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Original Article

Determinants of Types of Aortic Arch and Bovine Aortic Arch in Thrombectomy and Intraarterial Thrombolytic Procedures in Acute Ischemic Stroke

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ABSTRACT

Objective: Complex aortic arch anatomy increases technical difficulties in acute ischemic stroke interventions. We hypothesized that aortic arch variations correlate with patient age and atherosclerotic burden in thrombectomy and intraarterial thrombolytic therapy (IAT) patients.

Methods: This retrospective study analyzed aortic arch morphology in 63 consecutive patients (39 males, 24 females; median age 72 years) who underwent thrombectomy and IAT for acute ischemic stroke. Aortography was systematically performed before intervention to classify arch types (I, II, III) and identify bovine arch variants. Statistical analysis examined relationships between arch variations, patient demographics, and risk factors.

Results: Type II arch was most prevalent (37 patients, 58.7%), followed by Type I (13 patients, 20.6%) and Type III (13 patients, 20.6%). Bovine arch occurred in 16 patients (25.4%). Patients with Type II/III arches were significantly older than those with Type I ($p=0.028$). Aortic plaque presence strongly correlated with arch type ($p<0.001$), with 92.3% of Type III patients having plaques versus 7.7% of Type I patients. Procedural success was achieved in 59/63 cases (93.7%).

Conclusion: This retrospective analysis demonstrates that aortic arch variations increase with age and correlate with atherosclerotic burden. Type II and III arches predominate in stroke intervention patients, requiring specialized catheter techniques while maintaining high procedural success rates.

INTRODUCTION

The brain receives blood supply through supraaortic vessels. The aortic arch generates the supraaortic arteries, often called the great vessels. Types of aortic arch have been described in humans, namely type I, II and III (Fig. 1). Classification of the aortic arch is determined by measuring the gap from its peak to the innominate artery's origin (Fig. 2).[1] The most frequent structural form of the aortic arch in humans is the standard type. This common structure is estimated to appear in nearly 70% of individuals. The Bovine arch is the second most frequent variant of the aortic arch (Fig.3). When the left CCA emerges from the innominate artery, it is identified as a 'Bovine origin'.

In proximal intracranial occlusion affecting the anterior circulation, intraarterial intervention within six hours and stent retriever thrombectomy are proven to be both safe and effective.[2,3] For intracranial and extracranial interventional procedures, the first stage is the passage of catheters through the aortic arch. Endovascular interventions using

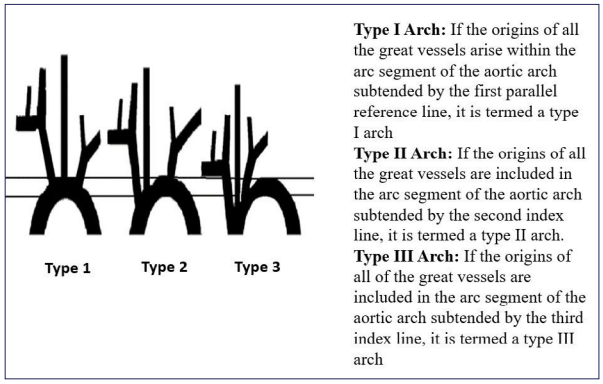

Figure 1. Aortic arch classification system. Type I: normal anatomy suitable for standard catheters; Type II: moderate elongation requiring modified approach; Type III: severe angulation creating technical challenges for endovascular procedures.

Figure 2. Type III aortic arch showing severe angulation between arch apex and innominate artery. This configuration complicates catheter navigation and requires specialized techniques during stroke interventions.

stents and coils for carotid stenosis and aneurysms are established treatment modalities with demonstrated positive outcomes and durable results.[4]

The congenitally variable anatomy of the supraaortic vessels increases the complications of endovascular interventions (carotid artery stenting, thrombectomy, IAT, etc.).[5,6] In addition to extending the processing time. Type I arc is normal and suitable for intervention while type II, III and Bovine arch are difficult for endovascular intervenions. Thus, recognizing aortic arch classification is essential for intervention planning. Aortography can identify different aortic arch variations before intervention. So that appropriate materials can be selected. Anatomical differences in the aortic arch arise from congenital or acquired influences. The exact causes of these anatomical variations remain undetermined in research. All individuals are initially born possessing a Type I arch.[7]

We analyzed aortic arch variations and their risk factors in patients who underwent thrombectomy and intra-arterial

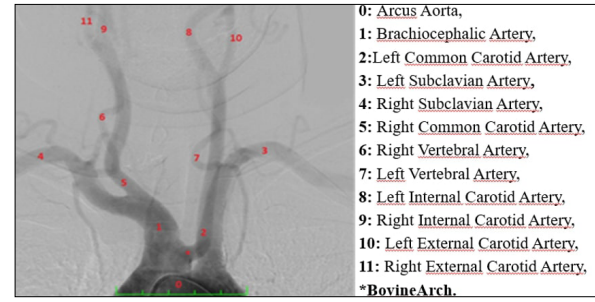

Figure 3. Bovine arch variant with common origin of innominate and left carotid arteries. Present in 25.4% of our cohort, this anatomy alters standard catheter approach during emergency procedures.

(IA) thrombolysis for acute ischemic stroke, drawing from our own experience.

MATERIALS AND METHODS

This retrospective study was conducted in accordance with the Declaration of Helsinki. Approval was obtained for retrospective analysis of patient data from the Zonguldak Bulent Ecevit University Ethics Committee (No: 2025/01, Date: 08/01/2025).

This retrospective study analyzed 63 consecutive patients who underwent thrombectomy and intraarterial (IA) therapy for acute ischemic stroke in our hospital's catheter lab. This was a single-center retrospective observational study. All interventions and imaging procedures were performed as part of standard clinical care for acute stroke management. Patient data were collected retrospectively from medical records and our catheter lab database

Patients were transported to the hospital by air or ground ambulance and received IA-tPA treatment within the 6-hour therapeutic window and patients who received thrombectomy were taken within 8 hours (Fig. 4; Fig. 5). All patients routinely were received aortograph before the thrombectomy and IAT.

Inclusion criteria for IA fibrinolytic therapy: Moderate benefits observed in those with severe deficiencies in the 0 to 6 hour window and minor or branch of large artery (large arteries: ICA, middle cerebral artery and basilar artery) cerebral thrombotic occlusions.

Inclusion criteria for thrombectomy: In the 0- to 8-hour window moderate net benefits when applied to all patients with potentially disabling deficits and large artery cerebral thrombotic occlusions. Exclusion criteria for IA fibrinolytic therapy and thrombectomy: Patients with imaging evidence of extensive ischemic damage, absence of salvageable ischemic penumbra, and standard contraindications for angiography (e.g., severe contrast allergy, severe renal dysfunction, inability to obtain vascular access).

All patients underwent risk factors evaluation prior and after thrombectomy or IAT in the hospital. Plaques in the

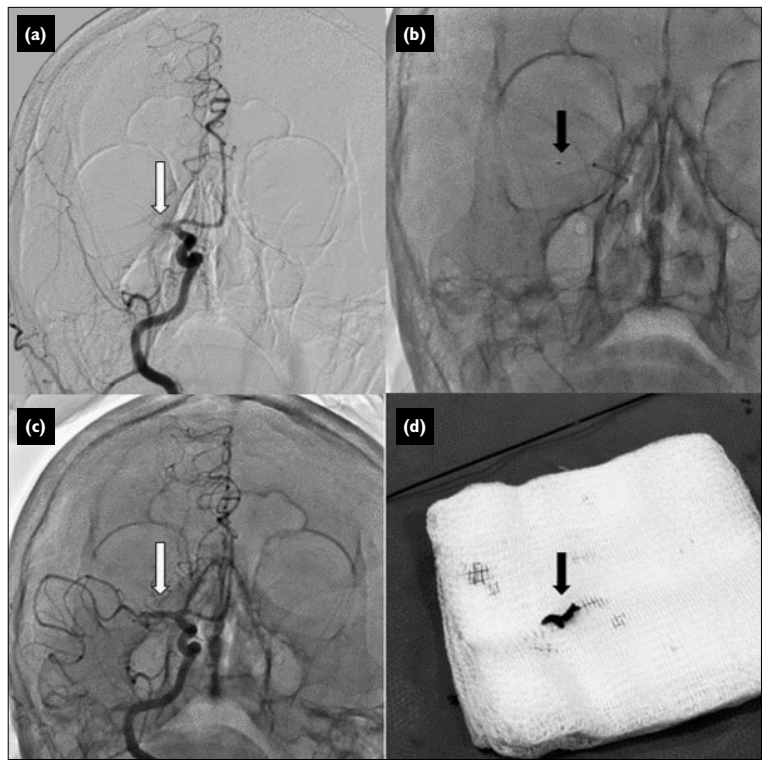

Figure 4. Mechanical thrombectomy procedure. **(a)** Right MCA occlusion (white arrow); **(b)** Stent retriever deployment (black arrow); **(c)** Complete recanalization (white arrow); **(d)** Retrieved clot material (black arrow). Demonstrates successful endovascular technique.

Figure 5. Intraarterial thrombolysis procedure. **(a)** Inferior MCA division occlusion (black arrow); **(b)** Alteplase administration via microcatheter (black arrow); **(c)** Post-treatment recanalization. Shows effective pharmacological intervention for branch vessel occlusions.

aorta and large arteries were recorded during angiography. The relationship between the types of aortic arch, Bovine aortic arch and plaques was studied in digital subtraction angiography (DSA). Additionally, we studied the relationship with risk factors.

Power Analysis: Sample size calculation was performed using G*Power 3.1.9.7. With an alpha level of 0.05, power of 80%, and expected effect size of 0.5 based on preliminary data, the minimum required sample size was calculated as 52 patients. Our study included 63 patients, providing adequate power (84%) for detecting clinically meaningful differences between arch types.

Aortography procedure

Transfemoral access was utilized for angiographic imaging. After administering 2% lidocaine or xilocaine, the common femoral artery was punctured, and a 6F or 7F sheath was positioned. A pigtail catheter (6F) over a 0.035-inch, hydrophilic or non-hydrophilic guidewire was advanced for cannulation of the arcus aorta target was performed.

Arch angiography was performed with the patient's head turned right and chin elevated. The view was aligned to include the arch peak and carotid arteries up to the mandible. Each patient received 30 mL contrast at 15 mL/

min under 700 psi pressure, with no increase rate.

This retrospective analysis included 63 patients who underwent aortography during acute ischemic stroke interventions. The study population comprised 39 males and 24 females, with a median age of 72 years. DSA classified aortic arch forms, including the Bovine type. Arch variations, including Bovine type, were compared with prior studies and their clinical impact assessed.

"The manuscript is entered in the system under "Clinical Trial Registration" as being a clinical trial that does not require registration. Because the treatments are performed on a routine basis. But The World Medical Association (WMA) Helsinki Declaration has been evaluated."

Statistical Analysis

PASW 18.0for Windows program was used for statistical analysis. Descriptive statistics, average for numeric variables, standard deviation, median, percentile 25 (Q1), percentile 75 (Q3) was presented as minimum and maximum. Normal distribution of variables were examined using visual (histogram and probability graphics) and analytical (Kolmogorov-Smirnov / Shapiro-Wilk tests) methods. Mann Whitney U Test was used in two independent group comparison analyzes where no normal distribution condition was provided for numerical variables. Kruskal Wallis Test in multiple group comparisons; Chi-square test for binary and multiple comparisons for categorical variables, Fisher's Exact Test for binary comparisons not provided with chi-square condition, and Fisher's Exact Test for multiple comparisons was used. The level of statistical significance was accepted as the value of p less than 0.05.

Table 1. Main clinical characteristics of our study population

	Overall (n=63)
Age (years)	72 (64-76)
Age group, n (%)	
(45-59 years)	10 (15.9)
(60-69 years)	15 (23.8)
(70-79 years)	29 (46.0)
(80≤ years)	9 (14.3)
Female gender, n (%)	24 (38.1)
Types of aortic arch, n (%)	
Type I	13 (20.6)
Type II	37 (58.7)
Type III	13 (20.6)
Bovine aortic arch, n (%)	16 (25.4)
Plaque, n (%)	31 (49.2)
Risk factors	
Diabetes mellitus, n (%)	14 (22.2)
Current smoker, n (%)	16 (25.4)
Hyperlipidemia, n (%)	14 (22.2)
Hypertension, n (%)	45 (71.4)
Heart diseases, n (%)	45 (71.4)

RESULTS

Baseline characteristics and demographics are shown in Table 1. 63 patients were studied (39 men and 24 women), there were 13 type I arch, 37 type II arch and 13 type III arch. The mean age of participants was 72 (64-76) years undergoing thrombectomy or IAT were included in the

Table 2. Relationship between arch types and demographic and clinical features

	Types of Aortic Arch			
	Type I	**Type II**	**Type III**	**p**
Bovine, n (%)	1 (7.7)	12 (32.4)	3 (23.1)	0.244
Plaque, n (%)	1 (7.7)	18 (48.6)	12 (92.3)	**<0.001**
Gender, n (%)				
Male	9 (69.2)	20 (54.1)	10 (76.9)	
Female	4 (30.8)	17 (45.9)	3 (23.1)	0.324
Age, median(Q1-Q3)	64 (51-73)	72 (66-76)	74 (67-83)	0.689
Age group, n (%)				
45-59 years	5 (38.5)	4 (10.8)	1 (7.7)	
60-69 years	2 (15.4)	10 (27.0)	3 (23.1)	**0.028**
70-79 years	5 (38.5)	20 (54.1)	4 (30.8)	
80≤ years	1 (7.7)	3 (8.1)	5 (38.5)	
Risk factors, n (%)				
Hypertension	7 (53.8)	28 (75.7)	10 (76.9)	0.313
Hyperlipidemia	3 (23.1)	5 (13.5)	6 (46.2)	0.055
Diabetesmellitus	3 (23.1)	8 (21.6)	3 (23.1)	1.000
Current smoker	4 (30.8)	6 (16.2)	6 (46.2)	0.095
Heart diseases	6 (46.2)	29 (78.4)	10 (76.9)	0.088

Table 3. Association between bovine arch variant and patient characteristics

	Bovine Arch (-)	Bovine Arch (+)	p
Types of Aortic Arch, n (%)			
Type I	12 (25.5)	1 (6.3)	0.251
Type II	25 (53.2)	12 (75.0)	
Type III	10 (21.3)	3 (18.8)	
Plaque, n (%)	20 (42.6)	11 (68.8)	0.070
Gender, n (%)			
Male	32 (68.1)	7 (43.8)	0.083
Female	15 (31.9)	9 (56.3)	
Age, median (Q1-Q3)	72 (64-77)	75 (68-76)	0.575
Age group, n (%)			
45-59 years	7 (14.9)	3 (18.8)	0.658
60-69 years	13 (27.7)	2 (12.5)	
70-79 years	20 (42.6)	9 (56.3)	
80 ≤ years	7 (14.9)	2 (12.5)	
Risk factors, n (%)			
Hypertension	31 (66.0)	14 (87.5)	0.121
Hyperlipidemia	11 (23.4)	3 (18.8)	1.000
Diabetesmellitus	12 (25.5)	2 (12.5)	0.487
Current smoker	13 (27.7)	3 (18.8)	0.740
Heart diseases	32 (68.1)	13 (81.3)	0.522

study. Procedural failure occurred in four patients (three patients had type III aorta and one patient had type II aorta), three patients were then referred for the intravenous thrombolytic therapy. One patient was not eligible for this treatment. All remaining procedures were successfully completed.

Patients with "type II and III," compared to those with type I, exhibited a significantly higher aging (p=0,028) (Table 2). In the whole patients, Bovine aortic arch was present in 16 cases (25.4%): 1 (7.7%) patient had a type I arch, 12 (32.4%) patients had a type II arch, 3 (23.1%) patients had type III arch (p=0.244) (Table 3). Patients with plaque in aortic arch were comparable in types of aortic arch. The difference is statistically significant (p<0.001) (Table 4). There were no statistically significant difference in the types of the aortic arch types among the genders, risk factors (hypertension, hyperlipidemia, diabetes, smoking, heart diseases).

DISCUSSION

Endovascular stroke interventions including thrombectomy and IAT comprise three critical phases: Vascular access, supraaortic navigation, and clot retrieval using mechanical devices. Cannulation of the supraaortic arteries is crucial for procedural success. Variations in the arch or branches may complicate routine angiography. Awareness of aortic arch structure and its variants is vital for procedures. Conventional angiography begins with aortic arch imaging to determine optimal catheter selection, thereby reducing procedure time and contrast material usage. Subsequently, this facilitates appropriate device selection for the planned intervention. Types of aortic arch and Bovine arch have been presented by some other authors but has not been studied during acute ischemic stroke therapy.[8-10] Most studies have been performed on carotid artery stenting (CAS). Macdonald et al.[11] developed a scoring framework for anatomical assessment. CAS assessment considers anatomical aspects like access (short or tortuous CCA, occluded ECA), arch structure (severe atheroma, vessel origin disease, type III or Bovine arch), and target vessel traits (pinhole narrowing, ICA angulation, circumferential calcification).

Thrombectomy and IAT are growing interventions for acute stroke, but feasibility depends on patient factors like arch anatomy. Previous studies reported for unfavorable anatomic variants an overall increased risk of procedural failure and neurological complications in the course of supraaortic interventionals.[5,6,12] These studies, however, were focused on carotid artery stending. This study retrospectively examined aortic structure using pre-thrombectomy or IAT digital subtraction angiography, categorizing aortic anatomy and Bovine type. The time is very important in acute ischemic stroke. Late treatment results in high morbidity and mortality. Type III arch is associated with challenging supraaortic access. In this study, Type II was most prevalent (58.7%), followed by Type I (20.6%) and Type III (20.6%).

This research indicates an association between older age and Type II/III arches. These rates surpass earlier findings, likely due to no preprocedural screening and an older population.[9,13] Specialized techniques and tools are needed

Table 4. Correlation between aortic arch morphology and atherosclerotic plaque burden

	Plaque (-)	Plaque (+)	p
Types of Aortic Arch, n (%)			
Type I	12 (37.5)	1 (3.2)	**<0.001**
Type II	19 (59.4)	18 (58.1)	
Type III	1 (3.1)	12 (38.7)	
Bovine, n (%)	5 (15.6)	11 (35.5)	0.070
Gender, n (%)			
Male	21 (65.6)	18 (58.1)	0.537
Female	11 (34.4)	13 (41.9)	
Age, median (Q1-Q3)	71 (61-75)	75 (67-79)	**0.026**
Age group, n (%)			
45-59 years	8 (25.0)	2 (6.5)	0.064
60-69 years	6 (18.8)	9 (29.0)	
70-79 years	16 (50.0)	13 (41.9)	
80 ≤ years	2 (6.3)	7 (22.6)	
Risk factors, n (%)			
Hypertension	21 (65.6)	24 (77.4)	0.300
Hyperlipidemia	5 (15.6)	9 (29.0)	0.201
Diabetesmellitus	11 (34.4)	3 (9.7)	**0.018**
Current smoker	6 (18.8)	10 (32.3)	0.218
Heart diseases	19 (59.4)	26 (83.9)	0.031

for aortic arch anomalies. Various methods have been suggested to aid supraaortic artery access in cases of aortic arch anomalies.[14]

This study confirms thrombectomy and IAT feasibility across different aortic arch anomalies, with only 4 failures in 63 cases. These high success rates align with expertise and likely result from meticulous planning tailored to aortic anatomy. In this experience, using a dedicated guiding catheter without a diagnostic one facilitated quicker supraaortic artery access, reducing fluoroscopy and total procedure time.

Aortic arch anomalies can elevate the risk of neurological and local complications due to the increased technical challenge of supraaortic access. We had three patients who developed transient vasospasm during ICA intervention.

There were no statistically significant relationship between gender, risk factors and arch types. There was no significant difference between sexes. Standard Aortic Arch is the most common anatomic appearance in humans. Here, the innominate artery splits into the right carotid and subclavian arteries. The Bovine configuration is the most common variant of the aortic arch. In a Bovine arch, the innominate and left common carotid arteries originate from the same point. As a result, two primary vessels emerge from the aortic arch. This pattern of branching is seen in approximately 13% of patients.[15]

Changes in the development of aortic arch arteries during embryogenesis likely cause variations in the branching pattern of the arch. Our study supported this with its results. In our study, no significant difference was observed between the different age groups with the cattle belt.

There are some studies in literature that aortic arch variations lead to cerebrovascular diseases.[16-19] Patil et al.[16] investigated seventy-five aortic arches from adult cadavers of Indian origin. In this study, the usual three-branched aortic arch was found in 58 cadavers (77.3%), 7 (12%) were diagnosed with cerebrovascular disease, while in the case of variant branching pattern, type II and type III, 4 (23.5%) cadavers out of 17 had cerebrovascular disease. Our study supported these claims. Because only 20.6% of patients had a type I aorta.

A significant correlation was found between aortic plaque presence and age groups in the aortic arch. This is particularly true for patients with type 3 aorta who are older than 80 years. This research represents the experience of a single center. A major limitation of this research is the limited sample size. Because of the stroke is seen in older ages, another limitation of this study is the age of patients is advanced. More studies with a bigger sample and multicenter randomized trials are essential.

Complex arch anatomy creates intervention obstacles through sharp angulation and altered vessel origins. Type II/III configurations necessitate alternative catheter designs, extending procedure duration and radiation exposure.[20,21] Our data demonstrates higher procedural complexity correlates with patient age and atherosclerotic disease burden.

Contemporary studies report similar arch distribution

patterns in stroke populations compared to our findings.[20-22] The elevated bovine variant frequency in our cohort suggests anatomical predisposition among intervention candidates. Despite these challenges, our success metrics remain comparable to established benchmarks.

Conclusion

Immediate improvements include: Enhanced pre-intervention imaging protocols, specialized equipment availability, and operator skill development for complex cases. Institutions should establish arch-specific procedural pathways and monitor outcomes accordingly. Future efforts should focus on technique standardization and technology advancement for challenging anatomical scenarios.

Ethics Committee Approval

This retrospective study was conducted in accordance with the Declaration of Helsinki. Approval was obtained for retrospective analysis of patient data from the Zonguldak Bulent Ecevit University Ethics Committee (Date: 08.01.2025, Decision No: 2025/01).

Informed Consent

Individual informed consent was waived due to the retrospective nature of the study and anonymous data analysis.

Peer-review

Externally peer-reviewed.

Authorship Contributions

Concept: G.Ö.; Design: G.Ö., E.K.; Supervision: G.Ö., E.A.; Fundings: G.Ö., M.S.G.; Materials: E.A.; Data: G.Ö., E.K.; Analysis: M.S.G., E.K.; Literature search: E.A., E.K.; Writing: G.Ö., E.K.; Critical revision: E.A.

Conflict of Interest

None declared.

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Akut İskemik İnmenin Endovasküler Tedavisinde Aort Ark Varyasyonları ve Belirleyicileri

Amaç: Karmaşık aort arkı anatomisi, akut iskemik inme müdahalelerinde teknik zorlukları artırmaktadır. Trombektomi ve intraarteriyel trombolitik tedavi (İATT) uygulanan hastalarda aort arkı varyasyonlarının hasta yaşı ve aterosklerotik yük ile ilişkili olduğu hipotezini öne sürdük.

Gereç ve Yöntem: Bu retrospektif çalışmada, akut iskemik inme nedeniyle trombektomi ve İATT uygulanan 63 ardışık hastada (39 erkek, 24 kadın; ortanca yaş 72) aort ark morfolojisi analiz edildi. Ark tiplerini (I, II, III) sınıflandırmak ve sığır ark varyantlarını belirlemek için müdahaleden önce sistematik olarak aortografi yapıldı. İstatistiksel analizde ark varyasyonları, hasta demografisi ve risk faktörleri arasındaki ilişkiler incelendi.

Bulgular: Tip II ark en yaygın olanıydı (37 hasta, %58.7), bunu Tip I (13 hasta, %20.6) ve Tip III (13 hasta, %20.6) izledi. Sığır arkı 16 hastada (%25.4) meydana geldi. Tip II/III arkı olan hastalar, Tip I olanlardan anlamlı derecede daha yaşlıydı ($p=0.028$). Aort plak varlığı ark tipiyle güçlü bir korelasyon gösterdi ($p<0.001$), Tip III hastaların %92.3'ünde plak bulunurken, Tip I hastaların %7.7'sinde plak vardı. İşlem başarısı 63 vakanın 59'unda (%93.7) sağlandı.

Sonuç: Bu retrospektif analiz, aort ark varyasyonlarının yaşla birlikte arttığını ve aterosklerotik yük ile ilişkili olduğunu göstermektedir. İnme müdahalesi yapılan hastalarda tip II ve III arklar baskın olup, yüksek işlem başarı oranları korunurken özel kateter teknikleri gerektirmektedir.

Anahtar Sözcükler: Arkus; aorta; inme; intraarteriyel trombolitik; trombektomi.