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ORIGINAL STUDIES
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CONGENITAL ANOMALIES OF THE AORTIC ARCH – AUTOPSY STUDY

UROĐENE ANOMALIJE AORTNOG LUKA – AUTOPSIJSKA STUDIJA

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Abstract

Introduction. Congenital anomalies of the aortic arch encompass a diverse range of cardiovascular malformations that are less well-known and infrequently diagnosed in clinical settings. The study aims to assess the prevalence of aortic arch anomalies, their correlation with other heart defects, and their distribution by gender. **Material and Methods.** Data were collected through a retrospective analysis of autopsy records from the Archive for Congenital Heart Defects at the Institute of Pathology, Faculty of Medicine, University of Belgrade, spanning from 1961 to 2013. The archive also included autopsies conducted at the Institute for Mother and Child Health Care "Dr. Vukan Čupić" and the Gynecology and Obstetrics Clinic at the Clinical Center of Serbia. The study sample consisted of 245 autopsies. Both descriptive and analytical statistical methods were employed for data analysis. **Results.** The most common anomaly identified was the right aortic arch, observed in 26.94% of cases. A vascular ring was detected in 3.67% of cases, while tubular hypoplasia was found in 20.41% of cases. Aortic coarctation was present in 21.63% of cases, and interrupted aortic arch was noted in 12.65%. Aortic arch atresia was identified in 6.94% of the cases. **Conclusion.** Congenital anomalies of the aortic arch are relatively obscure and seldom clinically diagnosed cardiovascular anomalies. The findings of this study indicate that the right aortic arch is the most prevalent congenital anomaly of the aortic arch, occurring in 26.94% of cases. Among the anomalies incompatible with life, vascular ring, interruption of the aortic arch, and aortic arch atresia were observed.

Key words: Aorta, Thoracic; Congenital Abnormalities; Heart Defects, Congenital; Autopsy

Sažetak

Uvod. Urođene anomalije aortnog luka predstavljaju širok spektar manje poznatih i ređe klinički dijagnostikovanih kardiovaskularnih anomalija. Cilj rada je ispitivanje učestalosti anomalija aortnog luka, njihove udruženosti sa drugim srčanim manama i učestalost prema polu. **Materijal i metode.** Podaci su dobijeni retrospektivnom analizom obdukcionih protokola Instituta za patologiju Medicinskog fakulteta Univerziteta u Beogradu (Arhiva za urođene srčane mane) iz vremenskog perioda od 1961. do 2013. godine. Arhiva je obuhvatala i autopsije rađene na Institutu za zdravstvenu zaštitu majke i deteta "Dr Vukan Čupić" i na Ginekološko-akušerskoj klinici Kliničkog centra Srbije. Uzorak obuhvata 245 autopsija. Za analizu podataka korišćene su deskriptivne i analitičke statističke metode. **Rezultati.** Desni aortni luk se javio kod 26,94% slučajeva. Vaskularni prsten je uočen kod 3,67% slučajeva. Tubularna hipoplazija je zabeležena kod 20,41% slučajeva. Koarktacija aorte je uočena kod 21,63% slučajeva. Prekid aortnog luka je zabeležen kod 12,65% slučajeva, a atrezija aortnog luka se javila u 6,94% slučajeva. **Zaključak.** Urođene anomalije aortnog luka su manje poznate i retko klinički dijagnostikovane kardiovaskularne anomalije. Rezultati istraživanju su pokazali da je najčešća urođena anomalija aortnog luka desni aortni luk, koji je zabeležen kod 26,94% slučajeva. Od anomalija koje su inkompatibilne sa životom uočeni su vaskularni prsten, prekid aortnog luka i atrezija aortnog luka.

Ključne reči: grudna aorta; urođene anomalije; kongenitalne srčane mane; autopsija

Introduction

Congenital heart anomalies refer to structural abnormalities of the heart or major blood vessels that are present at birth. Most of these anomalies originate during embryogenesis, typically between the third and eighth week of gestation, while the primary structures of the cardiovascular system are formed. Although the reported prevalence can vary across different studies, congenital heart defects generally occur in 1% of the general population, making them the most common type heart disease in children [1].

Congenital anomalies of the aortic arch are among the lesser-known and less frequently diagnosed cardiovascular malformations. The spectrum of these anomalies is broad, ranging from anatomical variations that may be an incidental finding during autopsy to severe malformations incompatible with life,

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Abbreviations

ASD – atrial septal defect
VSD – ventricular septal defect
PDA – patent ductus arteriosus
TGA – transposition of great arteries
DAL – right aortic arch
LAL – left aortic arch
VP – vascular ring
TH – tubular hipoplasia
CoA – coartaction of aorta
PAL – interrupted aortic arch
AtrAo – aortic arch atresia

such as vascular ring and interrupted aortic arches. Early detection and clinical diagnosis of these anomalies are essential, as timely surgical intervention can often lead to favorable outcome for the patient [1].

To classify and understand the morphology of different subtypes of aortic arch anomalies, it is crucial to consider the developmental model proposed by Edwards. He introduced a hypothetical model that consists of paired aortic arches on either side, paired bilateral ductus arteriosus, and a single dorsal aorta. In this model, the carotid and subclavian vessels originate from the aortic arch, with the carotid arteries positioned anteriorly and the subclavian arteries posteriorly.

The normal left aortic arch is formed by the regression of the right aortic arch, right-sided ductus arteriosus, and right dorsal aorta. The proximal segment of the right dorsal aorta contributes to the formation of the right subclavian artery, while the left dorsal aorta forms the distal aortic arch and the descending thoracic aorta.

Various aortic arch anomalies can be explained by abnormal persistence or regression of different segments in the Edwards' double aortic arch model, resulting in a range of malformations [2, 3].

The objective of this study is to investigate the prevalence of aortic arch anomalies, their association with other heart defects, and their distribution according to gender.

Material and Methods

This study is based on a retrospective analysis of autopsy records from the Archive for Congenital Heart Defects at the Institute of Pathology, Faculty of Medicine, University of Belgrade, covering the period from 1961 to 2013. The dataset also includes autopsy reports from the Institute for Mother and Child Health Care "Dr. Vukan Čupić" and at the Gynecology and Obstetrics Clinic of the Clinical Center of Serbia. The total sample comprises 245 autopsies.

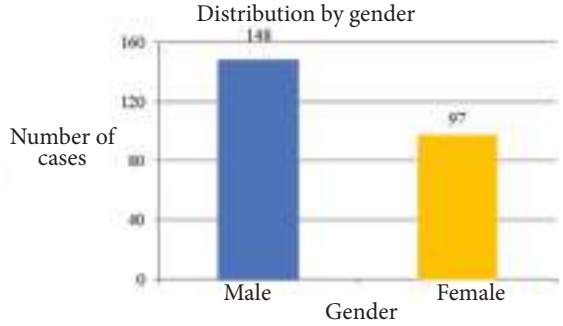
A pathological and morphological autopsy analysis of cases involving congenital heart defects was conducted using the modified Rokitansky technique.

For investigating the genesis of aortic arch anomalies, the study applied Edward's model of the primary double aortic arch in embryonic development. Data were analyzed using appropriate statistical methods, including measures of central tendency (mean and standard deviation), the chi-squared (χ^2) test. All statistical analyses were performed using SPSS software, version 17.0.

Results

From 1961 to 2013, a total of 1460 patients who underwent autopsies were diagnosed with congenital heart defects. Among these, congenital anomalies of the aortic arch were identified in 245 cases, representing 16.78% of the total.

These anomalies were found in 148 (60.41%) males and 97 (39.59%) females **(Graph 1).** This difference was statistically significant, with a higher prevalence in males (χ^2=10.616, p=0.0011).

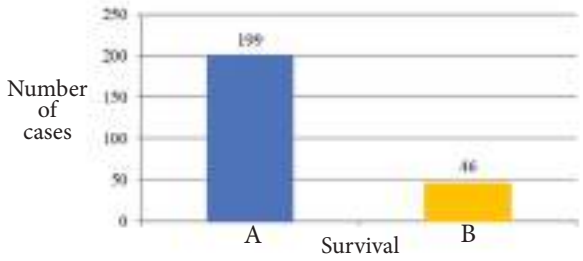


Graph 1. Prevalence of congenital aortic arch defects by gender

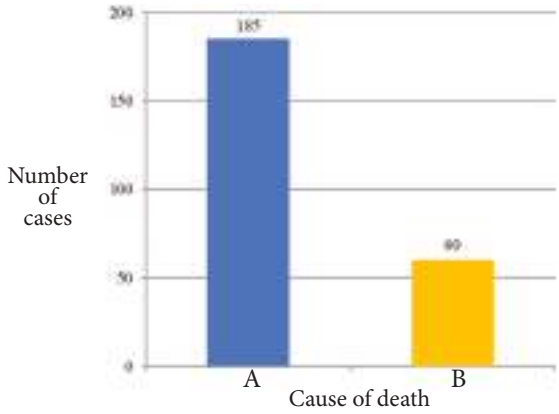
A survival rate beyond the first year of life was observed in 46 cases (18.78%), while 199 cases (81.22%) did not survive beyond one year **(Graph 2)**, showing a statistically significant difference (χ^2=95.547, p<0.001).

Cardiopulmonary diseases were recorded as the immediate cause of death in 185 cases (75.51%), whereas the remaining 60 cases (24.49%) died due to other etiologies, such as brain edema, cerebral hemorrhage, or peritonitis **(Graph 3).** The predominance of cardiopulmonary diseases as the cause of death was statistically significant (χ^2=63.776, p<0.001).

Among the 245 cases with aortic arch anomalies, the right aortic arch was noted in 66 cases (26.94%) **(Graph 4)**. The right aortic arch was observed in 36 males (54.55%) and 30 females (45.45%), with no statistically significant difference by gender (χ^2=0.545, p=0.4602). A survival rate greater than one year was noted in 16 cases (24.24%), while 50 cases (75.76%) did not survive beyond the first year, showing a statistically significant difference (χ^2=17.515, p<0.001). In 42 cases (63.64%), the immediate cause of death was a congenital heart defect,



Graph 2. Survival in relation to the first year of life
A – cardiopulmonary etiology; B – other causes (brain edema, cerebral hemorrhage, peritonitis, pericarditis)

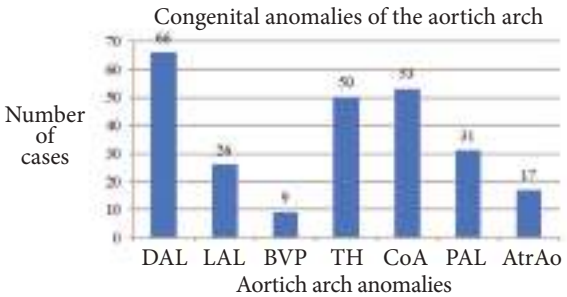


Graph 3. Cause of death in congenital aortic arch anomalies
A – cardiopulmonary etiology; B – other causes (brain edema, cerebral hemorrhage, peritonitis, pericarditis)

while in 24 cases (36.36%), it was due to another etiology, with a statistically significant difference (χ^2=4.909, p=0.0267). The right aortic arch was associated with atrial septal defect (ASD) and ventricular septal defect (VSD) in 26 cases (39.39%).

A left aortic arch with an aberrant subclavian artery was present in 26 cases (10.61%) in the analyzed cohort of aortic arch anomalies **(Graph 4)**.

A vascular ring was diagnosed in 9 cases (3.67%) (**Graph 4)**, with a male predominance: 7 cases (77.77%) in males and 2 cases (22.23%) in females. All 9 cases did not survive beyond the first year of life. Of these, 6 cases (66.67%) were associated with other congenital heart defects, while 3 cases (33.33%) presented as isolated aortic arch anomalies. In 8 cases (88.89%), the



Graph 4. Distribution of congenital aortic arch anomalies

immediate cause of death was cardiopulmonary in nature.

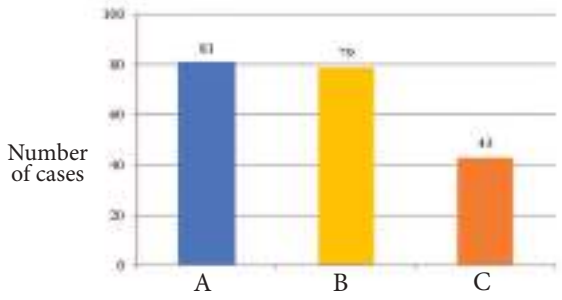
Tubular hypoplasia was observed in 50 cases (20.41%) **(Graph 4)**, with 33 cases (66%) in males and 17 cases (34%) in females, indicating a statistically significant higher occurrence in males (χ^2=5.120, p=0.0237). Only 2 cases (4%) survived beyond the first year of life, whereas 48 cases (96%) did not (χ^2=42.320, p<0.001). Tubular hypoplasia was associated with aortic coarctation in 26 cases (52%) and with Patent ductus arteriosus (PDA) in 21 cases (42%), while in only 3 cases it occurred as an isolated defect. Cardiopulmonary insufficiency was the immediate cause of death in 40 cases (80%), which was statistically significant (χ^2=18.000, p<0.001).

Aortic coarctation was recorded in 53 cases (21.63%), with 33 cases (62.26%) in males and 20 cases (37.74%) in females, without a statistically significant gender difference (χ^2=3.189, p = 0.0741). A total of 25 cases (47.16%) survived beyond the first year of life, while 28 cases (52.84%) did not (χ^2= 0.170, p= 0.6803). An association with other congenital heart defects was noted in 26 cases (49.06%) with tubular hypoplasia, in 11 cases (20.75%) with other congenital heart defects, and in 16 cases (30.19%) as an isolated defect, with a distribution nearing statistical significance (χ^2=5.895, df=2, p=0.0525). Cardiorespiratory failure was the immediate cause of death in 40 cases (75.47%) (χ^2=13.755, p<0.001).

Interrupted aortic arch was found in 31 cases (12.65%), with no significant difference in distribution between males (15 cases) and females (16 cases) (χ^2=0.032, p=0.8575). Of these, 26 cases (83.87%) were associated with other congenital heart defects (χ^2=14.226, p=0.0002), including 12 cases (38.71%) associated with VSD, and 5 cases (16.13%) as isolated defects. None of these cases survived beyond the first year of life. In 22 cases (71%), the cause of death was of cardiopulmonary etiology, while 9 cases died of other causes (χ^2=5.452, p=0.0196).

Aortic arch atresia was present in 17 cases (6.93%), with 12 cases (70.59%) in males and 5 cases (29.41%) in females. None of these cases survived the first year of life. In 14 cases (82.35%), aortic arch atresia was associated with other congenital heart defect, while in 3 cases (17.65%) it occurred in isolation. Cardiopulmonary insufficiency was the cause of death in 13 cases (76.47%), and in 4 cases (23.53%) the cause of death was of other etiology.

Among the 245 autopsied cases with congenital anomalies of the aortic arch, 202 cases (82.45%) were associated with other congenital heart defects **(Graph 5)**, while 43 cases (17.55%) presented as isolated forms, showing statistical significance (χ^2 = 103.188, p<0.001). Among the associated congenital heart defects **(Graph**



Graph 5. Association of aortic arch defects with other congenital heart defects
A – anomalies associated with TGA, PDA; B – anomalies associated with ASD or VSD; C – aortic arch anomalies associated with each other

5), 30 cases (14.85%) were found with transposition of the great arteries (TGA), 12 cases (5.94%) with PDA, 79 cases (39.11%) with ASD or VSD, and 81 cases (40.1%) with other aortic arch anomalies such as tubular hypoplasia and aortic coarctation.

Discussion

Congenital anomalies of the aortic arch result from aberrant development of one or more embryonic components of the pharyngeal arches. During early embryogenesis, six symmetrical pairs of pharyngeal arches merge with the branchial arches to form a primitive vascular structure. Each segment of the embryological arch system may abnormally regress or persist, resulting in aortic arch anomalies [4].

Anomalies of the aortic arch represent a rare subset of cardiovascular anomalies, accounting for 16.78% of all congenital heart defects.

The results of our study demonstrate a higher frequency of these anomalies in the male population, comprising 60.41% of cases. The severity of these defects is underscored by the high mortality rate when surgical correction is not performed, often due to cardiac or renal failure or intracranial bleeding [5, 6]. Our findings showed that 199 (81.23%) did not survive beyond the first year if life, with a statistically significant difference (p=0.01), highlighting the crucial nature of these defects when left untreated. Furthermore, 185 cases (75.51%) died from cardiopulmonary causes, consistent with the findings of other studies [5, 6].

The most common anomaly of the aortic arch identified in our study was the right aortic arch, found in 66 cases (26.94%). According to the literature, this anomaly occurs in approximately 1 in 2,500 autopsied cases [7]. In our data, 26 cases (39.39%) presented with concurrent ASD or VSD, aligning with previously reported results [7, 8]. Of those with a right aortic arch, 24.24% survived beyond one year, while 75.76% did not, demonstrating a statistically significant difference (p=0.016). The immediate cause of death was congenital heart anomalies in 63.64% of cases, with other etiologies accounting for the remaining 36.36%, thought this difference was not statistically significant (p>0.05).

Vascular ring is an exceedingly rare defect in our dataset, with only 9 cases (3.67%) of all congenital aortic arch anomalies. Among these, 8 cases (89%) died from cardiopulmonary causes, which is consistent with literature suggesting that these patients most commonly succumb to aspiration bronchopneumonia [9].

Tubular hypoplasia, another aortic arch anomaly, rarely appears in isolation; in our study, it was isolated in only 3 cases (6%). It was most commonly associated with aortic coarctation in 26 cases (52%) and with other congenital heart defects in 21 cases (42%), which is in agreement with literature data [9, 10].

Aortic coarctation was identified in 53 cases (21.63%). Literature suggests that aortic coarctation ranks fifth in frequency, accounting for 6-8% of all congenital heart defects, and occurs in approximately 1 in 2,500 cases [11, 12]. Our results revealed a male-to-female ratio of 1.62:1, closely matching the literature-reported ratio of 1.74:1 [13]. Among those affected, coarctation of the aorta had the highest percentage of cases surviving beyond the first year, with 47.16% of cases achieving this milestone. Aortic coarctation was most frequently associated with tubular hypoplasia, observed in 49.05% of cases, while 20.75% were associated with other anomalies of the aortic arch. The literature commonly cites association with hypoplastic left heart syndrome or VSD [14].

Interrupted aortic arch was present in 31 cases (12.65%), which constitute 2.12% of all congenital heart defects in our study. The literature reports that this anomaly accounts for about 1% of all congenital heart defects [15]. In our findings, 38.71% of cases of interrupted aortic arch were associated with VSD, aligning with literature that indicates this association is most common [16]. None of the cases with an interrupted aortic arch survived beyond the first year of life, indicating a high statistical significance (p<0.0001). The literature also states that without surgical intervention, the mortality rate exceeds 90% [17].

Aortic arch atresia was identifies in 17 cases (6.93%). None of these cases survived the first year of life, demonstrating a high statistical significance (p<0.0001), underscoring the severity of this defect if not diagnosed and managed promptly.

Conclusion

The study examined the frequency of congenital aortic arch anomalies, their distribution between

sexes, survival rates, and association with other defects. We analyzed 245 cases of congenital aortic arch anomalies and found that these are indeed rare defects. Among these, interrupted aortic arch, vascular ring, and aortic arch atresia are particularly uncommon, accounting for only a small percentage of cases. However, without surgical intervention, these anomalies are invariably fatal. Our findings also indicate that aortic arch anomalies are more prevalent in males, and the majority of deaths were due to cardiopulmonary insufficiency. Early diagnosis and prompt surgical management of these anomalies are crucial for improving survival and extending life expectancy.

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