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FULL PAPER

CT patterns of acute type A aortic arch dissection: longer, higher, more anterior

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Objectives: This study analysed CT patterns of the acute dissected aortic arch using original biometric features along with comparison with normal aortas.

Methods: The diagnostic CT scans of 57 patients (42 males, age (mean $\pm$ SD: 64.5 $\pm$ 13.8 years) admitted with acute Stanford type A dissection involving the aortic arch were analysed by semi-automatic detection protocol of the true lumen of the dissection. We measured the distances from the apex to the ascending and descending aorta, the curvilinear length of the entire arch and of its segments (especially between the brachiocephalic artery trunk and the left subclavian artery), as well as the surface area, angle, height and shift of the arch. These measurements were compared with results previously obtained in a healthy cohort in an analysis adjusted for age, sex and weight. The surface area and rotation of the false lumen were also analysed.

Results: Compared to normal aortic arches (N), dissected aortic arches (D) were longer (D: 155 $\pm$ 26 mm, N: 135 $\pm$ 25 mm, p = 0.002), higher (D: 51 $\pm$ 10 mm, N: 45 $\pm$ 9 mm, p = 0.04), and with a more anterior apex (shift: D: 1.19 $\pm$ 0.56, N: 1.40 $\pm$ 0.62, p = 0.007). False lumen occupied between 47–65% of the aorta, turned preferentially clockwise and its rotation decreased progressively along the arch.

Conclusions: The morphology of the dissected aortic arch differs from that of the normal arch. Thus, our compilation of aortic arch measurements may help improve existing endovascular devices and/or design of new endoprostheses.

Advances in knowledge: In this article, we provide a comprehensive set of measurements of the dissected aortic arch, and show that dissected aortic arches are longer, higher, and with a more anterior apex than normal arches.

INTRODUCTION

Treatment of the aortic arch, particularly when acutely dissected, is a complex procedure, owing to its anatomy and role in cerebral vascularization.^{1,2} Procedures combining surgical and endovascular techniques have been reported^{3,4} but are still undergoing evaluation and there are few reports of successful endovascular procedures.^{5,6} The lack of evidence may be due to the complex anatomy of the dissected arch and insufficiently adapted endoprostheses.^{7–9}

The development of endovascular-dedicated devices requires detailed knowledge of the anatomy of dissected aortic arches. While the anatomical characteristics of the aortic arch have been radiologically established,^{10,11} descriptions of dissected arches are less common. In a transoesophageal echocardiography study, Parish et al¹² showed that dissected ascending aortas were mildly dilated,

62% of which were smaller than 55 mm. CT examinations of dissected arches have generally been used only for measuring aortic diameter in pre-therapeutic studies.¹³ Using CT, Ryłski et al¹⁴ recently found that the ascending aorta increased in diameter after dissection, deforming the arch and descending aorta. However, changes in aortic length and angulation are poorly documented.

The objective of this CT-based study was to better establish the morphology of dissected arches in comparison with that of normal arches.

METHODS AND MATERIALS

Patients

Patients treated in our hospital between 1 June 2007 and 1 June 2013 for acute type A aortic dissection (stanford classification) involving all or part of the aortic arch were

included. All had a pre-therapeutic evaluation of the dissection by CT angiography. Exclusion criteria were a type A dissection confined to the ascending aorta, a type B dissection, and an aortic intramural hematoma.

Patients were retrospectively identified from our hospital's Radiology Information System (Xplore, EDL, La Seyne-sur-Mer, France) and the cardiovascular surgery service database. Patient characteristics were collected prospectively at admission. The scans were retrieved from the picture archiving and communication system or from digital backup copies from patient files. All patients with an available CT angiography were included.

Sex, age, body weight, height, main cardiovascular risk factors, collagen or elastic fibre diseases, body mass index and body surface area were matched with the corresponding images and rendered anonymous. This descriptive, retrospective, observational single-centre study was conducted according to ethical principles for medical research involving human subjects in French university hospitals.¹⁵

CT-scan analysis

47 (82%) of the initial scans were performed in our hospital. The remaining were performed in outlying hospitals and were considered to be of sufficient quality at the time of admission for them not to be repeated. ECG-gating was performed in 8 patients (14%) with data acquired during cardiac diastole. All scans used a 512×512 matrix and were of sufficient quality to be analysed further (median slice thickness: 1.25 mm, median tube voltage: 120 kV, median tube current: 347 mA, median field of view: 403 mm, median collimation: 1.25 mm, median pitch: 1.375, median rotation time: 0.7 s, median number of detectors: 16, median dose-length product and volume CT Dose Index (CTDIvol) of the arterial phase: 972 mGy.cm and 15.76 mGy, median contrast volume: 100 ml, median contrast concentration: 400 mg.ml^{-1}).

Scans were analysed on a General Electric Advantage Workstation 4.4 (General Electric, Waukesha, WI), using a semi-automatic segmentation of the true lumen of the aorta based on the density difference between the two lumens. Measurements were made by a single operator. A curvilinear reconstruction of the aortic arch was performed and the centreline in the true lumen was automatically determined, given that the centreline of flow has already been used to assess thoracic stent graft migration¹⁶ or the morphology of dissected aortas.^{14,17} Reference points and measurements were based on those used in a previous anatomical study of normal arches.¹¹ The analysed segment, referred to as "aortic arch", extended from the true lumen centre in the ascending thoracic aorta at the mid-level of the right pulmonary artery flow (A) to the corresponding point of the descending aorta (D). The following were defined on the centreline (Figure 1): (i) the most cranial point of the centreline (apex of the arch) (point C), (ii) the points of the centreline located at the anterior margin of the brachiocephalic artery trunk, at the posterior margin of the left common carotid artery and at the posterior margin of the left subclavian artery (BCT, LCCA and LSCA, respectively), and (iii) a point 5 cm

Figure 1. Geometrical constructions. (a) "Volume rendering" reconstruction of the aortic arch with the positions of reference points. A and D, true lumen centre at the mid-level of the right pulmonary artery flow in ascending and descending thoracic aorta, respectively. C (Apex), highest point in the centre flow line of the true lumen; Cp, orthogonal projection of C on the AD line; BCT, brachiocephalic artery trunk; LCCA, left common carotid artery; LSCA, left subclavian artery; 5LSCA, 5 cm downstream LSCA. (b) Position of the clock face dial serving as a locator of the intimal flap junction points for the different measurement sites. 12 o'clock is on the greater curve of the arch. LL, longest length of the aortic arch; SL, shortest length of the aortic arch; Med, medial.

downstream of the LSCA point corresponding to the proximal descending aorta (5LSCA), since it represents a possible landing zone for endoprostheses. Point Cp is the orthogonal projection of C on the AD line.

Figure 2. Aortic shift. (a) Schematic description of the shift, corresponding to the ACp/CpD ratio. (b and c) Examples of dissected aortic arches with extreme shift value. (A) and (D), true lumen centre at the mid-level of the right pulmonary artery flow in, respectively, ascending and descending thoracic aorta. C (Apex), highest point in the centre flow line of the true lumen; Cp, orthogonal projection of C on the AD line.

Measurements

Curvilinear lengths were automatically measured along the previous centreline for the aortic arch (A-D) and the different segments (LSCA-C segment was negative when C was upstream of LSCA). Using the coordinates of A, C and D (thus in the ACD plane), the rectilinear transverse AD, ascending AC and descending CD lengths, the height of the arch (CCp), and the shift (ACp/CpD ratio, see Figure 2) were calculated, as well as angles in the ACD triangle. The surface area (SA) of the total aorta, true and false lumen at A, BCT, LCCA, LSCA, 5LSCA and D were measured (with an automated measurement for the true lumen, a manual contouring for the total aorta, and by computing the difference between these two measurements for the false lumen).

Comparison with healthy subjects

The biometric measurements of the dissected aortic arches were compared with previously obtained values on “normal for the age” aortas, using the same reference points.¹¹ They were measured on 344 patients (182 males) who had a contrast-enhanced thoracic CT-scan requested by hospital departments without cardiovascular activity, no vascular disease on CT-scan

(except uncomplicated atheroma) and no history of cardiac or thoracic surgery.

False lumen analysis

The entry sites of the false lumen, the position of the false lumen and its rotation were also studied. If entry sites were visible, the curvilinear lengths between BCT and these entry sites were assessed, and denoted negatively or positively when the sites were upstream or downstream of BCT, respectively. At BCT, LCCA, LSCA and 5LSCA, the junction sites of the intimal flap with the aortic wall and the positions of the different lumens relative to these junction sites were placed onto a clock face perpendicular to the flow, with 12 o'clock on the greater curve of the arch (Figure 1). The position of the false lumen was defined by the clock position that corresponded to the middle of the false lumen arc; these positions were grouped into 4 quadrants of 3 h each, centred on 12 (superior quadrant), 6 (inferior quadrant), 3 and 9 o'clock (lateral quadrants). The false lumen rotation was determined by following the change in the clock position of the false lumen between the reference points (Figure 3) and was divided by the curvilinear length between these points to obtain the speed of rotation.

Statistical analysis

Categorical variables are described as frequencies and proportions while continuous data are presented as the mean $\pm$ SD, unless stated otherwise. Distributions of continuous variables were evaluated systematically by a test of normality. The alpha risk was set at 5% and no correction for multiple testing was necessary. Between the different measurement points, comparisons of means were performed by analysis of variance and categorical variables were compared by Fisher's exact tests. Continuous variables characterizing normal and dissected aorta were initially compared without adjustment by Student's *t*-test or Wilcoxon test as appropriate. An additional analysis was performed with a generalized linear model adjusting for age, sex and body weight by direct tercile standardization. The raw and adjusted dissection odds-ratio was calculated for each biometric

Figure 3. Example of a -30° (-1 h) rotation of the false lumen between brachiocephalic artery trunk and left common carotid artery.

Table 1. Patient characteristics

	n	Mean $\pm$ SD (or median [1st quartile – 3rd quartile])
Age	57	64.5 $\pm$ 13.8
Weight (kg)	50	81.5 $\pm$ 16.2
Height (cm) ^a	50	172.5 [165–179]
BMI ^a	50	27.5 [23.2–30.5]
BSA (m ²)	50	1.96 $\pm$ 0.22
Cardiovascular risk factors	50	
Hypertension	42 (84%)	
Smokers	12 (24%)	
Diabetes	4 (8%)	
Dyslipidemia	12 (24%)	

BMI, body mass index; BSA, body surface area calculated according to the Mosteller formula.

^aSignificant test of normality, rejecting the hypothesis of a normal distribution.

parameter by logistic regression for raw and standardized data. Statistical analysis was performed with SAS 9.4 software (SAS Institute Inc., Cary, NC).

RESULTS

The scans of 57 patients (45 males) were analysed (average age: 65 $\pm$ 14 years). Clinical data were complete for 50 (88%) patients who underwent surgery (Table 1).

Aortic arch

Table 2 shows the curvilinear and rectilinear aortic arch lengths, SA and angles. It can be seen that the SA of the aorta varied significantly ($p < 0.001$) along the arch, decreasing from 1418 $\pm$ 421 mm² at BCT to 961 $\pm$ 259 mm² at LCCA, 803 $\pm$ 205 mm² at LSCA and 868 $\pm$ 255 mm² at 5LSCA. The distribution of the angle at the apex was unimodal, without two clear populations of angulation, although 4 (7%) patients had an angle under 60°. In the unadjusted analysis, the rectilinear transverse and ascending lengths were significantly longer in dissected arches than in normal arches ($p = 0.001$ and $p = 0.038$, respectively), as well as the curvilinear length of the descending aorta ($p = 0.004$). These differences were no longer significant after adjustment. The other significant differences in the unadjusted analysis remained significant after adjustment. In the adjusted analysis (Table 3), the dissected arches were longer than the normal arches, although the curvilinear length of the BCT-LSCA segment was not significantly different between dissected and normal aortas, as well as distances between supra-aortic trunks. Dissected ascending aortas had a longer curvilinear length than normal aortas, although their rectilinear length was not significantly different. In contrast, dissected descending aortas had a longer rectilinear length whereas their curvilinear length was not significantly different in normal arches. The SA of the dissected (D) arches was greater than the SA of normal (N) arches at BCT

Table 2. Biometric variables of the aortic arch. Lengths are in mm, angles are in degrees. A and D, true lumen centre at the mid-level of the right pulmonary artery flow in ascending and descending thoracic aorta, respectively

	Mean $\pm$ SD (or median [1st quartile – 3rd quartile])
Curvilinear length	
Arch	155 $\pm$ 26
BCT-LSCA	35 $\pm$ 9
Ascending aorta	45 $\pm$ 11
BCT-LCCA	19 $\pm$ 7
LCCA-LSCA ^a	16 [12–18]
LSCA-C	−0.8 $\pm$ 12.9
Descending aorta	75 $\pm$ 18
Rectilinear length	
Transverse (AD)	85 $\pm$ 17
Ascending (AC)	68 $\pm$ 13
Descending (CD)	67 $\pm$ 11
Aortic arch height	51 $\pm$ 10
Angle	
Apex	79 $\pm$ 13
Ascending	50 $\pm$ 8
Descending	51 $\pm$ 10
Shift ^a	1.07 [0.78–1.49]

C (Apex), highest point in centre flow line of the true lumen; BCT, brachiocephalic artery trunk; LCCA, left common carotid artery; LSCA, left subclavian artery.

^aSignificant test of normality, rejecting the hypothesis of a normal distribution.

(D: 1418 $\pm$ 421 mm², N: 701 $\pm$ 181 mm², $p < 0.0001$), LCCA (D: 961 $\pm$ 259 mm², N: 554 $\pm$ 135 mm², $p < 0.0001$), and LSCA (D: 803 $\pm$ 205 mm², N: 482 $\pm$ 242 mm², $p < 0.0001$). Figure 4 summarizes these differences.

Intimal flap and false lumen

27 (47%) patients had no visible entry point along the aortic arch (Figure 5). A single intimal tear was found in 25 (44%) patients (15 upstream of BCT, and 10 downstream), 4 (7%) had 2 intimal tears and 1 (1.8%) patient had 3 tears. The first “downstream of BCT” entry point was located at 24 $\pm$ 15 mm. Three types of false lumen (Figure 6) were identified, defined by the number of junction points between the intimal flap and the aortic wall: two junction points (type 1), more than two junction points (type 2), and no junction points (type 3) (Table 4). The type of false lumen could change between two points – 15 (26%) changed between BCT and LCCA, 13 (23%) between LCCA and LSCA, and 12 (21%) between LSCA and 5LSCA. The proportion of the aorta occupied by the false lumen varied significantly ($p < 0.001$) according to the measurement point. The false lumen occupied a progressively decreasing proportion of the aorta between BCT and LSCA while it increased at 5LSCA (Table 4).

Table 3. Comparison of biometric values of healthy and dissected aortic arches. Lengths are in mm, surface areas are in mm², angles are in degrees. A and D, true lumen centre at the mid-level of the right pulmonary artery flow in ascending and descending thoracic aorta, respectively

	Unadjusted means $\pm$ SD		Analysis adjusted for sex, age and weight [95% confidence interval]	
	Non-dissected	Dissected	Odds-ratios for the occurrence of a dissection ^a	<i>p</i>
Curvilinear length				
Arch (A–D)	135 $\pm$ 25	155 $\pm$ 26	1.568 [1.17–2.102]	0.0022*
BCT–LSCA	33 $\pm$ 7	35 $\pm$ 9	0.937 [0.701–1.254]	0.66
Ascending aorta	34 $\pm$ 8	45 $\pm$ 11	2.171 [1.588–2.968]	<0.0001*
BCT–LCCA	18 $\pm$ 4	19 $\pm$ 7	1.069 [0.804–1.421]	0.72
LCCA–LSCA	16 $\pm$ 5	16 $\pm$ 5	0.803 [0.594–1.086]	0.13
LSCA–C	3.3 $\pm$ 10.3	–0.8 $\pm$ 12.9	0.726 [0.539–0.978]	0.034*
Descending aorta	68 $\pm$ 18	75 $\pm$ 18	1.203 [0.903–1.602]	0.21
Rectilinear length				
Transverse (AD)	79 $\pm$ 14	85 $\pm$ 17	1.036 [0.776–1.382]	0.81
Ascending (AC)	64 $\pm$ 13	68 $\pm$ 13	0.968 [0.724–1.293]	0.83
Descending (CD)	57 $\pm$ 9	67 $\pm$ 11	1.954 [1.439–2.653]	<0.0001*
Height	45 $\pm$ 9	51 $\pm$ 10	1.35 [1.013–1.799]	0.040*
Angle				
Apex	82 $\pm$ 11	79 $\pm$ 13	0.751 [0.562–1.005]	0.053
Ascending	46 $\pm$ 6	50 $\pm$ 8	2.019 [1.498–2.722]	0.0001*
Descending	53 $\pm$ 8	51 $\pm$ 10	0.901 [0.673–1.205]	0.48
Shift	1.40 $\pm$ 0.62	1.19 $\pm$ 0.56	0.643 [0.456–0.908]	0.0074*

C (Apex), highest point in centre flow line of the true lumen; BCT, brachiocephalic artery trunk; LCCA, left common carotid artery; LSCA, left subclavian artery.

*Value is significant.

^aThe reference risk level for the odds-ratio calculations is one non-dissected aorta with biometric characteristics equal to the average. Odds-ratios were calculated for an increase in one SD for the studied parameter.

Figure 4. Schematic comparison of the morphology of normal and dissected aortic arches. Dissected arches are longer, higher, wider, and with a more anterior apex than normal arches. BCT, brachiocephalic artery trunk; LCCA, left common carotid artery; LSCA, left subclavian artery.

Figure 5. Positions of the entry sites of the false lumen.

Distribution of the rotation of the false lumen and its average speed are shown in Table 5. When the type of false lumen changed between reference points, analysis of the false lumen rotation was conservative and considered the smallest possible rotation. Between BCT and 5LSCA, 31 (54%) patients combined clockwise and counter-clockwise rotations. Regardless of the direction of rotation, the rotation speed significantly decreased ($p < 0.001$) from BCT to 5LSCA (BCT-LCCA: 2.8 ± 3.4 degree. mm^{-1} , LCCA-LSCA: 1.4 ± 1.8 degree. mm^{-1} , LSCA-5LSCA: 1.1 ± 0.7 degree. mm^{-1}).

At BCT, false lumens were equally distributed in the superior and both lateral quadrants (around 33% each), whereas they were only in the lateral quadrants at LCCA and LSCA (90 and 89% of the false lumens, respectively), and mostly in the superior quadrant at 5LSCA (60% of the false lumens).

DISCUSSION

The clear male predominance (79% males), the high prevalence of hypertension (84%) and the occurrence of an aortic dissection at around 60 years of age in our population were similar to the demographic characteristics reported in the International Registry of Acute Aortic Dissection (67% males, 67% hypertension prevalence, dissection occurring on average at 61 years).¹⁸

Dissected arch morphology

In this study, we found a mean length for the dissected aortic arch of 155 mm, with an average BTC-LSCA distance of 35 mm. Rylski et al¹⁴ reported a similar length (41 mm) for this segment on dissected aortic arch. On the basis of adjusted data, the apex of the dissected arches was located 6 mm higher and was more anterior (both respectively to the whole arch and respectively to the origin of the supra-aortic trunks) than in normal aortas. This displacement of the apex has, to our knowledge, never been

described. The increase observed in the curvilinear length of the ascending aorta was not accompanied by an increase in the ascending rectilinear length, which suggests that the ascending aorta is more curved in the oblique “sagittal” plane among patients with dissections. The measurement points used herein did not allow a direct measurement of this curvature, although our results are in accordance with those of Rylski et al,¹⁴ who found a significant increase in the index of tortuosity (the ratio of curvilinear to rectilinear length) at the level of the ascending aorta after dissection. Similarly, an increase in the descending rectilinear length without an increase in the curvilinear length of the descending aorta suggests that it is less curved among dissected patients.

Given the absence of data on aortic arch morphology before dissection, we were unable to determine whether the differences observed between normal and diseased aortas were secondary to the dissection or were pre-existing and, in the latter case, could correspond to an aortic morphology with a higher risk for dissection. However, wider aortas in the dissection group were expected owing to the fragility of the aortic wall secondary to dissection, and evidence from previous studies suggest that the diameter of the aortic arch is generally normal before dissection: in IRAD, only 6.8% of patients had a known pre-existing aortic aneurysm¹⁸ and only one patient (1.6%) in the study of Rylski et al¹⁴ had an aortic diameter greater than 5.5 cm before dissection. Rylski et al also suggest that the differences in length are secondary to the dissection.

False lumen morphology

We found that the false lumen occupied 47 to 65% of the aorta, although the systolic and diastolic movement of the intimal flap could not be analysed in our study, whereas Weber et al¹⁹ reported that the proportion of the aorta occupied by the true

Figure 6. Types of false lumens. Type 0 corresponds to an absence of a false lumen (*), type 1 to an intimal flap with two junction points, type 2 to an intimal flap with more than two junction points and type 3 to an intimal flap without a junction point [a circular false lumen around the true lumen (+)].

lumen could vary from approximately 15 to 25% during the cardiac cycle (in descending dissected aorta). This may partially explain the difference with the measurements of Sobocinski et al¹³: in their study, the proportion of the aorta occupied by the false lumen, computed from their diameters, varied between 21 and 30% of the aorta (assuming the aorta and the true lumen are

circular). However, our study evaluated SAs and not diameters, which are less sensitive to variations in the shape of the lumens.

The presence of multiple false lumens has previously been described, albeit mostly among patients with prior incidences of dissection.^{20,21} Multiple intimal flap junction points,

Table 4. Distribution of the types of false lumens according to the number of junction points of the intimal flap with the aortic wall, and proportion of the aortic surface area occupied by the false lumen at the level of reference points

	False lumen				Proportion of the aortic surface area occupied by the false lumen
	None	Type 1	Type 2	Type 3	Mean $\pm$ SD
BCT	0 (0%)	45 (78.9%)	11 (19.3%)	1 (1.8%)	0.6 $\pm$ 0.14
LCCA	0 (0%)	44 (77.2%)	13 (22.8%)	0 (0%)	0.52 $\pm$ 0.12
LSCA	3 (5.3%)	45 (78.9%)	9 (15.8%)	0 (0%)	0.47 $\pm$ 0.12
5LSCA	7 (12.3%)	50 (87.7%)	0 (0%)	0 (0%)	0.65 $\pm$ 0.13

BCT, brachiocephalic artery trunk; LCCA, left common carotid artery; LSCA, left subclavian artery; 5LSCA, 5 cm downstream LSCA.

Table 5. Rotation of the false lumen between reference points. When the type of false lumen changed between reference points, analysis of the false lumen rotation was conservative and considered the smallest possible rotation. Rotation speed is obtained by dividing the rotation angle by the curvilinear distance between reference points. Clockwise rotation is significantly more frequent than counter-clockwise rotation ($p = 0.001$), but rotation direction differs significantly ($p = 0.001$) depending on measurement site

	Clockwise rotation		Counter-clockwise rotation		No rotation	
	n	Average rotation speed	n	Average rotation speed	n	
BCT-LCCA	26 (46%)	3.8 degree.mm ⁻¹ [2.2–5.5]	23 (40%)	–2.7 degree.mm ⁻¹ [–3.7 – –1.7]	8 (14%)	57
LCCA-LSCA	17 (31%)	2.6 degree.mm ⁻¹ [1.6–3.5]	16 (30%)	–2.1 degree.mm ⁻¹ [–2.9 – –1.2]	21 (39%)	54
LSCA-5LSCA	27 (54%)	1.2 degree.mm ⁻¹ [0.9–1.4]	19 (38%)	–1.2 degree.mm ⁻¹ [–1.4 – –1.0]	4 (8%)	50
	70 (43%)		58 (36%)		33 (20%)	161

BCT, brachiocephalic artery trunk; LCCA, left common carotid artery; LSCA, left subclavian artery; 5LSCA, 5 cm downstream LSCA.

delineating several false lumens, probably represent local segmentation of the one and same false lumen, since the true lumen generally becomes fixed near the supra-aortic trunks in the greater curvature.²² Nagamine *et al*²³ described a similar cross-sectional CT aspect of “bilateral” false lumen at BCT and LSCA in about 40% type A aortic dissection, associated in 72% of the cases with an extension of the dissection to the supra-aortic trunks.

In our investigation, the extent of the false lumen rotation appeared to decrease progressively along the arch, regardless of rotation direction. There was a predominant clockwise rotation of the false lumen, although more than half of the patients combined clockwise and counter-clockwise rotation. This could result from the appearance of turbulent (especially helical) flow patterns in aortic dissections, as can occur in healthy subjects^{24,25} and also suggested by simulations.²⁶ The distribution of the positions of the false lumens suggests that from a variable position in the ascending aorta, the false lumen rotates to the lateral quadrants of the horizontal segment of the arch, and turns again to a posterior position in the descending aorta.

Clinical applications

One of the limitations of endovascular stenting on the aortic arch is its particular shape, which may lead to a lack of apposition of the stent along the aortic wall. This may lead to an endoleak or to a collapse of the stent, with major morbidity and mortality.^{7–9} In particular, an acute angle of the aortic arch has been implicated in stent-graft collapse, although several measurement methods have been described, rendering the establishment of a common threshold difficult to determine. Even though, as others,²⁷ we were unable to individualize several types of arch angulation, 7% of our patients had an apex angle under 60°. Thus, characterizing the aortic arch morphology is helpful for proper device choice and sizing. A better knowledge of this morphology may help in designing endovascular devices that are more suited to the angulation, diameter or length of the aortic arch. In the absence of a significant difference between dissected and normal aorta regarding the length of the BCT-LSCA segment, and for the lengths separating the supra-aortic trunks, it may be possible to develop a branched graft suited for aortic dissection but usable in other aortic diseases such as traumatic injuries. With a well-suited prosthesis, we believe it may be possible to use bare stents that would effectively close the false lumen by pushing the intimal flap against the aortic wall, and

simplify the treatment of the aortic arch without debranching of the supra-aortic trunks.

Study limitations

The risk of selective bias due to the study's retrospective nature was limited by the systematic inclusion of patients who met the selection criteria. Enrolment involved database cross-referencing and clinical information was obtained in more than 87% of the cases. The relative definition of the section position for the intimal flap junctions made it difficult to establish the position of the different lumens relative to the standard anatomical position. However, owing to the heterogeneous morphology of the arches, a fixed reference point would not have allowed homogenous and comparable measurements among patients. The systolic and diastolic variations in the intimal flap position may have influenced the SA of the false lumen as well as the position and number of entry sites detected. Finally, the results could have been biased by the comparison of the whole lumen of normal arches with the true lumen of dissected arches. Nevertheless, this is a more conservative comparison than with the entire dissected arch, whose morphology is more extensively affected by the expansion occurring with dissection. Thus, changes in the morphology of the true channel compared with that of normal aorta are more likely to represent pre-existing differences than that induced by dissection.

CONCLUSION

Our study provides a systematic compilation of aortic arch measurements for type A aortic dissections, most of which with poor or no prior documentation. We show that dissected aortic arches are longer and higher and have a more anterior apex than normal arches. The false lumen turns preferentially clockwise and its rotation appears to decrease progressively along the arch. These findings may help improve existing endovascular devices and be useful in the design of future devices.

ETHICAL APPROVAL

This descriptive, retrospective single-centre study was conducted according to ethical principles for medical research involving human subjects in French university hospitals (Claudot F, *et al*. Ethics and observational studies in medical research: various rules in a common framework. *Int J Epidemiol* 2009, 38 (4):1104–1108.)

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