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Anatomical analysis of azygos vein system in human cadavers

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Abstract

The azygos system veins vary greatly in their mode of origin, course, tributaries, anastomoses and termination. Therefore, we aimed to investigate the types of azygos system in this study. Our research was made in Anatomy departments on 48 conserved cadavers aging between 27–70 years, of which 35 were males and 13 females. In the research, the diameters and levels of the azygos vein, the hemiazygos vein, the accessory hemiazygos vein and the superior intercostal vein were investigated. The subjects were classified in Anson's system with a basis of vertical and horizontal connections in the azygos venous system the classification included primitive or embryological types, transient type, unicolon type as three basic types and their eleven subgroups. According to this classification (amongst 48 cadavers), one (2.1%) of our subjects was found to be Type I, 44 (91.7%) of them were found to be Type II, and one (2.1%) was found to be Type III. These values were similar to those in the literature, however two (4.2%) subjects did not fit in any otherwise defined groups and were named as atypic group. It is very important to identify the variations of the azygos system in the computed tomography and magnetic resonance imaging of mediastinum. The abnormal azygos venous system may easily be confused with aneurysm, lymphadenopathy and other abnormalities like tumor. It is important to keep these kinds of variations in mind while performing the mediastinal operations or surgery of large vessels.

Keywords: azygos vein, hemiazygos vein, venous anomalies, variations, anatomy.

Introduction

The azygos vein (gr. *azygos* – 'unpaired') typically starts from the posterior aspect of the inferior vena cava (IVC), at or below the level of the renal veins, although the origin is not constant. If present, the lumbar azygos ascends anterior to the upper lumbar vertebrae. It may pass behind the right crus of the diaphragm or pierce it, or it may traverse the aortic hiatus to the right of the cisterna chyli. Anterior to the twelfth thoracic vertebral body, the azygos is joined by a large vessel formed by the right ascending lumbar and subcostal veins that passes forward and to the right of the twelfth thoracic vertebra behind the right crus: in the absence of a lumbar azygos this common trunk may form the azygos vein itself. Whatever its origin, the azygos vein ascends in the posterior mediastinum to the level of the fourth thoracic vertebra, where it arches forward above the right pulmonary hilum. It ends in the superior vena cava, before the latter pierces the pericardium.

The hemiazygos vein is formed on the left side from the lower three posterior intercostal veins, a common trunk formed by the left ascending lumbar and subcostal veins, and by esophageal and mediastinal tributaries. It ascends anterior of the vertebral column to the eighth thoracic level then crosses the vertebral column posterior to the aorta, esophagus and thoracic duct and ends in the azygos vein. Its lower end is often connected to the left renal vein [1].

The accessory hemiazygos vein descends to the left of the vertebral column, and receives posterior intercostal veins from the fourth or fifth to eighth on the left side; it crosses the seventh thoracic vertebra to join the azygos vein. The accessory hemiazygos vein sometimes receives the left bronchial veins, and it may join the hemiazygos vein, in which case their common trunk opens into the azygos vein [1].

The azygos vein system makes the somatic vein network of the trunk. It is important that in pathologic situations it may function as collateral pathway [2, 3].

The azygos vein system functions as an additional drainage way when high pressure and obstruction occurs in most of the veins that inferior vena cava vein drains. In the obstruction of the IVC, it joins whole venous drainage below the diaphragm except the digestive system. This system connects to the cerebral vein system with the intercostal veins and vertebral venous plexuses. This connection is important because of venous metastatic pathways in breast and bronchial cancers. Also, in superior vena cava syndrome it joins with IVC [2–4].

Anson BJ, Seib GA, Falla A *et al.* determined the azygos vein system as three types and related subgroups in their studies [5–7]. In azygos vein system, there are many differences from person to person, because of the different division, adjunction and closure of 10 longitudinal and more transverse veins of which embryologically it developed, many combinations occur [8–11].

In this study, we aimed to investigate the types of azygos system in human cadavers.

Materials and Methods

This study was made in Anatomy departments on 48 conserved human cadavers aging between 27–70 years (mean age 48.29±12.097) of which 35 were males and 13 were females. The cadavers were examined between 2008 and 2011.

The pericardium, heart, lungs, thoracic aorta and esophagus were removed after the removal of the anterior thoracic wall. The azygos, hemiazygos, accessory hemiazygos and posterior intercostal veins were exposed by blunt dissection of the parietal pleura. Subsequently, the anterior abdominal wall was removed with its parietal peritoneum. The intestines and abdominal organs were removed, the diaphragm was elevated and the ascending lumbar veins were exposed. The azygos venous system made visible and its photos were taken and diagrammatized. The measurements [mm] given below were made with a caliper: (A) The diameters of azygos and hemiazygos veins at their origins (the diameter right after the joining of subcostal and ascending lumbar veins); (B) The diameter of azygos vein just before joining to the superior vena cava; (C) The diameters of hemiazygos, accessory hemiazygos and right superior intercostal veins just before their joining to the azygos vein; (D) The termination levels of the azygos, hemiazygos, accessory hemiazygos and right superior intercostal veins were determined.

The cases were evaluated based on the study of Anson BJ and McVay CB [5]. Three main types of azygos venous system (primitive or embryological type, transition type and single column type) were evaluated based on the vertical forms and horizontal connections. Furthermore, these three types were investigated in 11 subtypes.

Results

The diameters of the azygos and hemiazygos veins at their origins, the diameters of the azygos, hemiazygos, accessory hemiazygos and right superior intercostal veins at their terminations were measured (Table 1).

Table 1 – ***Descriptive statistics***

	N	Range	Min.	Max.	Mean	Std. dev.
Age [years]	48	43	27	70	48.29	12.097
DAVO	48	5.5	2.0	7.5	4.050	1.0256
DHAVO	37	2.7	2.3	5.0	3.168	0.7016
DAVT	45	7.2	5.0	12.2	8.558	1.2569
DHAVT	38	4.6	3.9	8.5	5.647	1.1740
DaHAVT	41	5.6	3.4	9.0	5.471	1.1665
DrSIVT	38	4.2	2.7	6.9	4.261	0.8815
Valid N (listwise)	25					

DAVO: Diameter of azygos vein (origin); DHAVO: Diameter of hemiazygos vein (origin); DAVT: Diameter of azygos vein (termination); DHAVT: Diameter of hemiazygos vein (termination); DaHAVT: Diameter of accessory hemiazygos vein (termination); DrSIVT: Diameter of right superior intercostal vein (termination); Min.: Minimum; Max: Maximum; Std. dev.: Standard deviation.

The termination levels of the azygos, hemiazygos, accessory hemiazygos and right superior intercostal veins were determined (Tables 2–5).

Table 2 – ***The termination levels of the azygos vein (LAVT)***

	Levels	Frequency	Percent	Valid percent	Cumulative percent
Valid	T2–3	6	12.5	13.3	13.3
	T2	6	12.5	13.3	26.7
	T3–4	3	6.3	6.7	33.3
	T3	30	62.5	66.7	100
	Total	45	93.8	100	–
Missing	–	3	6.3	–	–
Total		48	100	–	–

LAVT: Level of azygos vein (termination).

Table 3 – ***The termination levels of the hemiazygos vein (LHAVT)***

	Levels	Frequency	Percent	Valid percent	Cumulative percent
Valid	T10	2	4.2	5.3	5.3
	T6–7	1	2.1	2.6	7.9
	T6	1	2.1	2.6	10.5
	T7–8	3	6.3	7.9	18.4
	T7	4	8.3	10.5	28.9
	T8–9	2	4.2	5.3	34.2
	T8	13	27.1	34.2	68.4
	T9–1	2	4.2	5.3	73.7
	T9	10	20.8	26.3	100
	Total	38	79.2	100	–
Missing	–	10	20.8	–	–
Total		48	100	–	–

LHAVT: Level of hemiazygos vein (termination).

Table 4 – ***The termination levels of the accessory hemiazygos vein (LaHAVT)***

	Levels	Frequency	Percent	Valid percent	Cumulative percent
Valid	T6–7	2	4.2	4.9	4.9
	T6	7	14.6	17.1	22
	T7–8	1	2.1	2.4	24.4
	T7	12	25	29.3	53.7
	T8–9	1	2.1	2.4	56.1
	T8	13	27.1	31.7	87.8
	T9	5	10.4	12.2	100
	Total	41	85.4	100	–
Missing	–	7	14.6	–	–
Total		48	100	–	–

LaHAVT: Level of accessory hemiazygos vein (termination).

Table 5 – ***The termination levels of the right superior intercostal vein (LrSIVT)***

	Levels	Frequency	Percent	Valid percent	Cumulative percent
Valid	T2–3	1	2.1	2.6	2.6
	T3–4	5	10.4	13.2	15.8
	T3	11	22.9	28.9	44.7
	T4	21	43.8	55.3	100
	Total	38	79.2	100	–
Missing	–	10	20.8	–	–
Total		48	100	–	–

LrSIVT: Level of right superior intercostal vein (termination).

The mean diameter of the azygos vein at its origin was 4.05±1.03 mm, the mean diameter of the hemiazygos vein at its origin was 3.17±0.7 mm, the mean diameter of the azygos vein at its termination was 8.56±1.26 mm, the mean diameter of the hemiazygos vein at its termination was 5.65±1.17 mm, the mean diameter of the accessory hemiazygos vein at its termination was 5.47±1.16 mm and the mean diameter of the right superior intercostal vein at its termination was 4.26±0.88 mm.

The termination level of the azygos vein was at the level of T3 except the Case No. 6 (T2), the Cases No. 10, 12, 17, 18 and 22 (T2–3) and the Case No. 20 (T3–4). In addition, the termination levels of the hemiazygos vein were determined between T7 and T10. Just in one case (Case No. 18), it was at the level of T6. The termination levels for the accessory hemiazygos and right superior intercostal veins were T6–9 and T3–4 respectively. The azygos venous system was evaluated in three types and 11 subtypes with respect to the classification of Anson BJ (1984) (Table 6).

Table 6 – ***Cases in groups***

Groups	No. of cases	%
Group 1	1	2.1
Group 2	13	27.1
Group 3	1	2.1
Group 4	5	10.4
Group 5	5	10.4
Group 6A	4	8.3
Group 6B	4	8.3
Group 7	11	22.9
Group 8	0	0
Group 9	1	2.1
Group 10	0	0
Group 11	1	2.1
Atypic group	2	4.2

Note: Group 1 corresponds to Type I, Groups 2–10 correspond to Type II, and Group 11 corresponds to Type III. The cases in the atypic group do not correspond to Anson's classification.

According to this, one of the cases (2.1%) was corresponding to Type I (Group 1) (Figure 1A). Forty-four cases (91.7%) were corresponding to Type II. Of these cases, 13 (27.1%) was Group 2 (Figure 1B), one (2.1%) was Group 3 (Figure 1C), five (10.4%) were Group 4 (Figure 1D), five (10.4%) were Group 5 (Figure 1E), four (8.3%) were Group 6 (Figure 1F).

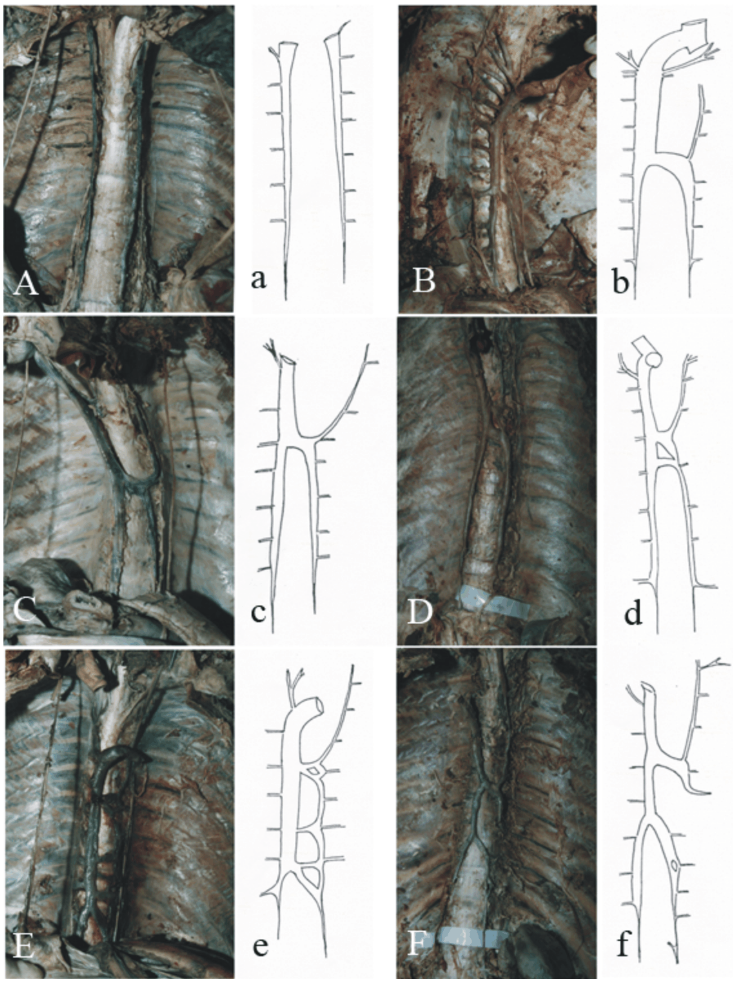

Figure 1 – ***Four cases (8.3%) were Group 6B (Figure 2A), 11 cases (22.9%) were Group 7 (Figure 2B), and one case (2.1%) was Group 9 (Figure 2C). One case (2.1%) was corresponding to Type III (Group 11) (Figure 2D). (A) Two completely separate veins lying in the posterior mediastinum. It corresponds to Type I and it is rare. Case of Type I and Group 1; (a) Schematic drawing of (A). (B) The most seen transition form which corresponds to Type II. Note that retro-aortic anastomoses between the azygos and hemi-azygos venous systems in Type II cases. Case of Type II and Group 2; (b) Schematic drawing of (B). (C) Case of Type II and Group 3; (c) Schematic drawing of (C). (D) Case of Type II and Group 4; (d) Schematic drawing of (D). (E) From Group 2 to Group 5 horizontal anastomoses are increased. Case of Type II and Group 5; (e) Schematic drawing of (E). (F) Beginning from Group 6, vertical bendings can be seen at the left. Case of Type II and Group 6A; (f) Schematic drawing of (F).***

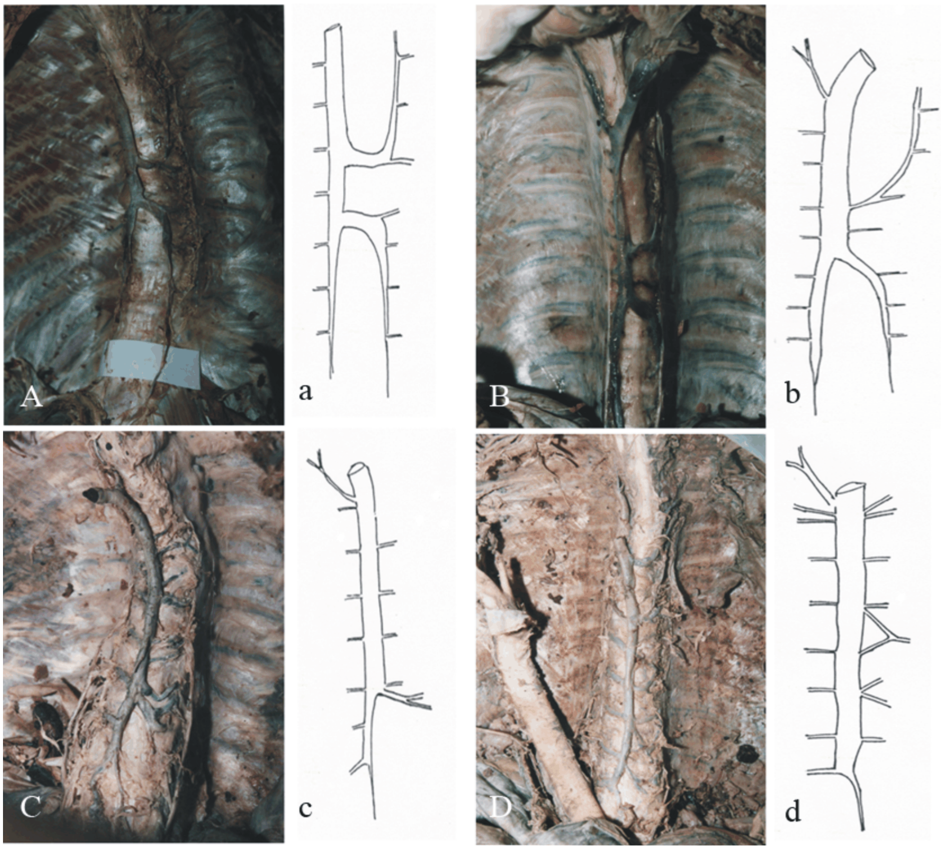

Figure 2 – ***In addition, two cases (4.2%) were not corresponding to any of these groups and these cases were evaluated as atypic (Figure 3). (A) Vertical bendings in the hemiazygos venous system can be seen at the left. Case of Type II and Group 6B; (a) Schematic drawing of (A). (B) Vertical bendings in the hemiazygos venous system can be seen at the left. Case of Type II and Group 7; (b) Schematic drawing of B. (C) The only case that corresponds to Group 9 in Type II; (c) Schematic drawing of (C). (D) Type III azygos vein: a single column azygos vein on the vertebral column. Case of Type III and Group 11; (d) Schematic drawing of (D).***

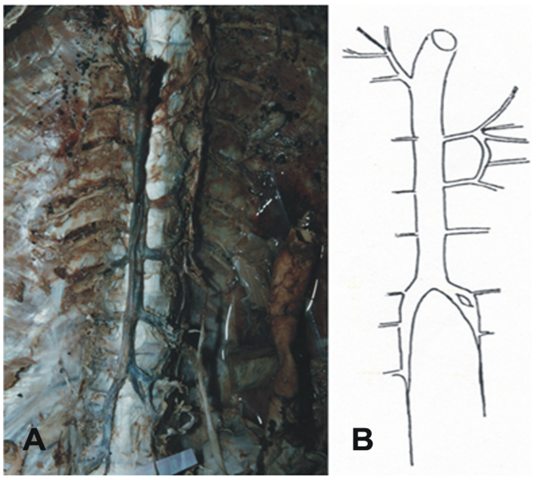

Figure 3 – ***The cases those not corresponding to the other groups. (A) Atypic case; (B) Schematic drawing of (A).***

Discussion

The embryology of the azygos–hemiazygos system is controversial, but the azygos vein is considered to derive from the upper right supracardinal vein, the azygos arch from an upper segment of the right posterior cardinal vein, and the hemiazygos vein from the upper left supracardinal vein. Development of an azygos lobe, also a controversial topic, has been attributed to the posterior cardinal vein failing to migrate over the apex of the right lung, resulting in the vein indenting the lung [3, 12].

During development, the intermediate segment of the right supracardinal vein joins the IVC and azygos or hemiazygos veins, but this segment normally regresses. If the suprarenal segment of the IVC fails to develop, however, the intermediate segment of the supracardinal vein persists, resulting in azygos or hemiazygos continuation [3, 13, 14]. Congenital absence of the azygos vein is rare [15]. Enlargement of the hemiazygos, accessory hemiazygos, and left superior intercostal veins is associated with it anomaly involves the IVC. Azygos and hemiazygos veins are continuation of the IVC. These anomalies may be isolated [16, 17] or associated with other anomalies [18–21]. The incidence in patients with congenital heart disease undergoing cardiac catheterization ranges from 0.2% to 1.3% [3, 12].

The azygos veins vary greatly in their mode of origin, course, tributaries, anastomoses and termination. The accessory hemiazygos is the most variable and may drain into the left brachiocephalic, azygos or hemiazygos vein. Commonly, there is a main 'right-sided' azygos and at least some representative of the hemiazygos veins. The latter vary, and one or other may be absent or poorly developed. Very occasionally, independent left and right azygos veins (the early embryonic form) persist, or a single azygos vein may occur in a midline position without hemiazygos tributaries. Retro-aortic transvertebral connections from hemiazygos and accessory hemiazygos veins to the azygos are also extremely variable: there may be up to five connections. When either of the hemiazygos veins are absent, the relevant intercostal veins cross the vertebral bodies and end in the azygos. These transvertebral routes are often very short, because the azygos vein is more commonly anterior to the vertebral column and often passes to the left of the midline for part of its course. When there is congenital interruption of the IVC, the azygos vein can become as large as the IVC that it has replaced [1].

In most cases, the azygos venous system was investigated in three types by various researchers. In his study of 100 cadaver dissections, Anson BJ has investigated the azygos venous system in three main types and 11 subtypes. According to this:

▪ Type I: This primitive and embryological form consists of two separate veins lying in parallel to each other in the posterior mediastinum, being anterior and lateral to the vertebral column. It is seen 1%. These parallel veins constitute the azygos vein at the right side and superior and inferior azygos veins, which are the continuation of each other's, at the left side. The veins at the left side, those that the left lumbar vein opens, subsequently open into the left brachiocephalic vein. There is only one subtype (Group 1) of this type and one (2.1%) of the cases corresponds to this subtype (Group 1).

▪ Type II: 98% of all cases are in this form and it is known as the transition type. It consists of Groups 2–10. There are multiple retro-aortic anastomoses between the azygos and hemiazygos venous systems. From Group 2 to Group 5 the quantity of these transverse anastomoses increases. There is continuity in the left side. Between Groups 6 and 10, it is seen a vertical bending and the number of the transverse anastomoses decreases gradually. Forty-four cases (91.7%) were corresponding to this type. Of these 44 cases, 13 (27.1%) was Group 2, one (2.1%) was Group 3, five (10.4%) was Group 4, five (10.4%) was Group 5, five (8.3%) was Group 6A, four (8.3%) was Group 6B, 11 (22.9%) was Group 7, and one (2.1%) was Group 9.

▪ Type III: It consists of a single azygos vein lying at the midline, on the anterior surface of the vertebral column. There is only one subtype (Group 11) of this main type. It is seen in 1% of all cases. In one (2.1%) of our cases, this subtype (Group 11) was seen. In addition, two (4.2%) cases were not corresponding to any of these groups and these cases were evaluated as atypic.

In his study of 200 cadaver dissections, Seib GA has reported the azygos venous system in three main types and 21 subtypes. He has also referred to these main types as double column, transition and single column types [6]. Likewise, Falla A *et al.* have classified their results in 11 groups, in their study of 100 cadaver dissections [7]. With respect to Seib GA [6], the cases in which the azygos and hemiazygos veins were not connected with each other (embryological type) were seen 1–2%. The cases in which the azygos and hemiazygos veins did not originate separately with the form of single column azygos vein was reported 1–2% and 5% by Kadir S and Seib GA, respectively [6, 22].

Tatar I *et al.* have measured the diameter of the azygos vein at the opening into the superior vena cava ranged between 4.3 mm and 16 mm. In their study, the azygos vein was at the midline in 41 cases. The arching and opening level of the azygos vein was at the fifth thoracic vertebra in most cases. The opening level was most often at the same level as the carina. Hemiazygos veins were detected in 90 patients [23].

Previously in literature [23] any statistical difference was not found between age groups and gender. We also did not observe any influence of age and gender.

In our study, the mean diameter of the azygos vein at its origin was 4.05±1.03 mm and the mean diameter of the azygos vein at its termination was 8.56±1.26 mm. The termination diameter was four times the origin diameter in the study of Tatar I *et al.* [23], whereas this difference was two times in our study. The mean diameter of the hemiazygos vein at its origin was 3.17±0.7 mm, the mean diameter of the hemiazygos vein at its termination was 5.65±1.17 mm, the mean diameter of the accessory hemiazygos vein at its termination was 5.47±1.16 mm and the mean diameter of the right superior intercostal vein at its termination was 4.26±0.88 mm. Since the hemiazygos veins are smaller than the azygos veins in diameter, they were measured proportionally smaller. In the literature, we could not find any reference regarding detailed information about the diameters of the hemiazygos veins.

Tatar I *et al.* have reported that the azygos vein terminates at the level of T5 in most cases [23]. In our study, the termination level of the azygos vein was at T3 in 41 of 48 cases. In that respect, there are differences between these studies. The termination levels of the hemiazygos vein were determined between T7 and T10 with the exception of one case (T6). The terminated levels for the accessory hemiazygos and right superior intercostal veins were T6-9 and T3–4 respectively. When the studies of last year's were investigated, any information could not be found about the vertebral levels of the hemiazygos veins. Although there are complete valves in some tributaries of azygos veins, there are usually incomplete valves varying between one and four in the azygos arch. Thus, the azygos vein functions as a collateral for the superior and IVC in case of their obstruction. The azygos vein connects the superior and IVC with ascending lumbar veins and their tributaries. In congenital obstruction of the IVC, the azygos vein provides the venous flow of the lower body half [22, 24–26].

The connection between azygos vein and portal venous system provides the blood flow to the superior vena cava through the esophageal veins in case of portal hypertension. In case of portal hypertension, collateral veins are produced between portal and caval venous systems mainly in five zones. One of these collateral veins in the retroperitoneal region is the "plexus venosus Retzius", which connects the veins of duodenum, pancreas, spleen and transverse colon with the azygos and inferior phrenic veins [3, 27–29].

It is important to determine the variations of the azygos venous system especially in the computed tomography and magnetic resonance imaging of mediastinum. The anomalous azygos venous system may easily be confused with aneurysm, lymphadenopathy and other anomalies like tumor [30–32]. It is crucial to keep in mind this kind of variations in mediastinal operations or in surgery of large vessels.

We discuss previous studies of Seib GA, Falla A *et al.*, which determined the azygos vein system as three types and related subgroups in their studies extensively. Classification of Anson BJ was most suitable and useful, because synthesize previous classifications. We found that classification of Seib GA was not enough objective because in his study in 1934 he compare racial differences. Additionally, classification of Falla A *et al.* [7] was nearly similar with classification of Anson.

Conclusions

This detailed anatomical study has demonstrated the diameters and levels of the azygos venous system in addition to the review of the types, groups and subgroups of the azygos venous system with detailed figures and diagrams. Additionally, all morphometrical data (diameters) and their termination levels can be used especially during preoperative computerize tomography evaluations before planning invasive mediastinal procedures. The results of this study can be useful in mediastinal surgery, mediastinoscopy and the surgery of the deformations of the vertebral column, neurovascular surgery of the retroperitoneal organs, disc herniations and fractures of the thoracal vertebrae.

Acknowledgments

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