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The complete anatomy of the azygos vein: a meta-analysis with clinical implications

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Background: *The azygos vein (AV) plays a crucial role in the mediastinal region, exhibiting considerable variability in its anatomy and relationship with surrounding structures. This study aims to assess the morphometry and anatomy of the AV through a comprehensive meta-analysis of studies reporting extractable data on this vessel.*

Materials and methods: *Major online medical databases such as PubMed, Scopus, ScienceDirect, Web of Science, SciELO, BIOSIS, Current Content Connect, Korean Journal Database, and Wiley Online Library were searched to gather all relevant studies regarding the anatomical characteristics of the AV.*

Results: *The results of the present meta-analysis comprised 40 studies, categorised into 8 groups for data analysis. The mean AV diameter at its origin was set at 3.86 mm (SE = 0.84). The most prevalent was type IIB, with a prevalence of 40.23% (95% CI: 29.06–51.92%). The pooled prevalence of the right subcostal and right ascending lumbar veins forming the AV was 73.82% (95% CI: 55.77–88.67%).*

Conclusions: *The AV exhibits a high degree of variability regarding its origin, trajectory, and connections with the hemiazygos system. The most prevalent type of AV, according to the Anson and McVay classification [4], was Type II (transitional type). Moreover, the vein was found to be formed by the right subcostal and the right ascending lumbar veins in most of the cases. This is the most comprehensive and current assessment of AV morphometry and anatomy to date. The findings are a valuable resource for physicians, especially surgeons performing various procedures in the mediastinum.* (Folia Morphol 2025; 84, 1: 22–36)

Keywords: azygos vein, azygos venous system, anatomy, thorax, mediastinum, surgery

INTRODUCTION

The azygos system of veins serves to drain the posterior and thoracoabdominal walls as well as the mediastinal viscera. This system displays significant variability in its origin, trajectory, tributaries, and connections. Typically, the azygos vein (derived from the Latin *azygos*, meaning unpaired) (AV) and its primary tributary, the hemi-azygos vein, originate from "roots" stemming from the posterior aspect of the inferior vena cava (IVC) and/or the renal vein, respectively, which then merge with the ascending lumbar veins [27, 32, 38].

Functioning as a collateral pathway between the superior vena cava (SVC) and IVC, the AV collects

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blood from the posterior walls of the thorax and abdomen. Its course traverses the posterior mediastinum, closely following the right sides of the bodies of the inferior 8 thoracic vertebrae. It subsequently arches over the superior aspect of the right lung's root to join the SVC, similarly to the arch of the aorta passing over the left lung's root. In addition to receiving blood from the posterior intercostal veins, the azygos vein communicates with the vertebral venous plexuses, which are responsible for draining the back, vertebrae, and structures within the vertebral canal. Furthermore, the azygos vein also collects blood from the mediastinal, oesophageal, and bronchial veins [10, 27].

The azygos system exhibits considerable variability in its origin, trajectory, tributaries, and termination. It is classified into 3 types (primitive or embryological type, transition type, and single column type) with 11 subgroups and an additional atypical subgroup [4]. Some variations are associated with the AV, including the formation of the AV, the characteristics of the connections between the azygos and hemiazygos venous systems, and the course of the AV, amongst others [34]. Enlargement of the AV is a significant symptom in numerous pathologies such as superior vena cava syndrome, inferior vena cava obstruction, constrictive pericarditis, cardiac tamponade, congestive heart failure, pulmonary hypertension/embolism, and portal hypertension [35]. Moreover, having adequate knowledge regarding the complete anatomy of the AV is of utmost importance when performing surgical procedures on the oesophagus, such as during the treatment of oesophageal atresia or during oesophagectomies [44, 57].

Therefore, the objective of this study was to provide comprehensive data on the morphometry, anatomy, and variations of the AV. To accomplish this, a systematic literature search and meta-analysis were conducted.

MATERIALS AND METHODS

Search strategy

Major online medical databases such as PubMed, Scopus, ScienceDirect, Web of Science, SciELO, BIOSIS, Current Content Connect, Korean Journal Database, and Wiley Online Library were searched to gather all studies on anatomical characteristics, morphometry, and variations with surrounding structures of the AV. The study collection ended in January 2024. In agreement with the Boolean technique, the following search terms were employed: (azygos vein anatomy) OR (azygos vein variation) OR (azygos vein anomaly). The search terms were customised for each database to reduce possible bias. No restrictions were placed on date, language, article type, or text availability. Additionally, references from the identified studies were searched at the end of the process to ensure accuracy of the search. During the study, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed. Furthermore, the Critical Appraisal Tool for Anatomical Meta-analysis (CATAM) and Anatomical Quality Assessment Tool (AQUA) were used to provide the highest quality findings [8, 14, 54].

Eligibility assessment

The database and manual searches yielded a total of 4755 studies, which were initially reviewed by 2 independent authors. After eliminating duplicates and irrelevant records, 257 articles were qualified for full-text evaluation. To reduce potential bias and uphold accurate statistical methodology, articles such as case reports, case series, conference reports, reviews, letters to editors, and studies with incomplete or irrelevant data were excluded. The inclusion criteria consisted of original studies with extractable numerical data regarding the topic of this study. Finally, a total of 41 studies were included in this meta-analysis.

Data extraction

Two independent reviewers extracted data from the eligible studies. Qualitative data, such as year of publication, country and continent of origin, data collection methodology, and information on diseases in the studied groups, were collected. Quantitative data, such as sample size, numerical data on anatomical characteristics, morphometry, and relationship with the anatomical surroundings of the AV, were also gathered. Discrepancies between studies identified by the 2 reviewers were resolved either by reaching out to the original study authors when possible or by consensus with a third reviewer.

Statistical analysis

To perform the meta-analyses, MetaXL version 5.3 software (EpiGear International Pty Ltd, Wilston, Queensland, Australia) and Comprehensive Meta-analysis version 3.0 software (Biostat Inc., Englewood, NJ, USA) were used. A random-effects model was used in all analyses. The heterogeneity among the studies was evaluated using both the chi-squared test and the I-squared statistic [15]. P-value < 0.05 and the confidence intervals (95% CI) were used to find statistically significant differences between the studied groups. In the case of overlapping confidence intervals, differences were considered statistically insignificant.

RESULTS

Search results

After the selection of the initially accepted 117 studies, a total of 76 studies were excluded. Most of them (n = 55) were disqualified due to the lack of relevant data. Eleven case reports were also excluded. Furthermore, 8 studies were excluded because they were review articles, and 2 because they were animal studies. Eventually, a total of 41 studies were included in this meta-analysis [1–4, 7, 9, 11–13, 16, 17, 19–22, 24, 26, 29–34, 36, 37, 39–43, 45, 47–53, 56, 59, 60]. According to the PRISMA guidelines, the overall data collection process is presented in Figure 1. Additionally, the characteristics of all the submitted studies are showcased in Table 1.

Diameter of the azygos vein

The mean AV diameter at its origin was set at 3.86 mm [standard error (SE) = 0.84]. The mean AV diameter at its termination into the SVC was 8.53 mm (SE = 1.05) in cadaveric studies and 8.34 mm (SE = = 0.66) in radiological studies. All the aforementioned results are demonstrated in Table 2.

Anson and McVay classification of the azygos vein

The Anson and McVay [4] classification, later modified by Dahran and Soames [7], divides AV types into 3 main categories: Type 1 — two longitudinal azygos lines with no connections in between [34]; Type 2 — two longitudinal azygos lines with at least one (Type IIA) up to five (Type IIE) connections in between, multiple retroaortic anastomoses between the azygos and hemi-azygos venous systems [34]; and Type 3 — a single vein located in the midline draining the posterior intercostal veins from both sides [34] (Fig. 2).

The analysis of the classification of AV was established, considering a total of 318 veins. The pooled prevalence for type II was 91.54% (95% CI: 84.01–96.95%). The most prevalent was type IIB, with a prevalence of 40.23% (95% CI: 29.06–51.92%). The other classification was based on 128 veins. The pooled prevalence for group 2 was 19.37% (95% CI: 9.26–31.91%). All the abovementioned results are showcased in Table 3 and Figure 3.

Formation of the azygos vein

A total of 390 veins were analysed concerning the type of trunk of the AV. The pooled prevalence for a single trunk was 89.54% (95% CI: 72.25–99.51%). Moreover, the results regarding the AV formation were based on 400 veins. The pooled prevalence of the right subcostal and right ascending lumbar veins forming the AV was 73.82% (95% CI: 55.77–88.67%). An analysis of the intermediate azygos root was gathered on 551 specimens. The pooled prevalence was 51.38% (95% CI: 26.72–75.73%). The results of the present section are demonstrated in Table 4.

Course of the azygos vein

The course of the AV was analysed based on the 883 specimens. The pooled prevalence of the right course of the midline of the vertebral column was 36.25% (95% CI: 21.67–52.17%), and the midline of the vertebral column was 30.75% (95% CI: 16.00–47.68%). All results mentioned previously and more detailed ones are gathered in Table 5.

Termination level of the azygos vein

The analyses of the termination level of the AV were conducted on a total of 1032 veins. The most prevalent variants were the T4 termination level, T5 termination level, and T3 termination level, with pooled prevalences established at 33.20% (95% CI: 15.78–53.16%), 15.04% (95% CI: 5.24–28.26%), and 11.55% (95% CI: 4.37–21.29%), respectively. All the abovementioned results are showcased in Table 6.

Venous valves of the azygos arch

The venous valves of the AV were analysed based on 1023 veins, and the pooled prevalence was set at 64.67% (95% CI: 55.22–73.59%). Moreover, venous valve reflux occurred with a pooled prevalence of 46.51% (95% CI: 36.12–57.04%), which was based on 956 specimens. The valve residual contrast occurred with the pooled prevalence of 48.58% (95% CI: 43.34–53.84%), which was established on 635 veins. The results of this section are presented in Table 7.

DISCUSSION

The azygos system exhibits a high degree of variability in its topographical and morphometric properties.

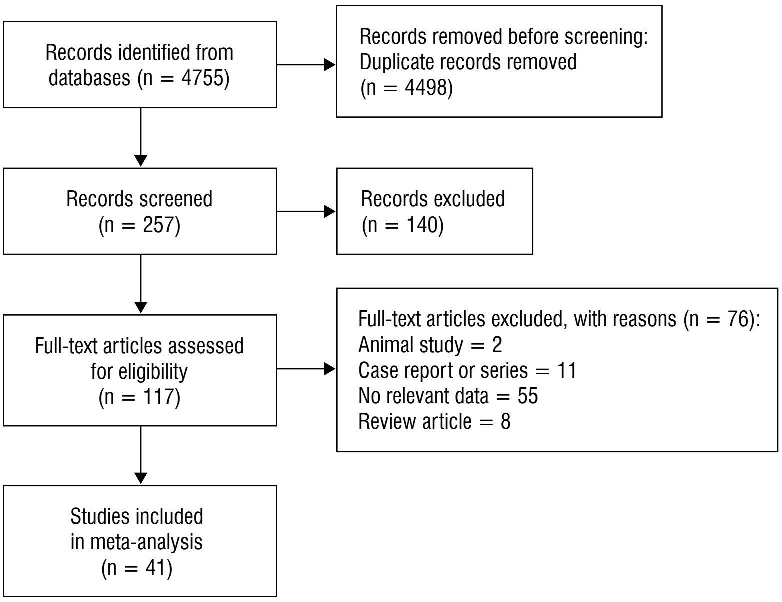

Figure 1. Flow diagram presenting process of collecting data included in this meta-analysis.

Numerous classification systems have been presented in the literature to showcase the complete anatomy of the AV clearly. The first classification system, consisting of 3 types and 11 groups, was demonstrated by Anson and McVay in 1984 [4]. The types were classified as Type I (primitive type), Type II (transitional type), and Type III (unicolumnar type). Type I represented 2 longitudinal azygos lines with no connections between them. Type II was described as multiple retro-aortic anastomoses between the azygos and hemiazygos venous systems. Finally, Type III was presented as a single AV lying at the anterior midline of the vertebral column. The classification system further divides the aforementioned types into 11 groups. Group 1 represented Type I, i.e. 2 separate parallelly ascending veins. Type II consists of groups 2–10: groups 2–5 are characterised by a gradual increase in the number of transverse anastomoses alongside a continuity on the left side. Meanwhile, groups 6–10 are described as vertical bending with a continuous decrease of anastomoses. Ultimately, Type III is equivalent to group 11 [34]. More recently, Dahran and Soames [7] expanded the abovementioned classification system with a special focus on Type II (transitional type) and the number of communications between the azygos and hemiazygos venous systems. The said type was grouped from Group A (one communication) to Group E (5 or more communications). The descriptions of the types and subgroups of the said classification systems may be found in Table 3 and Figure 2. The results of the present meta-analysis demonstrate that the most frequently occurring type, according to the Anson and McVay [4] classification, is Type II (transitional type), with a pooled prevalence of 91.54%. Moreover, the most prevalent subgroup was found to be Group 2, i.e. one midline horizontal connection usually at the level of T8, with a pooled prevalence of 19.37%. On the other hand, the most prevalent subgroup of Type II, according to the Dahran and Soames [7] classification, is Group B (2 communications between the azygos and hemiazygos venous systems) (40.23%).

Embryologically, the AV emerges from the final segment of the posterior cardinal veins. Its classification as a tributary of the SVC depends upon their shared lineage. Additionally, the proximal segment of the AV originates from the anterior common cardinal vein and the sinus venosus. The involvement of the proximal segment of the right posterior cardinal vein, along with the posterior cardinal derived veins known as supracardinal veins, contributes to the formation of the arch of the azygos system [10].

The formation of the AV is variable. The type of trunk in the formation of the AV may consist of a single trunk, being frequently described as the most common [2, 25], as well as double and triple trunks [2, 50]. In the present meta-analysis, the predominant

Table 1. Characteristics of the submitted studies.

Author, year and country	Parameters	Result
Alves 2011, Brazil, South America	Methods	Cadaveric dissection
	Participants	30 cadavers
	Outcomes	Trunk type, formation of AV
Andreassi 1931, Italy, Europe	Methods	Cadaveric dissection
	Participants	50 cadavers
	Outcomes	Intermediate root
Anson 1984, USA, North America	Methods	Cadaveric dissection
	Participants	100 cadavers
	Outcomes	AV classification
Dahran 2016, UK, Europe	Methods	Cadaveric dissection
	Participants	30 cadavers (18 females & 12 males) Age: 81.3 $\pm$ 12.4 years
	Outcomes	AV origin & termination diameter, termination level, AV classification
Diaconou 2012, USA, North America	Methods	Cadaveric dissection
	Participants	20 cadavers (13 females & 7 males) Age: 61.7 years
	Outcomes	AV valves
Endo 2008, Japan, Asia	Methods	Radiological study Imaging: CT
	Participants	132 adults (117 females & 15 males) Age: 52.8 (24–88) years
	Outcomes	AV valves
Fukutome 1951, Japan, Asia	Methods	Cadaveric dissection
	Participants	54 cadavers
	Outcomes	Course of AV
Gomes 2020, Brazil, South America	Methods	Cadaveric dissection
	Participants	13 cadavers
	Outcomes	Termination level, course of AV, formation of AV
Hage 2024, Asia, India	Methods	Cadaveric dissection
	Participants	47 cadavers (25 males & 22 females) Age range: 69 (34–95) years
	Outcomes	AV valves
Hovelacque 1914, France, Europe	Methods	Cadaveric dissection
	Participants	20 cadavers
	Outcomes	Intermediate root
Ichikawa 2008, Japan, Asia	Methods	Radiological study Imaging: CT
	Participants	194 adults (68 males & 126 females) Age: 58.4 (24–88) years
	Outcomes	AV valves
Kagami 1990, Japan, Asia	Methods	Cadaveric dissection & foetuses dissection
	Participants	26 cadavers & 10 foetuses Age: average 79 years & 5 months
	Outcomes	Course of AV
Kanchana 2013, India, Asia	Methods	Cadaveric dissection & foetuses dissection
	Participants	82 adult cadavers & 8 children cadavers & 10 foetuses
	Outcomes	Trunk type, termination level, formation of AV

→

Table 1 (cont.). Characteristics of the submitted studies.

Author, year and country	Parameters	Result
Koutsoufianiotis 2021, Greece, Europe	Methods	Radiological study Imaging: CT
	Participants	51 adults (25 males & 26 females) Age: 66.5 ± 17.2 years
	Outcomes	AV termination diameter, termination level, course of AV
Krakowiak-Sarnowska 2003, Poland, Europe	Methods	Foetuses dissection
	Participants	32 foetuses (14 males & 18 females) Age: 21–24 week of intrauterine life
	Outcomes	Termination level, course of AV
Kutoglu 2012, Turkey, Asia	Methods	Cadaveric dissection
	Participants	48 cadavers (35 males & 13 females) Age: 48.29 ± 12.097 years
	Outcomes	AV origin & termination diameter, termination level, AV classification
Mohanty 2022, India, Asia	Methods	Cadaveric dissection
	Participants	20 cadavers Age range: 50–70 years
	Outcomes	Termination level, AV classification
Mustafa 2016, Saudi Arabia, Asia	Methods	Cadaveric dissection
	Participants	30 cadavers
	Outcomes	Formation of AV
Nathan 1960, Israel, Asia	Methods	Cadaveric dissection
	Participants	150 cadavers (130 adults & 20 stillborn infants)
	Outcomes	Course of AV
Nirmala 2015, India, Asia	Methods	Cadaveric dissection
	Participants	50 cadavers
	Outcomes	Trunk type, termination level, course of AV, formation of AV
Parsons 1898, UK, Europe	Methods	Cadaveric dissection
	Participants	32 cadavers
	Outcomes	Intermediate root
Patra 2019, India, Asia	Methods	Cadaveric dissection
	Participants	30 cadavers (26 males & 4 females) Age: 40-65
	Outcomes	AV origin & termination diameter, termination level, AV classification, course of AV
Prasad 2018, India, Asia	Methods	Cadaveric dissection
	Participants	50 cadavers
	Outcomes	Trunk type, termination level, AV classification
Priya 2023, India, Asia	Methods	Cadaveric dissection
	Participants	30 cadavers
	Outcomes	Trunk type, intermediate root, AV origin & termination diameter, termination level, course of AV
Radhika 2016, India, Asia	Methods	Cadaveric dissection & foetuses dissection
	Participants	82 adult & 8 children cadavers & 10 foetuses
	Outcomes	Trunk type, termination level, formation of AV
Raghavendra 2017, India, Asia	Methods	Cadaveric dissection
	Participants	36 cadavers
	Outcomes	AV termination diameter, termination level

→

Table 1 (cont.). Characteristics of the submitted studies.

Author, year and country	Parameters	Result
Rao 2022, India, Asia	Methods	Cadaveric dissection
	Participants	50 cadavers
	Outcomes	Course of AV, formation of AV
Rohilla 2021, India, Asia	Methods	Cadaveric dissection
	Participants	30 cadavers
	Outcomes	AV classification
Rokunannda 1959, Japan, Asia	Methods	Cadaveric dissection
	Participants	50 cadavers
	Outcomes	Course of AV
Saito 2015, Japan, Asia	Methods	Cadaveric dissection
	Participants	47 cadavers (19 males & 28 females) Age: 84.7 ± 8.6 years
	Outcomes	Course of AV
Seib 1934, USA, North America	Methods	Cadaveric dissection
	Participants	200 cadavers (170 males & 30 females) Age range: 16–90 years
	Outcomes	Intermediate root, termination level
Shen 2015, China, Asia	Methods	Radiological study Imaging: CT
	Participants	100 adults (52 females & 48 males) Age: 53.5 ± 12.8 years
	Outcomes	Termination level
Singh 2019, India, Asia	Methods	Cadaveric dissection
	Participants	50 cadavers (25 females & 25 males)
	Outcomes	Course of AV
Steinke 2009, Australia, Australia & Oceania	Methods	Radiological study Imaging: CT
	Participants	321 adults (149 females & 172 males) 60.62 (16–99) years
	Outcomes	AV valves
Suresh 2016, India, Asia	Methods	Cadaveric dissection & radiological study Imaging: CT
	Participants	30 cadavers & 20 adults
	Outcomes	Trunk type, intermediate root, AV termination diameter, termination level, AV classification, course of AV, formation of AV
Tatar 2007, Turkey, Asia	Methods	Radiological study Imaging: CT
	Participants	103 adults (42 females & 61 males) Age: 47.08 ± 22.06
	Outcomes	AV termination diameter, termination level, course of AV
Tateshi 1939, Japan, Asia	Methods	Cadaveric dissection
	Participants	11 cadavers
	Outcomes	Course of AV
Tokutome 1951, Japan, Asia	Methods	Cadaveric dissection
	Participants	54 cadavers
	Outcomes	Course of AV

→

Table 1 (cont.). Characteristics of the submitted studies.

Author, year and country	Parameters	Result
Vedapriya 2018, India, Asia	Methods	Cadaveric dissection
	Participants	22 cadavers
	Outcomes	Course of AV
Yeh 2004, USA, North America	Methods	Radiological study
	Participants	309 volunteers (145 males & 164 females) Age: 60 (0.2–94) years
	Outcomes	AV valves
Zumatein 1896, Germany, Europe	Methods	Cadaveric dissection
	Participants	169 cadavers
	Outcomes	Intermediate root

AV — azygos vein; CT — computed tomography.

Table 2. Statistical results of this meta-analysis regarding the diameter and the azygos vein (AV).

Category	Mean	Standard error	Variance	Lower limit	Upper limit	Z-value	p-value
Azygos vein diameter at its origin [mm]							
Overall (cadaveric dissections)	3.86	0.84	0.70	2.21	5.50	4.60	0.00
Asia (cadaveric dissections)	4.44	0.76	0.57	2.96	5.93	5.87	0.00
Azygos vein diameter at its termination [mm]							
Overall (cadaveric dissections)	8.53	1.05	1.10	6.48	10.58	8.15	0.00
Overall (computed tomography)	8.34	0.66	0.43	7.05	9.64	12.65	0.00
Asia (cadaveric dissections)	9.12	1.09	1.18	6.99	11.25	8.39	0.00
Asia (computed tomography)	7.73	0.55	0.30	6.66	8.80	14.13	0.00

type of trunk forming the AV was the single trunk type, with a pooled prevalence of 89.54%. Moreover, our results demonstrate that, in most of the cases, the AV was formed by the right subcostal and the right ascending lumbar veins (73.82%). However, the AV was found to be formed only by the right subcostal vein and by the right subcostal vein, with contributions from the inferior vena cava relatively frequently (9.00% and 6.05%, respectively). Other sources have described the AV to arise from the lateral, intermediate, and/or medial roots or from any combination of the said roots [18]. The lateral root is said to represent the junction of the right ascending lumbar vein and right subcostal vein, i.e. the most prevalent origin of the AV, as demonstrated by our results. On the other hand, the intermediate root, described as arising from the dorsal side of the IVC, often as a common trunk with the segmental or right renal vein, occurs less frequently. Reports have presented prevalences ranging from 26.72% to 75.73% [16, 33, 37, 45, 50]. The results of the present study, which are based on all the data available in the literature, demonstrate that the intermediate root is present in more than half of the subjects (51.38%).

In the present meta-analysis, the distribution of the AV was 36.25% of the veins on the right side of the vertebral column, 30.75% on the midline of the vertebral column, and 11.88% on the left side of the vertebral column. Osteophytosis of the thoracic vertebral column, typically found on the right side, may contribute to the deviation of the AV to the left side [30, 43]. However, Kagami and Sakai [19] suggested that the course of the AV is not influenced by osteophytes; rather, osteophytes may be influenced by the AV.

The diameter of the AV at its origin and termination is crucial in investigations of aneurysms, mediastinal tumours, or enlarged lymph nodes [6]. Aneurysms predominantly occur in the arch of the AV, with approximately two-thirds of affected patients being female. Complications of undiagnosed AV aneurysms include rupture, thromboembolism, mediastinal mass effects, and pulmonary artery hypertension [23]. Additionally, the azygos system is

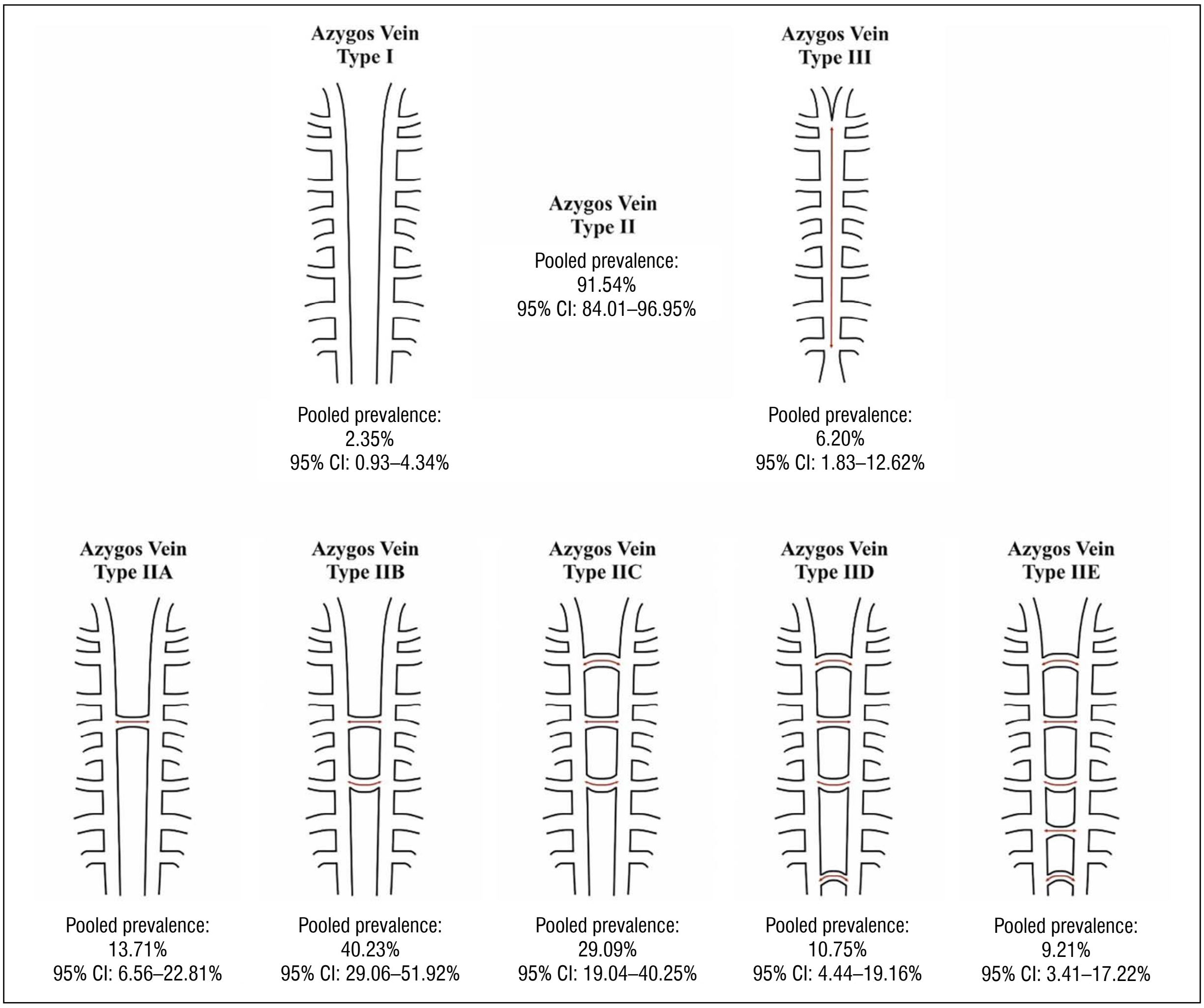

Figure 2. Illustrations of azygos vein types according to classification by Anson and McVay (1984): Type 1 — two longitudinal azygos lines with no connections in between (Patra et al. 2019); Type 2 — multiple retroaortic anastomoses between the azygos and hemi-azygos venous systems (Patra et al. 2019); Type 3 — a single vein located in the midline draining the posterior intercostal veins from both sides (Patra et al. 2019); (*) — type II was divided into 5 subgroups regarding retroaortic communications — a modification of an Anson and McVay (1984) [4] classification by Dahran and Soames [7] in 2016: Type IIA — 1 communication; Type IIB — two communications; Type IIC — three communications; Type IID — four communications; Type IIE — five or more communications (Patra et al. 2019).

an important metastatic pathway to the lungs [35]. Our study demonstrates that at its origin, the mean diameter of the AV was 3.86 mm, and at its termination, 8.53 mm (cadaveric-based data) and 8.34 mm (imaging study-based data).

The current literature is limited in its knowledge of the venous valves of the AV. However, certain studies have shed light on their prevalence and characteristics. These valves are most frequently observed in the arch of the AV, specifically in the third quartile of the distance from the opening of the right superior intercostal vein into the AV to the superior vena cava. Among the identified valves, the majority are bicuspid (70.2%), followed by tricuspid (10.6%) and unicuspid (8.5%) configurations.

The length of the cusp of the bicuspid valve ranged from 10 to 12 mm, while for the unicuspid valve, it ranged from 3 to 6 mm [13]. Notably, these valves often exhibit a distinctive 'coffee bean' appearance on angiocardiography due to contrast accumulation within the 2 valve cusps [55]. Morita et al. [28] suggested that the purpose of these AV valves is to prevent retrograde blood flow from the superior vena cava to the AV. In the present meta-analysis, retrograde flow of contrast into the azygos arch and contrast retention in or around the valve was observed in 46.51% and 48.58% of cases, respectively [13]. Therefore, it is crucial for radiologists to accurately discern the appearance of AV valves and flow dynamics in contrast imaging studies to prevent

Table 3. Statistical results of this meta-analysis regarding the prevalence of each azygos vein type.

Category	N	Pooled prevalence	LCI	HCI	Q	I^2
Classification I: Anson and McVay (1984) [4] & Dahran and Soames (2016) [7]						
Type I	318	2.35%	0.93%	4.34%	4.58	0.00
Type II		91.54%	84.01%	96.95%	26.82	73.90
IIA*	70	13.71%	6.56%	22.81%	0.45	0.00
IIB*		40.23%	29.06%	51.92%	0.52	0.00
IIC*		29.09%	19.04%	40.25%	0.47	0.00
IID*		10.75%	4.44%	19.16%	1.02	0.00
IIE*		9.21%	3.41%	17.22%	1.38	0.00
Type III	318	6.20%	1.83%	12.62%	24.40	71.31
Classification II: Anson and McVay (1984)						
Group 1	128	1.70%	0.06%	4.86%	1.95	0.00
Group 2		19.37%	9.26%	31.91%	5.21	61.59
Group 3		1.70%	0.06%	4.86%	1.95	0.00
Group 4		11.47%	6.48%	17.61%	0.26	0.00
Group 5		14.69%	7.96%	22.96%	2.89	30.83
Group 6A		2.50%	0.00%	8.63%	6.43	68.90
Group 6B		12.31%	4.60%	22.73%	4.73	57.75
Group 7		15.14%	5.22%	28.55%	6.56	69.52
Group 8		–	–	–	–	–
Group 9		2.75%	0.00%	7.25%	3.62	44.70
Group 10		2.63%	0.00%	8.37%	3.90	48.69
Group 11		2.75%	0.00%	7.25%	3.62	44.70
Atypical		8.59%	0.16%	24.20%	10.67	81.26

Classification I: Anson and McVay (1984): Type 1 — two longitudinal azygos lines with no connections in between (Patra et al. 2019). Type 2 — multiple retroaortic anastomoses between the azygos and hemi-azygos venous systems (Patra et al. 2019). Type 3 — a single vein located in the midline draining the posterior intercostal veins from both sides (Patra et al. 2019). *Type II was divided into 5 subgroups regarding retroaortic communications — a modification of an Anson and McVay (1984) [4] classification by Dahran and Soames in 2016 [7]: Type IIA — 1 communication; Type IIB — two communications; Type IIC — three communications; Type IID — four communications; Type IIE — five or more communications (Patra et al. 2019). Classification II: Anson and McVay 1984: Group 1 — two completely separate, parallel ascending veins; Group 2 — one midline horizontal connection usually at the level of T8; Group 3 — between right and left trunk, one horizontal connection above the level of T8; Group 4 — two horizontal connections between right and left trunk superior horizontal connection at T8 and inferior horizontal connection below the level of T8; Group 5 — three to five horizontal connections between right and left trunk; Group 6 — one breakage in left trunk; Group 6A: AHazv and left brachiocephalic trunk vein is connected; Group6B: No connection between AHazv and left brachiocephalic trunk vein; Group 7 — two breakages in left trunk; Group 8 — one break in the left trunk, above and below the break; posterior intercostal veins are joined by collaterals. This type was not observed in any of the qualified studies; Group 9 — five breakages in the lower part of the left trunk, and two single veins, in the lower part formed by joining of 11th and 12th intercostal vein and 10th and 9th intercostal vein; Group 10 — five breakages in the lower part of the left trunk; Group 11 — single azygos vein occupying the midline of the anterior surface of the thoracic vertebra. The descriptions of the second classification are based on a study by Prasad et al. 2018. HCI — higher confidence interval; LCI — lower confidence interval; Q — Cochran's Q.

misinterpretation of imaging findings related to thoracic pathology.

The findings of this meta-analysis hold significant implications for various surgical interventions involving the oesophagus, such as during the treatment of oesophageal atresia or during esophagectomies as a treatment for oesophageal cancer [44, 57]. Oesophageal atresia stands as a prevalent congenital anomaly within the digestive tract, affecting approximately one in every 3500 births [46]. Among the various presentations of oesophageal atresia, oesophageal atresia with tracheoesophageal fistula constitutes the majority, comprising around 70–90% of cases [5]. Timely surgical intervention is imperative to ensure the survival of affected infants. During the repair procedure for this anomaly, it is customary to ligate and divide the AV to facilitate the operation [57]. However, a recent meta-analysis conducted by Wang et al. [57] demonstrated that the preservation of the AV during the treatment of oesophageal atresia with tracheoesophageal fistula is associated with reduced prevalence of anastomotic leakage and mortality. Hence, having adequate knowledge regarding the complete anatomy of the AV is imperative for the safe and successful preservation of this structure during the treatment of patients affected by this anomaly.

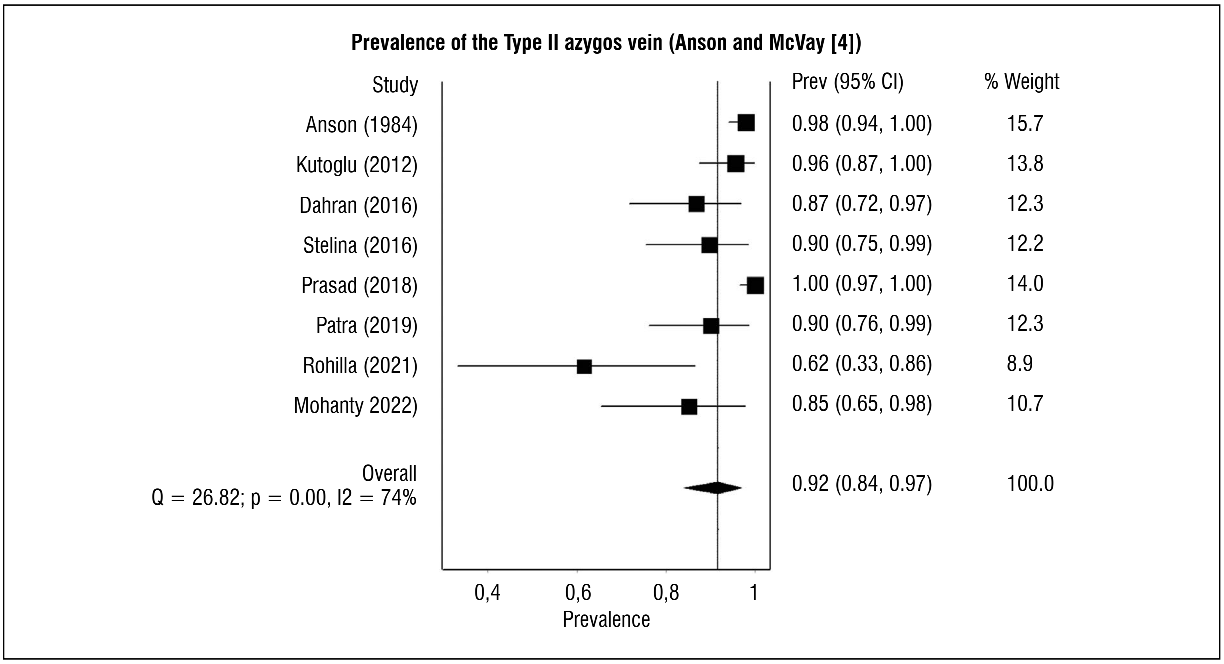

Figure 3. Forrest plot of the analysis regarding the pooled prevalence of the Type II azygos vein.

Table 4. Statistical results of this meta-analysis regarding the formation of the azygos vein.

Category	N	Pooled prevalence	LCI	HCI	Q	I²
Type of trunk in formation of the azygos vein						
Single	390	89.54%	72.25%	99.51%	102.35	94.14
Double		7.75%	0.40%	20.76%	73.88	91.88
Triple		2.13%	0.00%	6.58%	25.24	76.23
Formation of the azygos vein						
Right subcostal and right ascending lumbar veins	400	73.82%	55.77%	88.67%	91.26	92.33
Right subcostal vein		9.00%	2.22%	19.08%	53.46	86.91
Right subcostal vein with contribution from inferior vena cava		6.05%	0.00%	17.82%	82.21	91.49
Right and left subcostal veins		1.17%	0.03%	3.41%	13.83	49.40
Right subcostal vein with contribution from inferior vena cava and right ascending lumbar vein		0.69%	0.00%	2.10%	9.28	24.59
Other*		1.39%	0.00%	3.79%	19.63	64.33
Intermediate azygos root						
Prevalent	551	51.38%	26.72%	75.73%	172.70	96.53

*Other included right and left subcostal vein with contribution from inferior vena cava, right and left subcostal and left accessory renal veins; left renal vein; right subcostal and left gonadal veins and contribution from inferior vena cava; right subcostal and left renal veins; 11th posterior intercostal vein. HCI — higher confidence interval; LCI — lower confidence interval; Q — Cochran's Q.

On the other hand, during oesophagectomies in patients with oesophageal cancer, dissection of the AV has been strongly advised due to the frequent lymph node metastasis along the vein [44]. Therefore, surgeons performing *en bloc* oesophagectomies should be aware of the normal and variant anatomy of the AV to ensure adequate dissection of this vessel along with the accompanying lymph nodes.

This study has limitations that warrant acknowledgment. Potential bias may be present due to the varying accuracy of data extracted from diverse publications, which in turn affects the reliability of the

Table 5. Statistical results of this meta-analysis regarding the course of the azygos vein.

Category	N	Pooled prevalence	LCI	HCI	Q	I^2
Course of the azygos vein						
To the right of the midline of the VC	883	36.25%	21.67%	52.17%	373.67	95.45
Midline of the VC		30.75%	16.00%	47.68%	435.11	96.09
To the left of the midline of the VC		11.88%	2.77%	25.26%	422.69	95.98
Crossing to the left side of the VC		2.60%	0.00%	8.06%	299.10	94.32
Crossing to the middle of the VC		0.85%	0.12%	2.11%	37.55	54.73
Other		0.56%	0.15%	1.17%	13.70	0.00

HCI — higher confidence interval; LCI — lower confidence interval; Q — Cochran's Q; VC — vertebral column.

Table 6. Statistical results of this meta-analysis regarding the termination level of the Azygos Vein.

Category	N	Pooled prevalence	LCI	HCI	Q	I^2
Termination level						
T2	1032	1.80%	0.35%	4.14%	71.61	77.66
Between T2 and T3		1.92%	0.48%	4.16%	63.65	74.86
T3		11.55%	4.37%	21.29%	270.92	94.09
Between T3 and T4		5.16%	0.00%	13.31%	408.97	96.09
T4		33.20%	15.78%	53.16%	631.29	97.47
Between T4 and T5		2.30%	0.00%	6.11%	188.65	91.52
T5		15.04%	5.24%	28.26%	403.26	96.03
Between T5 and T6		1.14%	0.00%	3.42%	87.06	81.62
T6		1.99%	0.59%	4.09%	56.38	71.62
Between T6 and T7		0.54%	0.17%	1.09%	2.15	0.00

HCI — higher confidence interval; LCI — lower confidence interval; Q — Cochran's Q.

Table 7. Statistical results of this meta-analysis regarding the valves of the azygos vein.

Category	N	Pooled prevalence	LCI	HCI	Q	I^2
Valve occurrence	1023	64.67%	55.22%	73.59%	40.46	87.64
Valve reflux occurrence	956	46.51%	36.12%	57.04%	31.19	90.38
Valve residual contrast occurrence	635	48.58%	43.34%	53.84%	3.46	42.12

Valve reflux — retrograde flow of contrast into the azygos arch. Valve residual contrast — contrast remaining in or around the valve. HCI — higher confidence interval; LCI — lower confidence interval; Q — Cochran's Q.

results obtained in this meta-analysis. Furthermore, most of the included studies originate from Asia, potentially limiting the generalisability of the findings. Additionally, the absence of consistent data prevented the establishment of any sexual dimorphism in the anatomical characteristics of the AV, and gender-related statistics were not included in the analysis. Moreover, morphometric analysis of the AV in relation to the height of subjects or other parameters was not feasible due to the lack of such information in the primary studies. Despite these limitations, our meta-analysis attempts to provide insights into the anatomy of the AV based on evidence from the literature that meets the criteria of evidence-based anatomy [58].

CONCLUSIONS

The AV exhibits a high degree of variability regarding its origin, trajectory, and connections with the hemiazygos system. The most prevalent type of AV, according to the Anson and McVay [4] classification, was Type II (transitional type), with a pooled prevalence of 91.54%. Moreover, the vein was found to be formed by the right subcostal and the right ascending lumbar veins in most of the cases (73.82%).

Finally, the trajectory of the vein with respect to the vertebral column was most commonly on the right (36.25%) and on the midline (30.75%). These results might be of immense importance for surgeons performing *en block* oesophagectomies in patients with oesophageal cancer, because inadequate resection of the AV and the accompanying lymph nodes may lead to unsuccessful treatment.

ARTICLE INFORMATION AND DECLARATIONS

Data availability statement

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Author contributions

Dawid Plutecki: search, extraction, writing, tables. Michał Bonczar: statistical analysis, writing, figures. Patryk Ostrowski: literature, writing, figures. Bernard Solewski: search, extraction. Karolina Brzegowy-Solewska: search, extraction. Jerzy Walocha: statistical analysis, writing. Mateusz Koziej: statistical analysis, writing.

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Conflict of interest

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