# TOPOGRAPHY OF THE UNPAIRED VISCERAL BRANCHES OF THE ABDOMINAL AORTA

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## SCOPE OF THE INVESTIGATION

This report records the results of an investigation of the location of four points on the abdominal aorta:

(1) origin of the coeliac artery;

(2) origin of the superior mesenteric artery;

(3) origin of the inferior mesenteric artery; and

(4) the bifurcation of the abdominal aorta.

The location of each of these four points was determined with reference to its vertebral level and measurements were made of the distances between the four points and of the total length of the abdominal aorta.

## MATERIAL

The material used in this study comprised 120 dissecting room cadavera, of which 49 were from the University of Manitoba and 71 from the University of Toronto. Of the 120 subjects, 113 were adult males over 21 years of age. One male was aged 17 years and another male aged 20 years. The remaining five subjects were females. The details concerning the females are shown in the appendix on p. 205, and it will be noted that one of the females was 17 years of age and the other four over 21 years.

## TECHNIQUE

When the routine dissection of the abdomen was advanced sufficiently to display the abdominal aorta and its branches, a two-inch finishing nail (i.e. a wire nail with a small head) was hammered into the vertebral column through the centre of the origin of each unpaired visceral branch and also at the crotch marking the bifurcation of the abdominal aorta into the common iliac arteries. Care was taken to drive the nail in the transverse plane to avoid the error of an oblique insertion into the vertebral column. Measurements were then made of the distance between the four nails, using sliding calipers and measuring from the centre of one nail-head to the centre of the next nail-head.

When the abdominal viscera were removed and the abdominal aorta stripped from the front of the vertebral column, the vertebral level of each nail was determined, and this level was recorded as opposite a specified intervertebral fibrocartilage or the upper or middle or lower third of a certain vertebral body.

For purposes of mathematical treatment, the depth of an intervertebral disc is considered as equal to one-third of the depth of a vertebra. Thus, our class intervals, as shown in the tables, are all considered to be of equal size. The vertebral levels thus obtained are summarised in Table I.

Table I. *Frequency distribution of the vertebral levels of origin of the unpaired visceral branches of the abdominal aorta and of the site of bifurcation of the aorta.*

| | | Class interval | Coeliac artery | Superior mesenteric artery | Inferior mesenteric artery | Bifurcation of aorta |
|---|---|---|---|---|---|---|
| | | 1 | 1 | | | |
| XII | U. | 2 | 1 | | | |
| | M. | 3 | 6 | 1 | | |
| | L. | 4 | 18 | | | |
| | | 5 | 20 | 5 | | |
| I | U. | 6 | 25 | 17 | | |
| | M. | 7 | 17 | 20 | | |
| | L. | 8 | 7 | 29 | | |
| | | 9 | 1 | 21 | | |
| II | U. | 10 | | 2 | | |
| | M. | 11 | 1 | 2 | | |
| | L. | 12 | | | 2 | |
| | | 13 | | | 15 | |
| III | U. | 14 | | | 20 | |
| | M. | 15 | | | 28 | |
| | L. | 16 | | | 23 | 1 |
| | | 17 | | | 14 | 8 |
| IV | U. | 18 | | | 2 | 15 |
| | M. | 19 | | | 2 | 20 |
| | L. | 20 | | | 1 | 25 |
| | | 21 | | | | 23 |
| V | U. | 22 | | | | 7 |
| | M. | 23 | | | | 4 |
| | L. | 24 | | | | 2 |
| | | No. of cases | 97 | 97 | 107 | 105 |
| | | Mean | 5·5 | 7·6 | 15·1 | 19·8 |
| | | $\sigma$ | 1·59 | 1·39 | 1·53 | 1·64 |
| | | $E_m$ | 0·11 | 0·09 | 0·10 | 0·11 |

*Note:* The letters "U., M. and L." refer to upper, middle and lower thirds of the thoracic and lumbar vertebrae, the vertebral bodies being denoted by Roman numerals.

## COELIAC ARTERY

The vertebral level of the origin of the coeliac artery was observed in 97 cases. With the exception of three extreme cases, all of these origins were opposite the last thoracic or the first lumbar vertebrae or the intervening disc. The mean of the series was at the upper edge of the first lumbar vertebra (class interval 5·5 in Table I) with $\sigma$ 1·59 and $E_m$ $\pm$0·11.

The upper and lower limits (or levels) of origin were recorded for each artery. Of course, it is only the freaks of the series that occupy these extreme maximal and minimal or outlying positions; and they have therefore little interest for us. The standard deviation from the mean is of much greater significance. The standard deviation ($\sigma$) is a measure of variability so highly informative that it has been calculated for each artery. Its interpretation may be explained by the use of a simple example: let us suppose that the length of say 100 living objects such as leaves, bones or arteries has been taken and that the mean length of the series has been calculated to be 24 mm. with a standard deviation of 2. Now, these 100 objects would be found to arrange themselves or fall into a biometrical or normal curve of which 67 per cent., i.e. two-thirds, would be found within one standard deviation on each side of the mean. That is, $24 \pm 2$ or between 22 and 26 mm. Also it is found that 99 per cent., or practically every instance, would be embraced by three times the standard deviation on either side of the mean. That is, $24 \pm 6$ or between 18 and 30 mm. It is due to the fact that such biometrical data arrange themselves in the form of a normal curve that it is possible by means of the mean and a single other number ($\sigma$) to express the distribution of 67 and 99 per cent. of the cases.

Table II compares the results of our series with those of other observers.

Table II. *Vertebral level of origin of the coeliac artery.*

| Author of series | No. of cases | Location of mean | Class interval (Table I) | $\sigma$ |
|---|---|---|---|---|
| Our series (Canada) | 97 | Upper third of lumbar I | 5·5 | 1·59 |
| Adachi (Japan) | 50 | ,, ,, | 5·5 | 1·60 |
| Taniguchi (Japan) | 100 | ,, ,, | 5·6 | 1·53 |
| Heidsieck (Germany) | 94 | ,, ,, | 5·9 | 1·72 |

It will be noted that these means congregate opposite the upper third of the first lumbar vertebra. Poirier and Charpy, and Testut give the location as at the disc between the last thoracic and first lumbar vertebrae but do not quote a series of cases.

### Coeliac artery and the diaphragm

The origin of the coeliac artery in relation to the median arcuate ligament of the diaphragm was observed in 38 subjects. In 16 subjects the origin of the coeliac artery was separated from the diaphragm by an interval. In 14 subjects the origin of the coeliac artery was in contact with the diaphragm, and in eight subjects the diaphragm overlapped the origin of the coeliac artery.

## SUPERIOR MESENTERIC ARTERY

The vertebral level of the origin of the superior mesenteric artery was observed in 97 cases, ranging from the middle of the twelfth thoracic to the middle of the second lumbar vertebra. The mean of our series was at the junction of the middle and lower thirds of the first lumbar vertebra (class interval 7·6 in Table I) with $\sigma$ 1·39 and $E_m$ $\pm 0{\cdot}09$.

Table III compares the results of our series with those of other observers.

Table III. *Vertebral level of origin of the superior mesenteric artery.*

| Author of series | No. of cases | Location of mean | Class interval (Table I) | $\sigma$ |
|---|---|---|---|---|
| Our series (Canada) | 97 | Lower two-thirds of lumbar I | 7·6 | 1·39 |
| Heidsieck (Germany) | 95 | ,, ,, | 7·5 | 1·62 |
| Adachi (Japan) | 49 | Middle third of lumbar I | 6·8 | 1·55 |
| Taniguchi (Japan) | 100 | ,, ,, | 7·3 | 2·04 |

All of these means congregate opposite the lower two-thirds of the first lumbar vertebra. This is in rather sharp contrast with the statement of Poirier and Charpy who give the location as the disc between the second and third lumbar vertebrae but do not support the statement by a series of cases.

## INFERIOR MESENTERIC ARTERY

The vertebral level of the origin of the inferior mesenteric artery was observed in 107 cases. These ranged from the lower third of the second lumbar vertebra to the lower third of the fourth lumbar vertebra. The mean of our series was opposite the middle of the third lumbar vertebra (class interval 15·1 in Table I) with $\sigma$ 1·53 and $E_m$ $\pm 0{\cdot}10$.

Table IV compares the results of our series with those of other observers.

Table IV. *Vertebral level of origin of the inferior mesenteric artery.*

| Author of series | No. of cases | Location of mean | Class interval (Table I) | $\sigma$ |
|---|---|---|---|---|
| Our series (Canada) | 107 | Middle third of lumbar III | 15·1 | 1·53 |
| Adachi (Japan) | 53 | ,, ,, | 15·0 | 1·40 |
| Taniguchi (Japan) | 100 | ,, ,, | 15·2 | 1·31 |
| Heidsieck (Germany) | 98 | Lower third of lumbar III | 15·7 | 1·90 |

Three of these means congregate opposite the middle third of the third lumbar vertebra and the other mean is only very slightly lower. Testut and also Poirier and Charpy give the location as opposite the disc below the third vertebra and Von Bardeleben gives it as opposite the disc above, but none of these statements is supported by a series of cases.

## LENGTH OF STEM OF THE INFERIOR MESENTERIC ARTERY

The length of the stem of the inferior mesenteric artery (i.e. prior to the origin of its first branch, the left colic) was observed in 68 cadavers. The maximum stem-length was 9·0 cm., minimum 1·5 cm. and the mean of the series 3·8 cm.

The distribution according to stem length was as follows:

| Stem-length (cm.) | No. of cases |
|---|---|
| 1·5–2·4 | 3 |
| 2·5–3·4 | 24 |
| 3·5–4·4 | 25 |
| 4·5–5·4 | 7 |
| 5·5–6·4 | 5 |
| 6·5–7·4 | — |
| 7·5–8·4 | 3 |
| 8·5–9·0 | 1 |
| | 68 |

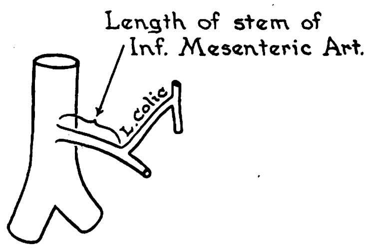


Fig. 1. Measurement of the stem-length of the inferior mesenteric artery from the abdominal aorta to the origin of its first branch, the left colic artery.

## BIFURCATION OF THE ABDOMINAL AORTA

The vertebral level of the bifurcation of the abdominal aorta was observed in 105 cases. These ranged from the lower third of the third lumbar vertebra to the lower third of the fifth lumbar vertebra. The mean of our series was opposite the lower third of the fourth lumbar vertebra (class interval 19·8 in Table I) with $\sigma$ 1·64 and $E_m$ $\pm$0·11.

Table V compares the results of our series with those of other observers.

Table V. *Vertebral level of bifurcation of the abdominal aorta.*

| Author of series | No. of cases | Location of mean | Class interval (Table I) | $\sigma$ |
|---|---|---|---|---|
| Our series (Canada) | 105 | Lower third of lumbar IV | 19·8 | 1·64 |
| Adachi (Japan) | 208 | ,, ,, | 20·2 | 1·29 |
| Taniguchi (Japan) | 100 | ,, ,, | 20·2 | 1·09 |
| Heidsieck (Germany) | 98 | ,, ,, | 20·2 | 1·45 |
| Dwight (U.S.A. whites) | 230 | Lower two-thirds of lumbar IV | 19·5 | 1·61 |
| Ssoson-Jaroschewitsch (European Russia) | 104 | ,, ,, | 19·5 | 1·81 |
| Quain (England) | 196 | Middle third of lumbar IV | 19·3 | 1·63 |

It is interesting to note that all of these seven means are opposite the lower two-thirds of the fourth lumbar vertebra. The following authors give the location but do not report a series of cases: Gray, "opposite the fourth lumbar vertebra"; Piersol, "middle of fourth lumbar or lower"; Von Bardeleben, "lower border of fourth lumbar"; Poirier and Charpy, "somewhere between the lower border of the fourth lumbar and the lumbo-sacral articulation."

## DISTANCES BETWEEN POINTS ON THE ABDOMINAL AORTA

### *Coeliac artery to superior mesenteric artery*

The distance between the origins of the coeliac artery and the superior mesenteric artery was measured in 94 cadavers. The maximum distance was 3·1 cm., minimum 0·5 cm. and the mean 1·6 cm. with $\sigma$ 0·50. The distribution by groups is as follows:

| Distance in cm. | No. of cases |
|---|---|
| 0·0–0·5 | 2 |
| 0·6–1·0 | 6 |
| 1·1–1·5 | 40 |
| 1·6–2·0 | 33 |
| 2·1–2·5 | 9 |
| 2·6–3·0 | 3 |
| 3·1–3·5 | 1 |
| | 94 |

Heidsieck measured this distance in 98 cadavers to an accuracy of 0·5 cm. and found the maximum distance was 3 cm., minimum 0·5 cm. and the mean 1·4 cm. with $\sigma$ 0·47. Gray gives the distance as "about 1 cm." and Piersol as about 1·5 cm." Von Bardeleben gives it as generally "1 to 2 cm." and Poirier and Charpy as "2 cm. in the adult but greater absolutely and relatively in the foetus and child." Testut gives it as "1·5 cm." on p. 217 and as "2·0 cm. but variable" on p. 322.

*Superior mesenteric to inferior mesenteric arteries*

The distance between the origins of the superior mesenteric artery and the inferior mesenteric artery was measured in 95 cadavers. The maximum distance was 10·3 cm., minimum 4·2 cm. and the mean 7·1 cm. with $\sigma$ 1·21. The distribution by groups is as follows:

| Distance in cm. | No. of cases |
|---|---|
| 4·0–4·9 | 3 |
| 5·0–5·9 | 10 |
| 6·0–6·9 | 34 |
| 7·0–7·9 | 27 |
| 8·0–8·9 | 16 |
| 9·0–9·9 | 2 |
| 10·0–10·9 | 3 |
| | 95 |

Heidsieck measured this distance in 93 cadavers to an accuracy of 0·5 cm. and found the maximum distance was 10 cm., minimum 5 cm. and the mean 7·5 cm. with $\sigma$ 1·08. Von Bardeleben gives this distance as "about 5 to 7 cm."

*Inferior mesenteric artery to aortic bifurcation*

The distance between the origin of the inferior mesenteric artery and the bifurcation of the abdominal aorta was measured in 92 cadavers. The maximum distance was 8·2 cm., minimum 2·7 cm. and the mean 4·6 cm. with $\sigma$ 1·02. The distribution by groups is as follows:

| Distance in cm. | No. of cases |
|---|---|
| 2·0–2·9 | 3 |
| 3·0–3·9 | 20 |
| 4·0–4·9 | 36 |
| 5·0–5·9 | 26 |
| 6·0–6·9 | 6 |
| 7·0–7·9 | 0 |
| 8·0–8·9 | 1 |
| | 92 |

Heidsieck measured this distance in 96 cadavers to an accuracy of 0·5 cm. and found the maximum distance was 7 cm., minimum 1 cm. and the mean 4·2 cm. with $\sigma$ 0·93. Poirier and Charpy and also Testut give this distance as "4 or 5 cm.," but both Piersol and Gray give it as "about 3 or 4 cm." According to Corsy, as quoted on p. 385 of Testut, the most frequent variations in this distance are as follows:

| | | |
|---|---|---|
| 3 cm. | ... ... ... ... ... | 66 cases |
| 4 ,, | ... ... ... ... ... | 42 ,, |
| 5 ,, | ... ... ... ... ... | 10 ,, |
| 6 ,, and more | ... ... ... ... | 2 ,, |
| | | 120 ,, |

As these frequencies of Corsy do not form a normal curve, it is difficult to believe that his data are accurate.

Quain measured the space between the origin of the inferior mesenteric artery and the bifurcation of the aorta in 80 cadavers and groups the distances as follows:

| | |
|---|---|
| Less than 1 in. (2·5 cm.) ... ... ... ... ... ... | 5 cases |
| 1 in. (2·5 cm.) ... ... ... ... ... ... ... | 10 .. |
| More than 1 in., not exceeding $1\frac{1}{2}$ (2·5–3·7 cm.) ... | 48 ,, |
| More than $1\frac{1}{2}$ in., not exceeding 2 (3·7–5·0 cm.) ... | 13 ,, |
| More than 2 in., not exceeding $2\frac{1}{2}$ (5·0–6·2 cm.) ... | 4 ,, |
| | 80 ,, |

The mean of Quain's series at 1·3 in. or 3·2 cm. is about the same as the figure given by Gray and Piersol and considerably less than our mean of 4·6 cm.

With reference to his measurements, Quain states: "The greater intervals placed at the lower part of this summary—those, namely, in which the space of two inches and upwards intervened between the origin of the inferior mesenteric and the end of the aorta—coincides, for the most part, with the low division of the aorta, referred to in the observations on the great artery."

*Length of the abdominal aorta*

The length of the abdominal aorta was measured in 81 cadavers. This measurement was not taken directly from the subjects but was computed as the sum of the distances between the four selected points from the origin of the coeliac artery to the bifurcation. The maximum length was 16·6 cm., minimum 9·5 cm. and the mean 13·2 cm. with $\sigma$ 1·39. The distribution by groups is as follows:

| Distance in cm. | No. of cases |
|---|---|
| 9·0– 9·9 | 1 |
| 10·0–10·9 | 2 |
| 11·0–11·9 | 11 |
| 12·0–12·9 | 18 |
| 13·0–13·9 | 26 |
| 14·0–14·9 | 13 |
| 15·0–15·9 | 8 |
| 16·0–16·9 | 2 |
| | 81 |

Heidsieck measured this distance directly from the origin of the coeliac artery to the bifurcation of the abdominal aorta in 86 cadavers to an accuracy of 0·5 cm. and found the maximum length was 16·5 cm., minimum 10 cm. and the mean 13·2 cm. with $\sigma$ 1·40. It will be noted that the mean of our series is identical with the mean of Heidsieck's series and that $\sigma$ is a close approximation.

## Age changes in the vertebral levels

Ssoson-Jaroschewitsch, working with European Russian cadavers, demonstrated that the vertebral level of the bifurcation of the abdominal aorta tends to sink distally as age increases. He examined 122 cadavers and found the vertebral level of the bifurcation by age groups to be as follows:

| Age group | No. of cases | Location of mean | Class interval (Table I) |
|---|---|---|---|
| Embryos and new born | 18 | Upper edge of lumbar IV | 17·5 |
| Under 25 years ... | 33 | Middle third of lumbar IV | 18·8 |
| 25 to 50 years ... | 56 | Lower third of lumbar IV | 19·8 |
| Over 50 years ... | 15 | ,, ,, | 20·3 |
| | 122 | | |

This distal recession, he observes, is not peculiar to the bifurcation of the abdominal aorta but is shared by the abdominal viscera generally.

We desired to test this suggestion of Ssoson-Jaroschewitsch but our series included no foetuses and too few young subjects to use his age groups, so we grouped our cases into two larger age groups, divided at the age of 59 years, and worked out the mean vertebral levels of origin as shown in Table VI.

Table VI. *Mean vertebral levels of origin by age groups of the unpaired visceral branches of the abdominal aorta and of the site of bifurcation of the abdominal aorta.*

| | Age group | | | |
|---|---|---|---|---|
| | Under 60 years | | 60 years and more | |
| Point of origin | No. of cases | Location of mean | No. of cases | Location of mean* |
| Coeliac artery | 38 | 5·1 | 58 | 5·7 |
| Superior mesenteric artery | 40 | 7·2 | 57 | 7·8 |
| Inferior mesenteric artery | 48 | 14·7 | 58 | 15·5 |
| Bifurcation of the abdominal aorta | 47 | 19·7 | 57 | 20·0 |

* I.e. location of mean vertebral level of origin by class intervals as in Table I.

In Table VI it will be noted that the mean vertebral level of each of the four points of origin is higher in the group of subjects under 60 years of age than in the older group. The differences between the two groups, in terms of class intervals, are:

| | |
|---|---|
| Coeliac artery ... ... ... ... | 0·6 class interval |
| Superior mesenteric artery ... ... | 0·6 ,, |
| Inferior mesenteric artery ... ... | 0·8 ,, |
| Bifurcation of the abdominal aorta ... | 0·3 ,, |

Each class interval, as shown in Table I, represents one-third of the height of a vertebra or one intervertebral disc. Therefore, 0·1 of a class interval equals 1/30 of the height of a vertebra. If we transfer our thought from class intervals to the vertebral heights they represent, we see that in the older group of subjects of 60 years or more, the locations shift distally approximately as follows:

1/5 of a vertebra for the origin of the coeliac artery;
1/5 of a vertebra for the origin of superior mesenteric artery;
1/4 of a vertebra for the origin of inferior mesenteric artery; and
1/10 for the bifurcation of the abdominal aorta.

This distal shift in the locations of the four points on the aorta, whilst perhaps not very significant, does tend to confirm the observations of Ssoson-Jaroschewitsch on the age change in the location of the bifurcation of the abdominal aorta.

SUMMARY

A study of the abdominal aorta in 120 adult white cadavers in Canada reveals:

(1) The mean location of the origin of the coeliac artery is opposite the upper edge of the first lumbar vertebra, of the superior mesenteric artery opposite the lower two-thirds of the first lumbar vertebra, of the inferior mesenteric artery opposite the middle of the third lumbar vertebra and of the bifurcation of the abdominal aorta opposite the lower third of the fourth lumbar vertebra (fig. 2).

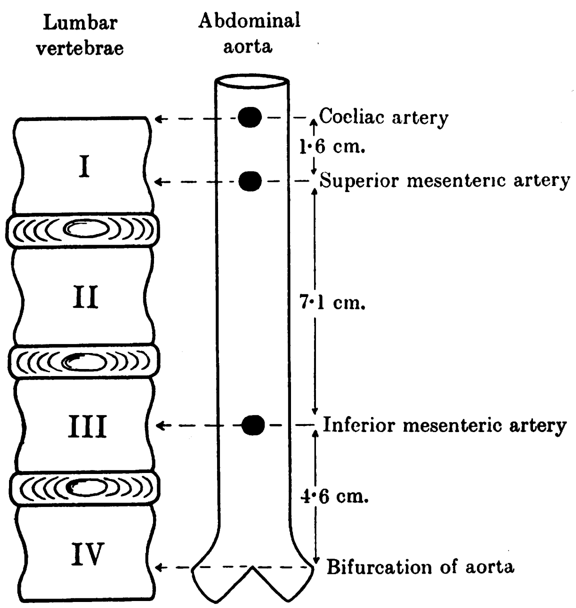


Fig. 2. Locations of the unpaired visceral branches of the abdominal aorta and of the bifurcation of the aorta taken from the means of our series.

(2) A deviation of the height of a vertebra from these means includes nearly all the cases.

(3) Series from other white races show much the same locations as our Canadian series.

(4) Locations given in several standard text-books, but not supported by a series of observations, are often unreliable.

(5) The diaphragm sometimes (8/38) overlaps the origin of the coeliac artery but more frequently the two are separated (16/38) or in contact (14/38).

(6) The mean distances between certain points on the abdominal aorta are:

Coeliac artery to superior mesenteric artery, 1·6 cm.;
Superior mesenteric to inferior mesenteric artery, 7·1 cm.;
Inferior mesenteric artery to aortic bifurcation, 4·6 cm.;
Coeliac artery to aortic bifurcation, 13·2 cm. (fig. 2).

(7) As age advances, there is a slight distal recession in the foregoing locations.

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## APPENDIX

The observations on the five female subjects in our series are as follows:

| | Sub. 1 | Sub. 13 | Sub. 33 | Sub. 40 | Sub. 73 |
|---|---|---|---|---|---|
| Age in years | 50 | 40 | 24 | 17 | 50 |
| Vertebral level of origin of: | | | | | |
| Coeliac artery | — | — | M. 12 | — | |
| Superior mesenteric artery | — | — | U. 1 | — | — |
| Inferior mesenteric artery | U. 3 | L. 3 | U. 3 | — | — |
| Aortic bifurcation | 4/5 | U. 5 | M. 4 | 4/5 | U. 4 |
| Distance in cm. between: | | | | | |
| Coeliac and superior mesenteric | — | — | 1·7 | — | — |
| Superior and inferior mesenteric | — | — | 7·6 | — | — |
| Inferior mesenteric and bifurcation | 5·7 | 6·7 | 4·2 | — | — |