of the descending thoracic aorta. *J Vasc Surg* 2009;**50**:1255—64.

3 Czerny M, Zimpfer D, Rodler S, Funovics M, Dorfmeister M, Schoder M, et al. Endovascular stent-graft placement of aneurysms involving the descending aorta originating from chronic type B dissections. *Ann Thorac Surg* 2007;**83**:1635—40.

4 Dake MD, Miller DC, Semba CP, Mitchell RS, Walker PJ, Liddell RP. Transluminal placement of endovascular stent-grafts for the treatment of descending thoracic aneurysms. *N Engl J Med* 1994;**331**:1729—34.

5 Dake MD, Kato N, Mitchell RS, Semba CP, Razavi MK, Shimono T, et al. Endovascular stent-graft placement for the treatment of acute aortic dissection. *N Engl J Med* 1994;**340**:1546—52.

6 Azizzadeh A, Charlton-Ouw KM, Chen Z, Rahbar MH, Estera AL, Amer H, et al. An outcome analysis of endovascular versus open repair of blunt traumatic aortic injuries. *J Vasc Surg* 2013;**57**:108—14.

7 Demetriades D, Velmahos GC, Scalea TM, Jurkovich GJ, Karmy-Jones R, Teixeira PG, et al. Operative repair of endovascular stent graft in blunt traumatic thoracic aortic injuries: results of an American Association for the Surgery of Trauma Multicenter Study. *J Trauma* 2008;**64**:561—71.

8 Jonker FHW, Giacovelli JK, Muhs BE, Sosa JA, Indes JE. Trends and outcomes of endovascular and open treatment for traumatic thoracic injury. *J Vasc Surg* 2010;**51**:565—71.

9 Leurs LJ, Bell R, Degrieck Y, Thomas S, Hobo R, Lundbom J. on behalf of the EUROSTAR and the UK Thoracic Endograft Registry collaborators. Endovascular treatment of thoracic aortic diseases: combined experience from the EUROSTAR and United Kingdom Thoracic Endograft registries. *J Vasc Surg* 2004;**40**:670—80.

10 Makaroun MS, Dillavou ED, Wheatley GH, Cambria RP. Gore TAG Investigators. Five-year results of endovascular treatment with the Gore TAG device compared with open repair of thoracic aortic aneurysms. *J Vasc Surg* 2008;**47**:912—8.

11 Matsumura JS, Cambria RP, Dake MD, Moore RD, Svensson LG, Snyder S. International controlled clinical trial of thoracic

endovascular aneurysm repair with the Zenith TX2 endovascular graft: 1-year results. *J Vasc Surg* 2008;**47**:247—57 [discussion 57].

12 Hinchliffe RJ, Krasznai A, Schultzekool L, Blankensteijn JD, Falkenberg M, Lonn L, et al. Observations on the failure of stent-grafts in the aortic arch. *Eur J Vasc Endovasc Surg* 2007;**34**:451—6.

13 Melissano G, Civilini E, Bertoglio L, Calliari F, Setacci F, Calori G, et al. Results of endografting of the aortic arch in different landing zones. *Eur J Vasc Endovasc Surg* 2007;**33**:561—6.

14 Malkawi AH, Hinchliffe RJ, Yates M, Holt PJ, Loftus IM, Thompson MM. Morphology of aortic arch pathology: implications for endovascular repair. *J Endovasc Ther* 2010;**17**:474—9.

15 Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap) — a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform* 2009;**42**:377—81.

16 Alsaif HA, Ramadan WS. An anatomical study of the aortic arch variations. *JKAU: Med Sci* 2010;**17**:37—54.

17 Berko NS, Jain VR, Godelman A, Stein EG, Ghosh S, Harmati LB. Variants and anomalies of thoracic vasculature on computed tomographic angiography in adults. *J Comput Assist Tomogr* 2009;**33**:532—8.

18 Pearce WH, Slaughter MS, LeMaire S, Salyapongse AN, Feinglass J, McCarthy WJ, et al. Aortic diameter as a function of age, gender, and body surface area. *Surgery* 1993;**114**:691—7.

19 Dixon AK, Lawrence JP, Mitchell JR. Age-related changes in the abdominal aorta shown by computed tomography. *Clin Radiol* 1984;**35**:33—7.

20 Horejs D, Gilbert PM, Burstein S, Vogelzang RL. Normal aortoiliac diameters by CT. *J Comput Assist Tomogr* 1988;**12**:602—3.

21 Sugawara J, Hayashi K, Yokoi T, Tanaka H. Age-associated elongation of the ascending aorta in adults. *JACC Cardiovasc Imaging* 2008;**1**:739—48.

22 Nichols W, O'Rourke MF. *McDonald's blood flow in arteries: theoretical, experimental and clinical principles*. 5th ed. London: Arnold; 2005.

23 Demertzis S, Hurni S, Stalder M, Gahl B, Herrmann G, Van den Berg J. Aortic arch morphometry in living humans. *J Anat* 2010;**217**:588—96.

24 Zamir M, Sinclair P. Origin of the brachiocephalic trunk, left carotid, and left subclavian arteries from the arch of the human aorta. *Invest Radiol* 1991;**26**:128—33.