

# International Journal of Medical and Pharmaceutical Research

Online ISSN-2958-3683 | Print ISSN-2958-3675 Frequency: Bi-Monthly Available online on: https://ijmpr.in/

# Original Article

# Prophylactic Versus Emergency Trans-Arterial Embolization for Large Renal Angiomyolipoma: Long-Term Tumor and Renal Function Outcomes

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Received: 17-09-2025 Accepted: 05-10-2025 Available online: 12-11-2025

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#### ABSTRACT

**Objective:** To compare long-term tumor control and renal function outcomes of Selective transarterial embolization (TAE) for large renal angiomyolipoma (AML  $\geq$ 10 cm) performed prophylactically versus emergency embolization for acute hemorrhage.

**Methods**: This retrospective single-center study included 44 patients (46 large renal AMLs) treated with selective TAE between July 2018 and June 2024. Mean tumor size was  $13.2 \pm 3.12$  cm, with a mean follow-up of 25.2 months. Patients were divided into a prophylactic embolization group (n = 34) and an emergency embolization group (n = 10). Primary outcomes were radiologic tumor size reduction and renal function preservation assessed using serum creatinine and estimated glomerular filtration rate (eGFR). Secondary outcomes included reintervention, hospital stay, and post-embolization complications.

**Results**: Mean tumor size significantly decreased from 13.2 cm pre-embolization to 10.3 cm post-embolization (p = 0.003), with no significant difference between prophylactic and emergency groups (p > 0.05). Renal function remained stable with no significant change in serum creatinine or eGFR (p = 0.6 and p = 0.8). Reintervention rates were higher after emergency embolization but were not statistically significant (20.0% vs. 11.8%, p > 0.05). Hospital stay was significantly longer in the emergency group (3.5  $\pm$  1.2 vs. 1.8  $\pm$  0.8 days, p < 0.05). Post-embolization syndrome was the most common complication (43.1%).

**Conclusion**: Selective TAE provides durable tumor control and preserves renal function in large renal angiomyolipoma. While radiologic outcomes are comparable, emergency embolization is associated with prolonged hospitalization, supporting early prophylactic treatment.

**Keywords**: Renal Neoplasms, Renal Angiomyolipoma, Transarterial Embolization, Post-Embolization Syndrome.

#### INTRODUCTION

Renal angiomyolipoma (rAML) is the most common benign mesenchymal neoplasm of the kidney, arising from perivascular epithelioid cells and histologically characterized by a variable admixture of mature adipose tissue, smooth muscle fibers, and dysmorphic blood vessels [1]. These tumors may occur sporadically or in association with genetic disorders such as tuberous sclerosis complex (TSC) and lymphangioleiomyomatosis (LAM), with sporadic rAMLs accounting for nearly 80–90% of cases [2]. Sporadic angiomyolipomas are more commonly detected incidentally due to the widespread use of cross-sectional imaging modalities, whereas TSC-associated lesions tend to be bilateral, multifocal, and larger in size [3].

Although rAMLs are generally considered benign and slow growing, their clinical significance lies in their potential to cause serious complications. Most small lesions remain asymptomatic and are managed conservatively with active surveillance. However, as tumor size increases, the abnormal vascular component—characterized by aneurysm formation and lack of elastic tissue—predisposes these lesions to spontaneous rupture and hemorrhage [4]. Retroperitoneal bleeding secondary to rAML rupture, known as Wunderlich syndrome, can present with acute flank pain, hematuria, hypovolemic shock, and may be life-threatening if not promptly managed [5].

Tumor size has consistently been identified as the most important predictor of hemorrhagic risk. Several studies have demonstrated a marked increase in bleeding risk in lesions exceeding 4 cm, leading to the widespread adoption of this threshold for prophylactic intervention [6,7]. More recently, attention has focused on large and giant angiomyolipomas, commonly defined as tumors measuring ≥10 cm, which carry a substantially higher risk of spontaneous rupture, repeated bleeding episodes, and progressive renal parenchymal compression [8]. In such large tumors, conservative management is often unsafe, and timely intervention becomes crucial to prevent catastrophic hemorrhage.

Management strategies for rAMLs include active surveillance, selective transarterial embolization (TAE), partial or radical nephrectomy, and, in select cases, medical therapy with mammalian target of rapamycin (mTOR) inhibitors, particularly in TSC-associated disease [9]. Among these options, selective TAE has emerged as a first-line treatment for both prophylactic management of high-risk lesions and emergency control of active hemorrhage. By selectively occluding tumor-feeding vessels, TAE effectively reduces tumor vascularity, induces volume reduction, and preserves surrounding renal parenchyma.

Compared with surgical approaches, TAE offers several advantages, including its minimally invasive nature, reduced perioperative morbidity, shorter hospital stay, and superior nephron-sparing capability. These benefits are particularly relevant in patients with bilateral disease, solitary kidneys, or compromised renal function. Consequently, TAE is increasingly preferred over surgery, especially in large angiomyolipomas where complete surgical excision may necessitate radical nephrectomy.

Despite the widespread use of TAE and well-documented short-term success, existing literature largely focuses on heterogeneous cohorts that include angiomyolipomas of varying sizes, etiologies, and clinical presentations. Moreover, while emergency embolization for acute hemorrhage has been shown to be effective in achieving hemostasis, it remains unclear whether outcomes differ significantly when embolization is performed prophylactically before rupture, particularly in the subset of large (≥10 cm) angiomyolipomas. Data directly comparing long-term clinical outcomes, tumor shrinkage, renal function preservation, and need for reintervention between prophylactic and emergency TAE in this high-risk group are limited.

Such comparative data are critical for optimizing treatment algorithms, determining the ideal timing of intervention, and improving patient counseling regarding the risks and benefits of early prophylactic treatment versus watchful waiting until symptomatic or hemorrhagic presentation. A clearer understanding of these outcomes may also help reduce emergency presentations and associated morbidity.

Therefore, the present study was designed to compare the long-term clinical, radiological, and functional outcomes of selective transarterial embolization performed prophylactically versus emergently in patients with large renal angiomyolipomas treated at our tertiary care center.

# MATERIALS AND METHODS

#### **Study Design and Patient Selection**

This retrospective single-center study included patients with large renal angiomyolipomas (≥10 cm) who underwent selective transarterial embolization between **July 2018 and June 2024**. Institutional ethical committee approval was obtained (2023-114-Mch-EXP-45)

A total of 44 patients with 46 large AMLs were included. Patients were divided into two groups based on indication:

- Prophylactic Group (n = 34): Elective embolization for large asymptomatic tumors or tumors causing non-hemorrhagic symptoms (pain, mass effect).
- Emergency Group (n = 10): Urgent embolization for acute retroperitoneal hemorrhage with hemodynamic instability or radiologic evidence of rupture.

#### **Data Collection**

Demographic variables, tuberous sclerosis complex (TSC) association, tumor size (maximum diameter on contrast-enhanced CT/MRI), renal function parameters (serum creatinine and estimated glomerular filtration rate [eGFR]), length of hospital stay, complications, and need for reintervention were retrieved from the hospital information system.

#### Follow Up:

Follow-up data, including clinical examinations and laboratory tests, CT or MRI scans which where were typically performed 3–6 months after SAE and annually thereafter. Treatment failure (need for reintervention) was defined as the recurrence of symptoms and/or an increase in tumor size greater than 2 cm on follow-up.

#### **Primary Outcomes**

- Tumor size reduction after TAE
- Preservation of renal function (serum creatinine and eGFR)

#### **Secondary Outcomes**

- Reintervention rate (defined as recurrence of symptoms or tumor growth >2 cm)
- Complications and their severity
- Length of hospital stay

#### **Statistical Analysis**

Continuous variables were expressed as mean  $\pm$  standard deviation and categorical variables as frequencies and percentages. Comparisons between groups were performed using the **Student's t-test** for continuous variables and the **Chi-square or Fisher's exact test** for categorical variables. A p value <0.05 was considered statistically significant. Statistical analysis was performed using SPSS version 25.

# **RESULTS**

#### **Patient Characteristics**

The study included 44 patients, of whom 38 (86.3%) were female. The mean age was  $40.39 \pm 11.8$  years. Tuberous sclerosis complex was present in 11 patients (25%), all of whom were offered everolimus therapy. There were no statistically significant differences between the prophylactic and emergency groups in terms of age, sex distribution, TSC association, or baseline tumor size (Table 1).

Variable	Prophylactic Group (n = 34)	Emergency Group (n = 10)	
			p-value
Mean age (years ± SD)	$40.5 \pm 12.0$	40.0 ± 11.0	0.88
Female sex, n (%)	29 (85.3)	9 (90.0)	0.99
TSC association, n (%)	8 (23.5)	3 (30.0)	0.99
Mean pre-TAE tumor size (cm ± SD)	13.1 ± 3.2	13.5 ± 2.8	0.74

# **Tumor Control and Renal Function**

Both groups achieved significant post-embolization tumor size reduction. The overall mean tumor size decreased from 13.2 cm to 10.3 cm, with a mean reduction of  $2.9 \pm 3.97$  cm. The extent of reduction did not differ significantly between the two groups (p = 0.68). Renal function remained stable in both cohorts. There was no statistically significant change in serum creatinine or eGFR during a mean follow-up of 25.2 months (Table 2).

Table 2. Treatment outcomes and complications

Outcome	Prophylactic Group(n = 34)	Emergency Group (n = 10)	p-value
Mean post-TAE size (cm ± SD)	10.1 ± 2.4	11.0 ± 2.6	0.35
Mean size reduction (cm $\pm$ SD)	$3.0 \pm 4.1$	$2.5 \pm 3.0$	0.68
Pre-TAE eGFR (mL/min/1.73 m²)	75.8 ± 25.5	77.1 ± 28.0	0.89
Post-TAE eGFR (mL/min/1.73 m²)	$71.5 \pm 22.8$	68.8 ± 21.0	0.78
Overall success rate, n (%)	29 (85.3)	8 (80.0)	0.99
Reintervention rate, n (%)	4 (11.8)	2 (20.0)	0.58
Mean hospital stay (days $\pm$ SD)	$1.8 \pm 0.8$	3.5 ± 1.2	0.001
Post-embolization syndrome	14 (41.2)	5 (50.0)	0.70

# **Reintervention and Complications**

The overall technical and clinical success rate was 84.7%. Reintervention was required in 4 patients (11.8%) in the prophylactic group and 2 patients (20%) in the emergency group, with no statistically significant difference (p = 0.58). The mean hospital stay was significantly longer in the emergency group (3.5 ± 1.2 days) compared with the prophylactic group (1.8 ± 0.8 days; p = 0.001).

Post-embolization syndrome was the most frequent complication (43.1%) and was comparable between groups. One patient (2.2%) in the prophylactic group developed a perinephric abscess requiring nephrectomy.

#### DISCUSSION

The present study demonstrates that selective transarterial embolization (TAE) is a highly effective nephron-sparing treatment for large renal angiomyolipomas ( $\geq 10$ cm), providing durable long-term tumor control and preservation of renal function irrespective of whether the procedure is performed in a prophylactic or emergency setting.

Importantly, this study adds to existing literature by offering a direct comparative analysis between prophylactic and emergency embolization exclusively in large AMLs, a population that remains underrepresented in previous series.

#### **Tumor Control in Large AMLs**

The overall mean tumor size reduction of 2.9 cm observed in our cohort is consistent with previously published angiographic series. Kothary N et al. [3] reported a mean reduction of nearly 50% in tumor volume following embolization of large AMLs, while Ramon J et al. [4] demonstrated sustained tumor shrinkage in over 90 % of patients at long-term follow-up. Similarly, Murray et al. [5], in a systematic review of over 500 patients, reported consistent volumetric reduction after TAE across studies.

In our study, no significant difference in tumor reduction was observed between prophylactic and emergency groups, indicating that the biological response of the tumor to devascularization remains effective even after rupture and acute hemorrhage. This directly supports the findings of Ramakrishnan A et al. [13], who showed that rupture does not compromise embolization success when complete devascularization is achieved.

# **Renal Function Preservation**

Preservation of renal function is a critical endpoint in the management of rAMLs, particularly given their frequent bilateral or multifocal nature and association with tuberous sclerosis complex (TSC). In our study, serum creatinine and eGFR remained stable in both groups, with no statistically significant deterioration over a mean follow-up of 25 months.

These findings are fully concordant with prior literature. Kothary N et al. [3] and Hocquelet A et al. [12] independently demonstrated that TAE does not lead to clinically meaningful long-term renal function decline, even after repeated embolization. Flum et al. [6] further emphasized that embolization offers superior renal function preservation when compared with partial nephrectomy in large AMLs.

#### Prophylactic Versus Emergency Embolization: Morbidity and Hospital Stay

The most clinically meaningful difference between the two groups in our study was the significantly longer hospital stay in the emergency group (3.5 vs. 1.8 days, p = 0.001). This reflects the additional burden of hemodynamic stabilization, blood transfusion requirements, and critical monitoring for rebleeding and post-hemorrhage complications. Chan et al. [7] demonstrated that urgent superselective transcatheter arterial embolization was an effective treatment for emergency patients with ruptured renal angiomyolipomas, no significant renal function deteriorations was noted. Lin L et al. [9] showed that prophylactic embolization allowed planned short-stay admissions with faster recovery, findings that are strongly reinforced by our comparative data.

Thus, while both approaches yield comparable long-term oncologic and renal outcomes, prophylactic embolization clearly outperforms emergency intervention in terms of short-term morbidity and healthcare resource utilization.

#### **Reintervention Rates and Tumor Recurrence**

The overall reintervention rate in our study was 13.6%, which falls well within the 10–25% range reported in the literature [4,5,10]. Although the emergency group demonstrated a numerically higher reintervention rate (20% vs. 11.8%), this did not reach statistical significance.

Farg HM et al. [10] and Ramon et al. [4] suggested that ruptured AMLs often exhibit complex intratumoral pseudoaneurysms and hypervascular components, predisposing them to incomplete infarction and future regrowth. Our emergency cohort followed a similar trend, supporting the hypothesis that ruptured AMLs represent a biologically more aggressive vascular subtype.

# Post-Embolization Syndrome and Complications

Post-embolization syndrome (PES) was the most common complication in our series (43.1%), consistent with reported incidences ranging from 30–60% [5,8]. Crucially, the rate of PES did not differ significantly between prophylactic and emergency groups, indicating that symptom burden is primarily related to tumor infarction rather than the indication for embolization.

Major complications were rare. Only one patient (2.2%) required nephrectomy for perinephric abscess, which aligns with the low major complication rates (2–6%) reported in large meta-analyses [5,6].

#### **Tuberous Sclerosis-Associated AMLs**

TSC-associated AMLs constituted 25% of our cohort, all of whom were offered everolimus. Prior studies have shown that TSC-related AMLs demonstrate higher recurrence and reintervention rates because of multifocality and aggressive angiogenesis [6,14]. However, in our limited sample, TSC status did not significantly influence embolization outcomes, though this warrants validation in larger cohorts.

#### **Clinical Implications and Decision-Making**

The findings of this study provide strong evidence supporting prophylactic embolization as the preferred strategy for Large AMLs ≥10 cm, even in asymptomatic patients, with effective prevention of rupture-related morbidity and reduction in hospital stay and healthcare burden. For patients presenting with acute hemorrhage, emergency SAE remains a highly effective life-saving intervention, achieving comparable long-term tumor control and renal preservation.

First, technical factors related to embolization may influence outcomes in large AMLs. These tumors frequently demonstrate complex vascular anatomy with multiple feeding arteries and intratumoral aneurysms. Complete superselective embolization using permanent embolic agents is essential to ensure durable devascularization and minimize recurrence. Although embolic agent selection was not standardized in this study, the favorable long-term outcomes observed suggest that meticulous embolization technique plays a critical role irrespective of whether the procedure is performed electively or emergently.

Second, the comparable long-term outcomes between prophylactic and emergency embolization emphasize the importance of timing primarily in relation to short-term morbidity rather than ultimate tumor control. Emergency embolization remains indispensable in the setting of acute hemorrhage; however, delaying intervention until rupture exposes patients to avoidable risks including hemodynamic instability, transfusion requirements, and prolonged hospitalization. Early prophylactic embolization in large AMLs may therefore represent a safer and more resource-efficient management strategy.

Finally, when compared with alternative treatment modalities such as partial or radical nephrectomy, embolization offers significant advantages in terms of nephron preservation, reduced morbidity, and faster recovery. While mTOR inhibitors play an important role in selected patients with TSC-associated AMLs, they do not provide immediate protection against hemorrhage. In this context, selective transarterial embolization remains the cornerstone treatment for large renal angiomyolipomas, either as definitive therapy or as part of a multimodal treatment approach.

The limitations of our study was that it was a retrospective single-center study with a relatively small emergency cohort, limiting statistical power. Follow-up duration, although adequate for intermediate outcomes, may not fully capture very long-term recurrences. Variability in embolic agents and operator techniques may have influenced outcomes.

#### **CONCLUSION**

Selective transarterial embolization is a safe and effective treatment for large renal angiomyolipomas, achieving sustained tumor control with excellent renal function preservation. While long-term outcomes are comparable between prophylactic and emergency embolization, emergency intervention is associated with significantly prolonged hospital stay and greater acute morbidity. These findings strongly support early prophylactic embolization as the preferred management strategy for large AMLs.

Future prospective, multicenter studies with larger patient cohorts and longer follow-up are warranted to further refine patient selection criteria, optimize embolization techniques, and evaluate standardized embolic agent protocols. Such studies may also help clarify the role of adjunctive medical therapy, particularly in tuberous sclerosis—associated AMLs, and establish evidence-based guidelines for the timing of intervention in large renal angiomyolipomas.

#### **Declaration:**

Conflicts of interests: The authors declare no conflicts of interest. Author contribution: All authors have contributed in the manuscript.

Author funding: Nill

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