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Selective arterial embolization for renal angiomyolipoma: The role of optimal embolization

Renal anjiyomiyolipomda selektif arteriyel embolizasyon: Optimal embolizasyonun rolü

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ABSTRACT

Aim: The study aims to evaluate the efficacy and safety of selective arterial embolization (SAE) for renal angiomyolipoma (rAML).

Material and Methods: This retrospective study included patients with rAML who underwent SAE between February 2009 and December 2022. The primary outcome was procedural success, defined as cessation of bleeding and reduction in tumor size. Secondary outcomes included complication rates, changes in symptoms, and the need for reintervention. Kaplan-Meier analysis was performed to assess reintervention-free survival.

Results: A total of 42 patients with 62 rAMLs were included, with a mean age of 43.9 ± 12.2 years (range: 23–68). The majority were female (80.9%, n = 34), and 18.1% (n = 8) had TSC-associated rAML. TSC-associated cases presented at a younger age and had significantly larger tumor volumes (p = 0.002), lower hemoglobin levels (p = 0.02), and higher creatinine levels (p = 0.05) compared to sporadic rAML cases. SAE achieved a 100% technical success rate. The mean hospitalization duration was 4.16 ± 4.04 days, and no major complications were observed. The mean follow-up period was 35.27 ± 37.67 months. During follow-up, 6 patients (14.3%) required reintervention, including 4 re-embolizations and 2 surgical procedures. The overall Kaplan-Meier estimate of freedom from reintervention at 4.6 years was 68%, with significantly higher reintervention rates in TSC-associated cases (p = 0.04). When comparing embolization techniques, optimal embolization (coils + polyvinyl alcohol [PVA] particles) resulted in significantly greater tumor volume reduction (p = 0.049). In contrast, non-optimal embolization (coils or PVA alone) was associated with a less significant reduction in maximum lesion diameter (p = 0.059). Despite this, there was no significant difference in pre- and post-procedure laboratory parameters between the two embolization groups, except for lesion volume.

Conclusions: SAE is effective for managing rAMLs, with high technical success and acceptable re-intervention rates. Optimal embolization plays a pivotal role in enhancing treatment efficacy.

Keywords: renal angiomyolipoma (rAML), embolization, selective arterial embolization (SAE), tuberous sclerosis complex (TSC)

ÖZ

Amaç: *Bu çalışma, renal anjiyomiyolipom (rAML) için selektif arteriyel embolizasyonun (SAE) etkinlik ve güvenliliğini değerlendirmeyi amaçlamaktadır.*

Gereç ve Yöntemler: *Bu retrospektif çalışmaya, Şubat 2009 ile Aralık 2022 tarihleri arasında SAE uygulanan rAML hastaları dahil edilmiştir. Birincil sonlanım noktası; kanamanın durması ve tümör boyutunda küçülme olarak tanımlanan işlem başarısıdır. İkincil sonuçlar; komplikasyon oranlarını, semptomlardaki değişiklikleri ve yeniden girişim ihtiyacını içermektedir. Yeniden girişimsiz sağkalımı değerlendirmek için Kaplan-Meier analizi uygulanmıştır.*

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Bulgular: *Toplam 62 rAML'ye sahip 42 hasta çalışmaya dahil edilmiş olup, ortalama yaş 43,9 ± 12,2 yıldır (aralık: 23–68). Hastaların çoğunluğu kadındır (%80,9, n = 34) ve %18,1'inde (n = 8) Tüberos Skleroz Kompleksi (TSK) ilişkili rAML mevcuttur. TSK ilişkili olgular, sporadik rAML olgularına kıyasla daha genç yaşta başvurmuş; bu olgularda istatistiksel olarak anlamlı düzeyde daha büyük tümör hacimleri (p = 0,002), daha düşük hemoglobin seviyeleri (p = 0,02) ve daha yüksek kreatinin seviyeleri (p = 0,05) saptanmıştır. SAE ile %100 teknik başarı oranı elde edilmiştir. Ortalama hastanede kalış süresi 4,16 ± 4,04 gün olup, majör bir komplikasyon gözlenmemiştir. Ortalama takip süresi 35,27 ± 37,67 aydır. Takip sürecinde, 4 re-embolizasyon ve 2 cerrahi prosedür olmak üzere 6 hastada (%14,3) yeniden girişim gerekmiştir. Genel Kaplan-Meier tahmini ile 4,6 yılda yeniden girişimden bağımsızlık oranı %68 olarak bulunmuş; TSK ilişkili olgularda yeniden girişim oranlarının anlamlı derecede daha yüksek olduğu görülmüştür (p = 0,04). Embolizasyon teknikleri karşılaştırıldığında, optimal embolizasyon (koil + polivinil alkol [PVA] partikülleri), anlamlı düzeyde daha büyük tümör hacmi küçülmesi sağlamıştır (p = 0,049). Buna karşın, optimal olmayan embolizasyon (tek başına koil veya PVA) maksimum lezyon çapında daha az belirgin bir azalma ile ilişkilendirilmiştir (p = 0,059). Buna rağmen, iki embolizasyon grubu arasında lezyon hacmi dışında işlem öncesi ve sonrası laboratuvar parametrelerinde anlamlı bir fark bulunmamıştır.*

Sonuç: *SAE, yüksek teknik başarı ve kabul edilebilir yeniden girişim oranları ile rAML yönetiminde etkilidir. Optimal embolizasyon, tedavi etkinliğinin artırılmasında kilit bir rol oynamaktadır.*

Anahtar Sözcükler: *Renal anjiomiyolipom (rAML), embolizasyon, selektif arteriyel embolizasyon (SAE) tuberos skleroz kompleksi (TSC)*

INTRODUCTION

Renal angiomyolipoma (rAML) is the most common benign mesenchymal kidney tumor, composed of dysmorphic blood vessels, adipose tissue, and smooth muscle. It is more prevalent in females, with a reported prevalence of 0.3% to 5% in the general population and accounting for up to 3% of kidney masses (1-3). rAML occurs in two main forms: approximately 80% arise sporadically in healthy individuals, while the remaining cases are associated with tuberous sclerosis complex (TSC) or lymphangioleiomyomatosis (LAM), both rare genetic disorders. TSC is diagnosed based on clinical criteria, including benign tumors in various organs and specific genetic mutations. Compared to sporadic cases, TSC-associated rAML has a worse prognosis and a higher risk of requiring reintervention after selective arterial embolization (SAE), necessitating closer monitoring (4).

Management strategies depend on tumor size and symptoms, with a primary focus on preventing acute complications and preserving renal function. Treatment options include SAE, nephron-sparing surgery, total nephrectomy, cryo- and radiofrequency ablation, and mTOR inhibitors. Among these, SAE is a minimally invasive, nephron-sparing procedure with lower complication rates and shorter hospital stays compared to surgery. It is used for prophylactic treatment of high-risk rAMLs, emergency management of hemorrhagic cases, and preoperative reduction of intraoperative blood loss (5-7).

This study aims to evaluate the efficacy and safety of SAE and optimal embolization in the management of rAMLs at our center.

MATERIAL and METHODS

Our institutional review board approved this retrospective study (Protocol number: *24-1T/22*). Informed consent was not required due to this study's retrospective and observational nature. All identifiable details were anonymized during data collection and analysis to ensure patient confidentiality.

Study Design

The study included patients diagnosed with angiomyolipoma who underwent SAE From February 2009 to December 2022 (Figure-1). Data were collected retrospectively from the hospital's electronic health records system. The patients' images were retrospectively screened from the institutional picture archiving and communication systems (SECTRA PACS, Sectra AB, Linköping, Sweden).

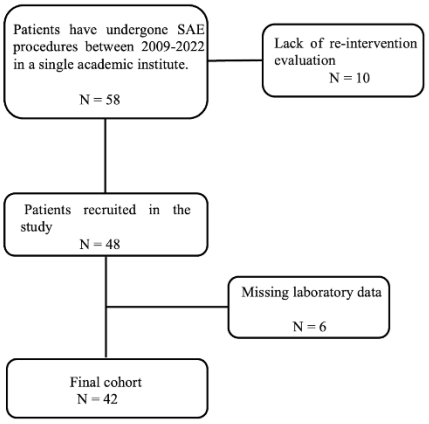

Figure-1. Flow diagram of included and excluded patients are shown.

Selective Arterial Embolization

The decision to proceed with embolization was made during a collaborative meeting involving radiologists, urologists, and nephrologists, except for patients experiencing bleeding. Criteria for embolization included a tumor diameter exceeding 4 cm, the presence of an aneurysm larger than 5 mm, and/or symptoms such as bleeding due to ruptured rAML, regardless of its size. The diagnosis was confirmed through imaging studies such as ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI). In CT scans, findings indicative of macroscopic fat typically appear at -15 Hounsfield units (HU) or lower. However, some rAMLs (4-5%) may contain little to no intralesional fat, making fat detection on CT challenging. These lesions, known as Fat-Poor rAMLs, appear hyperdense and become more pronounced following contrast administration (6).

Embolization was performed during hospitalization under local anesthesia via the common femoral artery, utilizing 5-French (Fr) angiographic catheters and coaxial microcatheters. The Allura XD 20 Clarity angiography suite (Philips, Best, The Netherlands) and Toshiba Infinix angiography suite (Tokyo, Japan) were employed for patients. Initially, an aortogram was conducted through a 5-Fr sheath to locate the renal arteries, identify any accessory renal arteries or extra-renal feeding arteries, and evaluate the vascularization of the rAML, the extension of tumor vessels outside the normal nephrogram, vessel displacements by the tumor, and identification of aneurysms. In cases of severe bleeding, active extravasation and retroperitoneal blood were identified. Subsequently, superselective catheterization of the rAML feeding vessels was achieved using a coaxial 2.4-Fr microcatheter (Progreat®; Terumo, Tokyo, Japan) and 2.4 Fr microcatheter (Direxion®; Boston Scientific, USA) to preserve renal parenchyma as much as possible.

Depending on the size and number of the vessels supplying the tumor, an appropriate quantity of embolic material was meticulously injected under continuous fluoroscopic guidance. Polyvinyl alcohol (PVA) particles (Contour®, Boston Scientific, USA) were chosen as embolic agents, selected at the physician's discretion to block the AML vessels. Additionally, microcoils (Pushable fibered platinum, Boston Scientific, USA) were employed to address aneurysms or to embolize proximal feeding arteries of AMLs if they exceeded 2 mm after distal embolic occlusion, thus minimizing the risk of incomplete occlusion or recanalization. Confirmation of tumor devascularization was achieved through post-embolization arteriography.

Selective arterial embolization was performed by a team of experienced interventional radiologists. The procedure involved the catheterization of the renal artery, followed by the selective catheterization of the artery supplying the angiomyolipoma. Embolizing agents were then injected to block the blood flow to the angiomyolipoma. The choice of embolizing agent was based on the individual patient’s condition and the radiologist’s judgment. All procedures were performed under imaging guidance to ensure precision and patient safety.

Outcome Measures

The primary outcome measure was procedural success, defined as the cessation of bleeding and a reduction in the size of the angiomyolipoma. The volume of the angiomyolipoma was calculated using imaging techniques (ultrasound, CT, or MRI) with the formula: length × width × height × 0.523, which assumes an ellipsoidal shape for most structures. Fat-rich rAML was defined as a lesion with a CT attenuation of –10 HU or less, while fat-poor rAML was characterized by a CT attenuation of more than –10 HU (8). Secondary outcome measures included the incidence of complications and post-treatment follow-up characteristics, such as changes in symptoms and the need for re-intervention. Re-intervention was considered necessary in cases of insufficient reduction in

tumor size, emergent conditions, or persistent patient symptoms.

Patients treated with either coil or PVA alone were considered to have undergone non-optimal embolization, whereas optimal embolization was defined as the use of both coil and PVA particles. Clinical success was defined as a reduction in the target tumor size without any complications related to the SAE. Technical success was characterized by the absence of blood flow in the feeding arteries and no opacification of the rAML on the post-SAE angiogram (9).

Statistical Analysis

The normality of data distribution was assessed using the Kolmogorov-Smirnov test. Continuous variables with a normal distribution are presented as means ± standard deviations (SD). Nominal variables are expressed as counts and percentages. Pre- and postoperative laboratory values were compared using either two-tailed paired t-tests or Wilcoxon tests. Mann-Whitney U tests or unpaired t-tests were employed to compare values between the TSC-associated and sporadic groups. Pearson's $\chi 2$ and Fisher's exact tests were utilized for the comparison of nominal variables.

Kaplan-Meier analysis was performed to illustrate the probability of reintervention, with the Log-rank test used to compare Kaplan-Meier curves. A p-value of ≤ 0.05 was considered statistically significant. The analyses were conducted using Microsoft Excel (version 14.7.1; Microsoft Corp, Redmond, WA, USA), and R (version 4.1.2; The R Foundation for Statistical Computing, Vienna, Austria).

To account for baseline differences between treatment groups, a multivariable linear regression analysis was performed on complete cases to evaluate the independent effect of the embolization technique on lesion volume reduction, adjusting for baseline lesion volume.

RESULTS

A total of 42 patients with 62 rAML were screened, consisting of 34 females (80.9%) and 8 males (19.04 %). The average age was 43.9 ± 12.2 years, ranging from 23 to 68 years. The etiology was associated with TSC in 8 patients (18.1%), while 36 patients (81.8%) had sporadic cases. The demographic and clinical data are presented in (Table-1).

Table-1. *Patients' demographics and clinical data.*

Variable	
Gender	Male (n = 8) Female (n = 34)
Type of rAMLs	Single (n = 22) Multiple (n = 20) Bilateral (n = 15)
Laterality of rAMLs	Unilateral (Left) (n = 11) Unilateral (Right) (n = 16)
Etiology	Tuberous Sclerosis Complex (n = 8) Sporadic (n = 34) Central (n = 2)
Location of rAMLs	Central and Exophytic (n = 7) Exophytic (n = 33)
Classification of rAMLs	Fat-rich (n = 40) Fat-poor (n = 2)
Presentation of rAMLs	Asymptomatic (n = 25) Symptomatic (n = 17)
Indication of SAE	Elective* (n = 26) Emergency** (n = 16)
Presence of Vascular Anomalies	Micro-aneurysm (n =12) Aneurysm (n = 20) No (n = 14)

**Prophylactic SAE: prevention of bleeding (tumors more than 4 cm in size, aneurysms more than 5 mm in size, and/or non-emergent symptoms).*
***Bleeding requiring emergency treatment*

TSC-associated rAML cases often present with multiple lesions and are observed at younger ages compared to sporadic cases (Table-2). Additionally, in TSC-associated cases, parameters such as size (p = 0.002), volume (p = 0.007), hemoglobin (p = 0.02), and creatinine (p = 0.05) are significantly worse compared to sporadic cases. The outcomes before and after embolization are presented in (Table-3).

When we examined the patients based on whether optimal embolization was performed, we found no significant difference in the values of both groups before and after the procedure, except for the lesion volume. The lesion volume in the non-optimal embolization group was significantly higher (p = 0.049). Also, in the non-optimal group, the reduction in the maximum diameter of the lesions was not significant (p = 0.059) (Table-4).

Table-2. *Comparison of clinical and demographic characteristics between sporadic and TSC-Associated cases.*

		Sporadic (n =34)	TSC associated (n =8)	*P value*
Age		45.88 ± 12.03	35.25 ± 10.27	**.025**
Subcutaneous fat thickness		24.03 ± 9.3	17.66 ± 9.09	.16
Gender	Male (n =8)	6 (%17.6)	2 (%25)	.65
	Female (n=34)	28 (%82.3)	6 (%75)	
Lesion (Single/Multiple)	Single (n = 22)	21 (%61.7)	1 (%12.5)	**.018**
	Multiple (n =20)	13 (%38.2)	7 (%87.5)	
Lesion Location	Left (n = 15)	13 (%38.2)	2(%25)	.74
	Right (n = 26)	20(%58.8)	6(%75)	
	Bilateral (n = 1)	1(%2.9)	0	
Lesion Character	Central (n = 9)	4 (%11.1)	5 (%16.6)	**.043**
	Exophytic (n = 40)	32 (%88.8)	8 (%61.5)	
ASA score	ASA1 (n =16)	15 (%44.1)	1 (%12.5)	**.002**
	ASA2 (n =19)	17 (%50)	2 (%25)	
	ASA3 (n =5)	1 (%2.9)	4 (%50)	
	ASA4 (n =2)	1 (%2.9)	1 (%12.5)	
Vascular anomaly	Aneurysm (n = 20)	14 (%40)	6 (% 54.5)	.202
	Microaneurysm (n =12)	8 (%22.8)	4 (% 36.3)	
	No (n = 14)	13 (%37.1)	1 (% 9)	
Hemorrhage before embolization	Yes (n =17)	12(%35.2)	5(%62.5)	.234
	No (n =25)	22(%64.7)	3(%37.5)	

Table-3. *Effects of SAE on lesion characteristics, and lab values in all patients, sporadic, and TSC-Associated cases.*

		All Patient (n =42)	*P value*	Sporadic (n =34)	*P value*	TSC associated (n = 8)	*P value*
Lesion maximum diameter	Before SAE	10.1 ± 5.6 cm	***< .001***	8.55 ± 3.53 cm	***< .001***	16.66 ± 8.04 cm	***< .001***
	After SAE	6.16 ± 2.34 cm		5.98 ± 2.33 cm		6.89 ± 2.41 cm	
Lesion Volume	Before SAE	665.76 ± 1164.75 cm^3	***< .001***	342.69 ± 338.78 cm^3	***< .001***	2038.83 ± 2177.92 cm^3	***.015***
	After SAE	150.05 ± 183.02 cm^3		129.9 ± 138.57 cm^3		235.71 ± 308.7 cm^3	
Hemoglobin	Before SAE	11.48 ± 2.08	.871	11.85 ± 1.81	.277	9.88 ± 2.48	.873
	After SAE	11.78 ± 1.96		12.21 ± 1.48		9.93 ± 2.7	
Creatin	Before SAE	1.09 ± 1.12	.128	0.92 ± 0.97	0.13	1.79 ± 1.46	**.042**
	After SAE	1.23 ± 1.42		0.92 ± 0.98		2.55 ± 2.22	

Table-4. *Comparison of lesion characteristics, and lab values between optimal and non-optimal embolization groups***.**

		Optimal Embolization* (n =36)	*P value*	Non-Optimal Embolization** (n =6)	*P value*
Lesion maximum diameter	Before SAE	9.34 ± 4.39 cm	***< .001***	14.65 ± 9.69 cm	.059
	After SAE	6.14 ± 2.31 cm		6.27 ± 2.78 cm	
Lesion Volume	Before SAE	471.86 ± 619.76 cm^3	***< .001***	1829.16 ± 2557.5 cm^3	**.031**
	After SAE	131.43 ± 136.34 cm^3		261.77 ± 356.45 cm^3	

Hemoglobin	Before SAE	11.47 ± 2.2	.81	11.5 ± 1.24	.44
	After SAE	11.76 ± 2.01		11.86 ± 1.78	
Creatinine	Before SAE	1.1 ± 1.19	.35	1.03 ± 0.53	.39
	After SAE	1.18 ± 1.4		1.54 ± 1.65	

**Optimal Embolization: Coil + Polyvinyl Alcohol Particles (PVA)*
***Non-optimal Embolization: Either just coil or just PVA*

Because the baseline lesion volume was substantially larger in the non-optimal embolization group, a multivariable linear regression model was utilized to adjust for baseline volume. After adjustment, the type of embolization technique (optimal vs. non-optimal) was not a statistically significant independent predictor of volume reduction (p = 0.24). Instead, the baseline lesion volume was the primary driver of the reduction magnitude (p < 0.001), indicating that the absolute volume reduction is highly dependent on the initial tumor size rather than the specific embolic agents used.

The mean follow-up period was 35.27 ± 37.67 months. During the follow-up, among the cases (n = 6), reintervention was required, including re-embolization (n = 4) and surgery (n = 2). The Kaplan-Meier estimate of freedom from reintervention at 4.6 years following initial embolization was 68%. According to the Kaplan-Meier analysis results, a statistically significant difference existed between the sporadic and tuberous sclerosis-associated patients (p = 0.04) (Figure-2).

All patients were treated with a 100% technical success rate. Furthermore, an initial clinical success rate of 100% was achieved, as target tumor size reduction was observed without any major SAE-related complications. The mean hospitalization time was 4.16 ± 4.04 days (Figure-3,4).

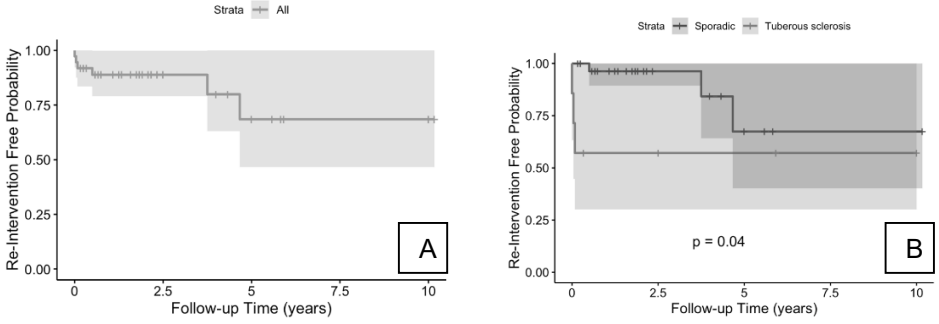

Figure-2. Kaplan–Meier curves showing freedom from reintervention, concerning time (years) for all patients (A) and subgroups (B).

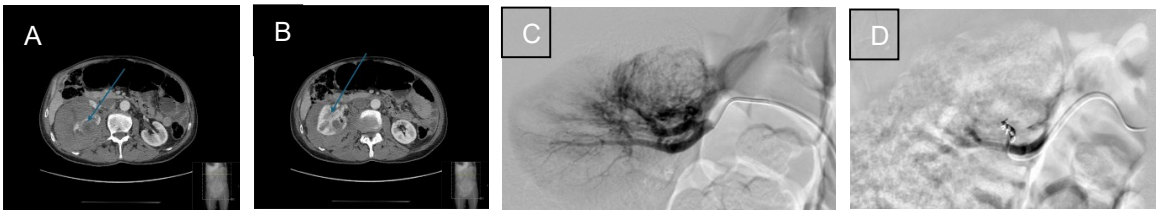

Figure-3. A 68-year-old male patient with sporadic rAML presented with severe flank pain. (A) Axial contrast-enhanced CT reveals a large retroperitoneal hematoma originating from the right kidney. (B) Axial CT scan shows a large tumor at the upper pole of the right kidney (arrow), composed of muscular, vascular, and fatty tissue. (C) Selective right renal arteriogram demonstrates tumor vessels and active bleeding in the upper portion of the kidney. (D) Post-embolization arteriogram confirms the disappearance of tumor vessels and cessation of active bleeding.

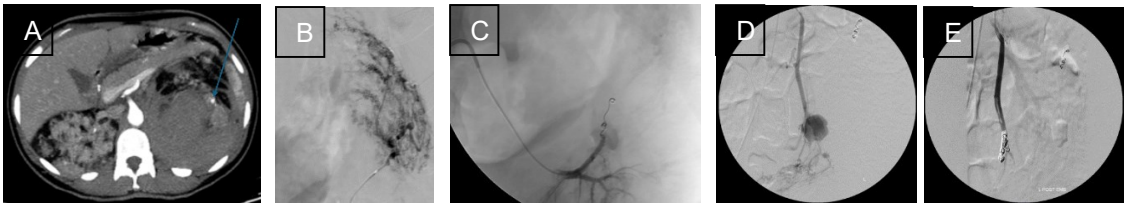

Figure-4. A 28-year-old female patient with TSC-associated rAML presented with severe flank pain and hypotension. (A) Axial contrast-enhanced CT of the kidney reveals a large retroperitoneal hematoma originating from the left kidney, with an intratumoral aneurysm measuring 7 mm (arrow). (B) Digital subtraction angiography (DSA) of the left kidney before selective embolization. (C) Post-embolization DSA showing successful occlusion of the ruptured artery, resulting in the resolution of the patient's hypotension. (D) Four years later, the same patient presented with recurrent bleeding from the lower pole of the left kidney. (E) Post-embolization DSA confirms occlusion of the ruptured artery following coil embolization

DISCUSSION

In this study, we evaluated the efficacy and safety of SAE in the management of rAML and found it to be highly effective, achieving a 100% technical success rate. Our findings demonstrated that SAE significantly reduced tumor size and successfully controlled acute bleeding, with a mean hospitalization period of 4.16 ± 4.04 days. Notably, patients with TSC-associated rAML had larger tumor volumes, higher creatinine levels, and lower hemoglobin levels compared to those with sporadic rAML, suggesting a more severe disease course in TSC cases. Additionally, six patients required reintervention, with a Kaplan-Meier estimated 68% probability of freedom from reintervention at 4.6 years. Importantly, the reintervention rate was significantly higher in TSC-associated rAML than in sporadic cases ($p = 0.04$). Furthermore, optimal embolization—using a combination of coils and PVA particles—resulted in significantly greater lesion volume reduction ($p = 0.049$), whereas non-optimal embolization was associated with a less pronounced decrease in lesion size ($p = 0.059$).

Advancements in microcatheter technology and diagnostic imaging have made SAE a viable option for both prophylactic and emergency management of rAMLs (1, 5). Consistent with previous studies (10), our findings confirm that the maximum diameter of rAMLs decreases significantly following SAE, irrespective of TSC status. While embolization does not eradicate tumors, it effectively reduces their size. Our results emphasize the importance of optimal embolization, as we observed that larger initial tumor volumes were more common in the non-optimal embolization group. This suggests that achieving optimal embolization is more challenging in larger tumors, likely due to an increased number of feeding vessels, greater vascular tortuosity, and unfavorable vascular angles, all of which complicate endovascular manipulation. The less significant diameter reduction in the non-optimal embolization group further supports the notion that treatment efficacy declines when optimal embolization is not achieved. Notably, our study achieved a 100% technical success rate, surpassing the 93% success rate reported by Jin et al. (11) underscoring the feasibility and reliability of the procedure.

The rationale for defining the combined use of polyvinyl alcohol (PVA) particles and microcoils as “optimal embolization” is rooted in the complementary and synergistic mechanisms of these two embolic agents. Particulate agents, such as PVA, act effectively at the capillary level to penetrate and permanently block the distal microvasculature of the angiomyolipoma. Following this distal occlusion, microcoils are synergistically employed to address concurrent intratumoral aneurysms and to embolize the proximal feeding arteries, particularly those exceeding 2 mm in diameter. This combined approach is theoretically superior to monotherapy because it simultaneously devascularizes the distal tumor bed and physically secures the proximal arterial inflow. Consequently, this technique minimizes the risk of retrograde collateral filling, incomplete occlusion, and delayed vascular recanalization that may occur when either agent is utilized in isolation.(12)

Our study included both sporadic and TSC-associated rAMLs, with 19% of cases linked to

tuberous sclerosis, a rate comparable to previous studies that report TSC-associated rAMLs in 7%–70% of cases (5, 7, 10, 13, 14). Patients with TSC were generally younger, had higher ASA scores, and presented with larger rAMLs. Laboratory parameters were significantly worse in TSC-associated cases, suggesting their potential utility in distinguishing TSC from sporadic cases.

Reintervention rates serve as an alternative measure of treatment durability. Prior studies have identified tuberous sclerosis as the strongest predictor of reintervention in binomial regression analyses (7). Consistent with our findings, other studies have demonstrated that the probability of remaining reintervention-free is significantly higher in sporadic rAML cases compared to TSC-associated cases (3, 5, 7). These results highlight the need for closer surveillance of TSC-associated rAMLs both preoperatively and postoperatively to optimize patient outcomes.

This study has several limitations. First, its retrospective design introduces potential selection bias, as the data were not originally collected for research purposes. Second, differences in case mix (sporadic vs. TSC-associated rAMLs) and treatment settings (elective vs. emergency embolization) complicate direct comparisons across groups and with previously published studies. Third, follow-up durations varied between sporadic and TSC-associated rAML cases, limiting long-term outcome assessments.

CONCLUSION

SAE is a safe and effective treatment for rAML, achieving a high technical success rate and acceptable reintervention rates. TSC-associated rAMLs present with larger tumor volumes, worse baseline laboratory parameters, and higher reintervention rates, necessitating closer long-term surveillance. Furthermore, optimal embolization plays a pivotal role in enhancing treatment efficacy, emphasizing the need for meticulous procedural planning.

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Declarations Ethics Approval: This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Ege University Faculty of Medicine (Date: 07.10.2024 Application no: *2024-3596*; Decision No: 24-1T/22).

Consent to Participate: The requirement for informed consent was waived by the Ethics Committee of Ege University Faculty of Medicine due to the retrospective nature of the study.

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