Radiologic Anatomy of the Abdominal Aorta and their Large Branches

By

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Introduction

The exact knowledge of the normal and radiologic anatomy of blood vessels is absolutely necessary for the diagnostics of malformations and acquired degenerative variations. The date of length, calibre and angle of the divisions of arteries became of increasing importance in the last years. Particularly essential are these data in the age of growth. Taber et al. (1972) were able to derive a linear correlation of the data to the body surface in children. If we know the normal parameters we can conclude as to functional impairments caused by irradiation (Colquhoun 1966), atherosclerosis (Steinberg et al. 1965) and other alterations. The correlation of data of morphological and angiographic investigations became of increasing importance.

Material and Methods

We used full size angiograms of the abdominal aorta done with a retrograde catheter after the puncture of the femoral artery. The distance of the focus to the film was 1.2 m. The coefficient of enlargement of the radiographic image in relation to the object was 1.33. Hence, all linear measurements of anatomic details on films were in

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reality one-third smaller. We investigated the angiograms of 61 grown-ups, 33 males and 28 females, aged between 17 and 74 years. We did not evaluate material suspect of anatomic varieties. The level of origin of an artery was regarded in projection to the skeletal system. The breadth of the column of contrast medium was taken as the calibre of the vessel (see Fig. 1). The length of the vessel was measured with a length measurer. We used the following statistical operations: mean values, standard deviations, t-test and F-test.

Results

The calibre of the abdominal aorta (see Figs. 2 and 3) decreased statistically significant in both sexes from Th_{12} (mean value 26 mm) down to the aortic bifurcation (mean value 19 mm). There were statistically significant sex-differences (see Fig. 3). The means calibre of the aorta was 2 mm minor in the female than in the male sex. In its course the aorta approached the median line more and more (see Fig. 2). This was always highly significant regarding the whole course. In some cases there were considerable oscillations of the calibre (see Fig. 4) caused by atherosclerosis or there was a marked tortuosity of the aorta and the iliac arteries resulting in a repeated crossing of the aorta over the median line (see Fig. 5). The mean angle of the aortic bifurcation was 37° (see Fig. 6). The mean angle of the iliac bifurcation was 29° on the right and about 20° on the left side. In the mean the aortic bifurcation had a level of L_4 (see Fig. 7). We observed a decrease of the bifurcation with advancing age. The sex distribution showed a similar result in females and males (see Fig. 8).

The mean calibre of the left and right renal artery was practically identical and measured about 7.8 mm (see Fig. 8). In the female sex the calibre was about 0.8 mm minor than in the male. The mean calibre of the splenic artery differed statistically significant to the calibre of the renal arteries. The renal arteries originated at a level of L_1 - L_2 (see Fig. 10). In our material the level of origin was slightly higher on the right than on the left side. We found, that the level of origin of the renal arteries decreased significantly with advancing age. In men (see Fig. 11) the level was in the mean about $1/2$ vertebral body lower in older than in younger individuals. The same result (see Fig. 12) was found in women.

The splenic artery originated in women and men at a level of Th_{12} - L_1 (see Fig. 13). The level decreased with advancing age, but this was not significant in our material. In this artery the increase of length with age was particularly marked. Sometimes the total length reached a value up to the four fold of the direct distance from

the origin to the hilus (see Fig. 14).

The calibre of the right common iliac artery did not differ significantly to the left (see Fig. 15). In the external iliac arteries we found a similar result. The mean calibre of the internal iliac artery was 6.1 mm on the right and 6.5 mm on the left side, but this difference was not statistically significant. The length of the common iliac arteries down to the iliac bifurcation varied considerably. This was due to the variable and age-dependent level of the bifurcations and to the tortuous course of the vessels. In the mean the tortuous course was somewhat more distinct on the left than on the right side. Nearly always such tortuosity occurred in hypertensive patients (see Figs. 16, 1, 5).

Discussion

The renal arteries are of particular clinical importance. Abnormal calibres, wall alterations and length differences in the angiogram may be the only symptom of an incipient impairment of function. The calibre is essential for diagnoses, because of reduction or irregularity of it can indicate renal or renovascular diseases, such as vessel hypoplasia, fibromuscular dysplasia and so on. In our material the level of the origin was slightly higher on the right than on the left side. This confirms the results of Hafferl (1957), Töndury (1970), Luzsa (1972) and Wicke et al. (1974). Heidsieck (1928) related the level of origin of the renal arteries to the origin of the superior mesenteric artery. He found the origin of the renal artery in the mean 0.1 cm higher on the right than on the left side. Contrary to the results of the former investigators, Vogler and Herbst (1958) wrote, that the origin of the renal arteries was in the mean higher on the left than on the right side. The level of origin of the renal arteries in relation to the vertebral column was investigated by several authors. Luzsa (1972) found the level in more than 50% of the cases within the lower half of L_1 and in 25% of cases at the first lumbar intervertebral disc. The renal arteries originated only in a small part of the cases at L_2 . De Luca and De Serio (1960) and Olsson (1964) achieved similar results. In the investigations of Danek (1973/4) the origin had a level of $L_{1,3}$ (lowest third), $L_{1,4}$ (intervertebral disc) or $L_{2,1}$ in 57% of the cases it was on the right and in 71% on the left side. Wicke et al. (1974) wrote, that the level ranged within $Th_{12,3}$ - $L_{2,3}$. Accessory renal arteries were not evaluated. In over 70% of the cases examined by Edsmann (1957) the level of the origin was found at the first lumbar vertebral body and intervertebral disc. The level ranged within $L_{1/2}$, $L_{1,3}$, $L_{1,4}$ or $L_{2,1}$ in more than 80% of the cases investigated by Ney and Friedenberg

(1968). Often it is very hard to notice the real origin of the renal arteries, because the shadow of the aorta may cover it. Therefore the origin is often evaluated at a lower level in the angiogram than in the sections revealing the actual origin. Pietrowski and Krylow (1968) investigated the distance between the origins of the coeliac trunk and the renal arteries and found generally two types of behaviour. The "compact type" showed a short distance, the "disperse type" of branching a long one. There are different results concerning the calibre of the renal arteries in the respective literature. The mean calibre of the renal arteries was 5.5 mm in Merklin and Michels (1957), 6.1 mm in Baudisch and Arndt (1969), who measured 2 cm from the origin, and 5 mm in Pietrowsky and Krylow (1968). Edsmann (1957) found a mean calibre of 7.9 mm in the male and 6.4 mm in the female sex, Danek 8 mm in the male (ranging from 6 up to 8 mm) and 7.2 mm (ranging from 5 up to 9 mm) in the female sex. Danek measured the calibre of the renal artery 5 mm from the origin. He also evaluated accessoric vessels, which was left out, because then it would have been hard to get statistically significant calibre values. In the investigations of Piasecki (1962) the calibre of the renal artery ranged from 2 up to 9 mm, in Hou Jensen (1947) from 4 up to 7 mm and in Bochenek and Reicher (1958) from 6 up to 8 mm. Adachi (1928), Bochenek and Reicher (1958) and Hou Jensen (1947) found a greater length of the renal artery on the right side than on the left one. This was caused by the aorta which was running somewhat on the left side. According to the results of Odman (1958) the calibre of the splenic artery ranged from 4 up to 8 mm with a mean value of 5.5 mm. The results of our investigations about the course and calibre of the abdominal aorta were similar to those of Steinberg (1965), who wrote that the aorta of the grown-up approached the median line and became smaller in its course. Luzsa (1972) found the upper third of the abdominal aorta in the median line or a little more to the left, then a straight or little bent course followed. In the material of Bochenek and Reicher (1958) the mean calibre of the aorta was 20 mm at the beginning of the abdominal part and 17 mm at the bifurcation. Steinberg et al. (1965) found a significant sex-difference of 2 mm. In our material the difference was just as statistically significant. The level of the aortic bifurcation is usually reported in literature at L₄ (Luzsa 1972, De Luca and De Serio 1960). The mean angle of the aortic bifurcation was 37° in our material. A much higher value was found by Luzsa in 1972 when he examined sections: 65° in the male and 75° in the female sex. Lize (1968) stated that the angle of the aortic bifurcation increased with age. We did not find such behaviour in our material. De Luca and De Serio (1960) reported that the length of the common iliac artery was 6.5 cm on the right and 6.3 cm on the

left side. The calibre was 0.89 cm on the right and 0.83 cm on the left side. Reich et al. (1964) found in 72% a longer common iliac artery on the left than on the right side. These authors described a lower iliac bifurcation on the left than on the right side. Luzsa (1972) evaluated the variable form of the internal iliac artery. The course was lateral concave in 39%, straight in 31%, medial concave in 22% and tortuous in 8%. The investigations of De Luca and De Serio revealed, that the mean length of the internal iliac artery was 3.9 cm on the right and 4.0 cm on the left side, the external iliac artery was 9.0 cm on the right and 8.8 cm on the left side. The calibre of the external iliac artery ranging from 0.4 up to 1 cm, in the mean 0.68 cm. Muratori (1963) saw a continual increase of the calibre of the abdominal aorta and its great branches with increasing age. Taber et al. (1972) derived a linear relation between data of vessels (the calibre of the aorta at Th_{11} , at the origin of the renal arteries and at the bifurcation and the calibre of the common iliac arteries) and body surface.

In our material the origins of the great vessels and the bifurcations were found at a lower level with increasing age. This resulted in a jolting of the iliac arteries. Together with the increase in length it caused the tortuous course of these vessels. This was particularly marked in hypertensive patients and might be one of the factors causing disturbances of the peripheral circulation. In the evaluation of angiograms made by percutaneous (first by Dos Santos et al. 1931) or retrograde aortography we have to take into consideration the limitation of the method. We are able to measure only the course and breadth of a column of contrast medium. The third dimension of the vessel course be evaluated by angiographic investigations in at least two planes. Up to this time such investigations have been carried out in cerebral vessels, but not yet in abdominal arteries. Our results can be related to those of Lize (1968), who made analogous investigations on the corpse. There have been combined investigations to compare the results, so by Goldberg (1965). The differences of angiographic results to those found in sections may amount to more than 50%. Tassel (1972) used catheters with known and normed size to decrease the failures made in the evaluations of angiograms.

Summary

We investigated the angiograms of 61 grown-up, 33 males and 28 females, aged between 17 and 74 years. In its course the aorta was gradually approaching the median line, the calibre decreased from Th_{12} (26 mm) down to the aortic bifurcation (19 mm). The aortic bifurcation had a mean angle of 37° , the iliac bifurcation one of 29° on

the right and 20° on the left side. In the mean the aortic bifurcation had a level of L_4 . The mean calibre of the left and right renal artery measured about 7.8 mm and differed significantly from the calibre of the splenic artery. In the mean the level of the origin of the renal arteries was slightly higher on the right than on the left side. The side-differences of the calibres of the common external and internal iliac arteries were not significant. In the higher age groups we observed a lowering of the aortic bifurcation and the origin of the renal arteries. The increase in length was particularly marked in the splenic artery. The length of the common iliac arteries varied considerably. This artery was rather more tortuous on the left than on the right side. This tortuosity was nearly always found in patients suffering from hypertension.

Zusammenfassung

Wir untersuchten die Angiogramme von 61 Personen, 33 Männern und 28 Frauen, im Alter zwischen 17 und 74 Jahren. Die Aorta näherte sich in ihrem Verlauf der Medianen mehr und mehr. Ihr Kaliber nahm von Th_{12} (26 mm) bis zur Aortenbifurkation (19 mm) laufend ab. Die Aortenbifurkation wies einen Durchschnittswinkel von 37° auf, die Werte der Iliakabifurkation betrugen 29° rechts und 20° links. L_4 war die Durchschnittshöhe der Aortenbifurkation. Das Durchschnittskaliber der Nierenarterie betrug 7.8 mm rechts und links und unterschied sich signifikant vom Kaliber der Milzarterie. Im Durchschnitt lag die Ursprungshöhe der Nierenarterien rechts höher als links. Statistisch signifikante Seitendifferenzen der Kaliber der Aa. iliacae communes, externae und internae bestanden nicht. In der höheren Altersklasse beobachteten wir ein Absinken der Aortenbifurkation und der Ursprünge der Nierenarterien, sowie eine deutliche Längenzunahme der Milzarterie. Die Länge der A. iliaca communis variierte beträchtlich. Diese Arterie war links etwas mehr geschlängelt als rechts. Beinahe immer trat eine derartige Schlängelung bei Hypertonikern auf.

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Explanations to the Figures

Plate I

Fig. 1. Angiogram of a 54 year old female, hypertonic, occlusion of the left renal artery, white and black ink indicate the measurements.

Plate II

Fig. 2. Scheme of the calibre (including standard deviation) of the abdominal aorta on various levels in mm, on the right part the distance of the median line.

Fig. 3. Exact calibre in mm of the abdominal aorta in male and female on various levels.

Fig. 2.

level	Th_{12}	L_1	L_2	L_3	L_4
male	27,90	24,45	21,48	20,58	20,04
female	23,96	22,11	19,07	19,21	18,01

Fig. 3.

Plate III

Fig. 4. Angiogram of a 64 year old male, diabetic, note (arrows) the multiple oscillations of the aorta.

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Plate IV

Fig. 5. Angiogram of a 37 year old diabetic male, note the repeated crossing of the aorta over the median line of the vertebral column.

Plate V

- Fig. 6. Summary of all statistically investigations, n....number, m....mean value, s standard deviation, FG 1 statistically significant, O not significant, 90% level,
- 1 - 5 calibre of the aorta from Th₁₂-L₄
 - 6 - 7 calibre of the right and left renal artery
 - 8 calibre of the splenic artery
 - 9 -16 deviation of the aorta from the median line in the abdominal part (measurements on the upper and lower third of the vertebra)
 - 17-18 calibre of the common iliac artery (right and left)
 - 19-20 calibre of the external iliac artery (right a. left)
 - 21-22 calibre of the internal iliac artery (right and left)
 - 29-30 length of common iliac artery (right and left)—direct distance
 - 31-32 length of the artery's course
 - 33-34 distance of the bifurcation of iliac art. from median
 - 36, 37, 38 angles of the bifurcations of the aorta, and right and left iliac arteries

		n	n	m	m	s	s		FG	Plate V
1	2	56	61	26, 14	23, 29	3, 51	3, 38	4, 4618	1 115	1, 0753
1	3	56	61	26, 14	20, 38	3, 51	2, 81	9, 7550	1 115	1, 5567
1	4	56	61	26, 14	19, 75	3, 51	2, 81	10, 8132	1 115	1, 5601
1	5	56	55	26, 14	18, 95	3, 51	2, 56	12, 3575	1 109	1, 8728
2	3	61	61	23, 29	20, 38	3, 38	2, 81	5, 1810	1 120	1, 4477
2	4	61	61	23, 29	19, 75	3, 38	2, 81	6, 2898	1 120	1, 4508
2	5	61	55	23, 29	18, 95	3, 38	2, 56	7, 8490	1 114	1, 7417
3	4	61	61	20, 38	19, 75	2, 81	2, 81	1, 2243	0 120	1, 0021
3	5	61	55	20, 38	18, 95	2, 81	2, 56	2, 8685	1 114	1, 2031
6	7	58	60	7, 81	7, 80	1, 46	1, 40	0, 0393	0 116	1, 0827
6	8	58	53	7, 81	7, 19	1, 46	1, 24	2, 4264	1 109	1, 3769
7	8	60	53	7, 80	7, 19	1, 40	1, 24	2, 4606	1 111	1, 2718
9	10	58	58	-10, 55	-9, 38	5, 59	5, 74	1, 1140	0 114	1, 0546
9	11	58	59	-10, 55	-8, 09	5, 59	7, 27	2, 0596	1 115	1, 6898
9	12	58	57	-10, 55	-7, 75	5, 59	8, 14	2, 1445	1 113	2, 1190
9	13	58	59	-10, 55	-7, 02	5, 59	8, 06	2, 7593	1 115	2, 0793
9	14	58	60	-10, 55	-6, 20	5, 59	7, 81	3, 4893	1 116	1, 9500
9	15	58	54	-10, 55	-6, 28	5, 59	5, 96	3, 9053	1 110	1, 1373
9	16	58	30	-10, 55	-6, 13	5, 59	5, 50	3, 5516	1 86	1, 0334
10	11	58	59	-9, 38	-8, 09	5, 74	7, 27	1, 0699	0 115	1, 6023
10	12	58	57	-9, 38	-7, 75	5, 74	8, 14	1, 2350	0 113	2, 0093
10	13	58	59	-9, 38	-7, 02	5, 74	8, 06	1, 8278	0 115	1, 9716
10	14	58	60	-9, 38	-6, 20	5, 74	7, 81	2, 5255	1 116	1, 8491
10	15	58	54	-9, 38	-6, 28	5, 74	5, 96	2, 7997	1 110	1, 0784
10	16	58	30	-9, 38	-6, 13	5, 74	5, 50	2, 5847	1 86	1, 0899
11	12	59	57	-8, 09	-7, 75	7, 27	8, 14	0, 2303	0 114	1, 2540
11	13	59	59	-8, 09	-7, 02	7, 27	8, 06	0, 7555	0 116	1, 2305
11	14	59	60	-8, 09	-6, 20	7, 27	7, 81	1, 3631	0 117	1, 1540
11	15	59	54	-8, 09	-6, 28	7, 27	5, 96	1, 4495	0 111	1, 4857
11	16	59	30	-8, 09	-6, 13	7, 27	5, 50	1, 4142	0 87	1, 7463
12	13	57	59	-7, 75	-7, 02	8, 14	8, 06	0, 4901	0 114	1, 0191
12	14	57	60	-7, 75	-6, 20	8, 14	7, 81	1, 0531	0 115	1, 0867
12	15	57	54	-7, 75	-6, 28	8, 14	5, 96	1, 0942	0 109	1, 8632
12	16	57	30	-7, 75	-6, 13	8, 14	5, 50	1, 1002	0 85	2, 1899
13	14	59	60	-7, 02	-6, 20	8, 06	7, 81	0, 5613	0 117	1, 0663
13	15	59	54	-7, 02	-6, 28	8, 06	5, 96	0, 5571	0 111	1, 8282
13	16	59	30	-7, 02	-6, 13	8, 06	5, 50	0, 6082	0 87	2, 1488
14	15	60	54	-6, 20	-6, 28	7, 81	5, 96	0, 0601	0 112	1, 7146
14	16	60	30	-6, 20	-6, 13	7, 81	5, 50	0, 0469	0 88	2, 0152
15	16	54	30	-6, 28	-6, 13	5, 96	5, 50	0, 1119	0 82	1, 1753
17	18	58	58	11, 90	11, 95	1, 76	1, 94	0, 1502	0 114	1, 2112
17	19	58	21	11, 90	9, 29	1, 76	1, 68	6, 0268	1 77	1, 1058
17	20	58	18	11, 90	9, 33	1, 76	1, 50	6, 0782	1 74	1, 3922
18	19	58	21	11, 85	9, 29	1, 94	1, 70	5, 9686	1 77	1, 3393
18	20	58	18	11, 95	9, 33	1, 94	1, 50	6, 0122	1 74	1, 6862
19	20	21	18	9, 29	9, 33	1, 68	1, 50	0, 0937	0 37	1, 2590
21	22	21	19	7, 62	7, 37	1, 16	1, 12	0, 6958	0 38	1, 0819
29	30	29	26	60, 86	65, 00	14, 11	14, 54	1, 0683	0 53	1, 0619
29	31	29	29	60, 86	64, 17	14, 11	15, 52	0, 8498	0 56	1, 2092
29	32	29	26	60, 86	71, 65	14, 11	16, 80	2, 5636	1 53	1, 4165
30	31	26	29	65, 00	64, 17	14, 54	15, 52	0, 2041	0 53	1, 1387
30	32	26	26	65, 00	71, 65	14, 54	16, 80	1, 5270	0 50	1, 3340
31	32	29	26	94, 17	71, 65	15, 52	16, 80	1, 7093	0 53	1, 1714
33	34	29	27	31, 41	41, 22	9, 38	9, 62	3, 8587	1 54	1, 0505
36	37	59	14	36, 83	41, 00	9, 99	20, 35	0, 7454	0 71	4, 1500
36	38	59	18	36, 83	29, 06	9, 99	15, 76	1, 9757	0 75	2, 4871
37	38	14	18	41, 00	29, 06	20, 35	15, 76	1, 8134	0 30	1, 6686

Plate VI

Fig. 7. Scheme of a mean value of the bifurcations of the aorta and iliac arteries with standard deviations of the angles and of the length of the arteries.

Fig. 8a. Level of the aortic bifurcation to the vertebral column, and the number of cases, for symbols look Fig. 8b.

Fig. 7.

Fig. 8-a.

Plate VII

Fig. 8b. Level of the aortic bifurcation, on the left males, on the right females.

Fig. 9. Calibre and number of the renal and splenic arteries, note that there is no statistically significant difference.

Fig. 8-b.

Fig. 9.

Plate VIII

Fig. 10. Level of the origin of the renal artery of both sexes to the vertebral column, note the symbols for age classes from Fig. 8b.

Fig. 11. Level of the origin of the renal arteries from males.

Fig. 10.

Fig. 11.

Plate IX

Fig. 12. Level of the origin of the renal arteries from females.

Fig. 13. Level of the origin of the splenic artery, on the left males, on the right, females, for age classes compare Fig. 8b.

Fig. 12.

Plate X

Fig. 14 Angiogram of a 50 year old diabetic and hypertonic male, atherosclerotic oscillations of the lower part of the abdominal aorta, high tortuosity of the splenic artery (arrow).

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Plate XI

Fig. 15. Caliber in mm and number in percent of the both common iliac arteries, note, that there is no statistically significant difference.

Fig. 15.

Plate XII

Fig. 16. Angiogram of a 4 year old, hypertonic male, note the tortuosity of the abdominal aorta as well as from their great branches