

Research Article

Prevalence of Non-Iatrogenic Arterio-Venous Fistula in Patients with Chronic Subdural Hematoma Undergoing Embolization of Middle Meningeal Artery (EMMA)

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ABSTRACT

Introduction: Efficacy of embolization of the middle meningeal artery (EMMA) for chronic subdural hematoma (cSDH) has been shown. Arteriovenous fistula (AVF) has been noted in patients with cSDH but the prevalence of AVFs in cSDH patients is not known. Our study aimed to ascertain the prevalence of AVFs and associated factors in patients undergoing EMMA.

Methodology: A prospective cohort study was conducted on patients with cSDH who underwent EMMA. Two independent reviewers assessed angiographic images to determine the presence of non-iatrogenic AVF, their location, arterial supply, venous drainage, and whether seen on diagnostic, microcatheter angiograms, or during embolization. The prevalence of non-iatrogenic AVF was calculated and the association with various demographic and clinical factors were assessed.

Results: From May 2021 to June 2023, 55 patients (43 Males; Median age 65 years; 14 primary EMMA; 41 post-surgical EMMA) underwent 64 EMMA procedures. Ten patients had bilateral cSDH were all male. Non-iatrogenic AVF were identified in 18 patients (32.7%) and in 21 EMMA (32.8%) with 4 demonstrating multiple AVFs. Most common arterial supply was from the posterior division of MMA (18 out of 26) and venous drainage into the osteodural vein (18 out of 26). Higher prevalence ($p=0.028$) of AVF was seen in those who did not undergo surgical drainage.

Conclusion: Non-iatrogenic AVFs were seen in one-third patients with cSDH undergoing EMMA with a higher prevalence in those without surgical drainage.

1. Introduction

Chronic subdural hematoma (cSDH) is a common neurosurgical condition, particularly affecting the elderly, and is managed through observation, medical therapy, or surgical intervention [1-6]. Recent research has suggested the efficacy of embolization of middle meningeal artery (EMMA) as either an adjunct or standalone treatment for cSDH [7-11]. There have been reports of arteriovenous fistulas (AVFs) in patients with cSDH [12-14]. AVFs are abnormal shunts between meningeal arteries and dural sinuses or veins. The presence of AVFs has been suggested to be a risk factor for cSDH [2, 12]. AVFs are also suggested to be iatrogenic, potentially resulting either from surgical drainage or EMMA itself [12, 14]. However the true prevalence of non-iatrogenic arterio-venous fistulous communications in patients with

cSDH has not been systematically studied. Our study aimed to determine the prevalence and angiographic characteristics of non-iatrogenic AVFs in patients cSDH undergoing EMMA.

2. Methodology

The study was approved by the institution's Research Ethics Board and written informed consent was obtained from all participants. We included consecutive patients who underwent EMMA as a part of prospective registry for cSDH between May 2021 to June 2023. Demographic and clinical data were collected including prior surgical interventions, embolization related complications, and anticoagulant use.

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2.1. Image Analysis

The angiographic images were independently reviewed by two reviewers: a senior medical student (TU) and an interventional neuroradiologist (JS) with more than 15 years of experience. Images were assessed for the presence of AVFs, their location, arterial supply, venous drainage, and embolization technique and embolic agent used.

AVFs were documented based on whether they were visualized on the diagnostic angiography, microcatheter injections, or during liquid embolic agent injection. AVFs were considered iatrogenic if they were identified near the microcatheter tip (suggestive of micro-guidewire injury), or at the prior craniotomy site. Patients with suspected iatrogenic AVFs were excluded to assess the true incidence of non-iatrogenic AVFs underlying CSDH. Selection of embolic agents was operator-dependent, based on angiographic anatomy and other logistic considerations.

2.2. Data Analysis

Statistical analysis was performed using the Stata 13.1 (StataCorp, Texas, USA). The prevalence of AVFs was calculated. The association

of AVFs with demographic and clinical factors were assessed using univariate analysis. Inter-rater agreement was evaluated using Kappa statistics. A p-value of less than 0.05 was considered statistically significant.

3. Results

A total of 55 patients (43 male; mean age- 62.7 years; median age- 65 years) underwent EMMA at our institution during the study period. Table 1 summarizes the demographic, clinical, and angiographic characteristics of the cohort. Of these, 41 underwent surgical intervention prior to EMMA, while 14 did not. One patient who underwent surgery after embolization was included in the non-surgical group for analysis. Bilateral CSDH was observed in 15 patients, all of whom were male. A total of 64 middle meningeal angiograms were performed. Three patients did not undergo embolization due to difficulties accessing the MMA, MMA origin from ophthalmic artery, and MMA ligation during surgery. Arteriovenous Fistula (Figure 1). Eighteen patients (32.7%) were found to have AVFs. Because some patients underwent bilateral EMMA, a total of 64 embolizations were analyzed. AVFs were detected in 21 angiograms (32.8%). Four patients had more than one AVF (Table 1).

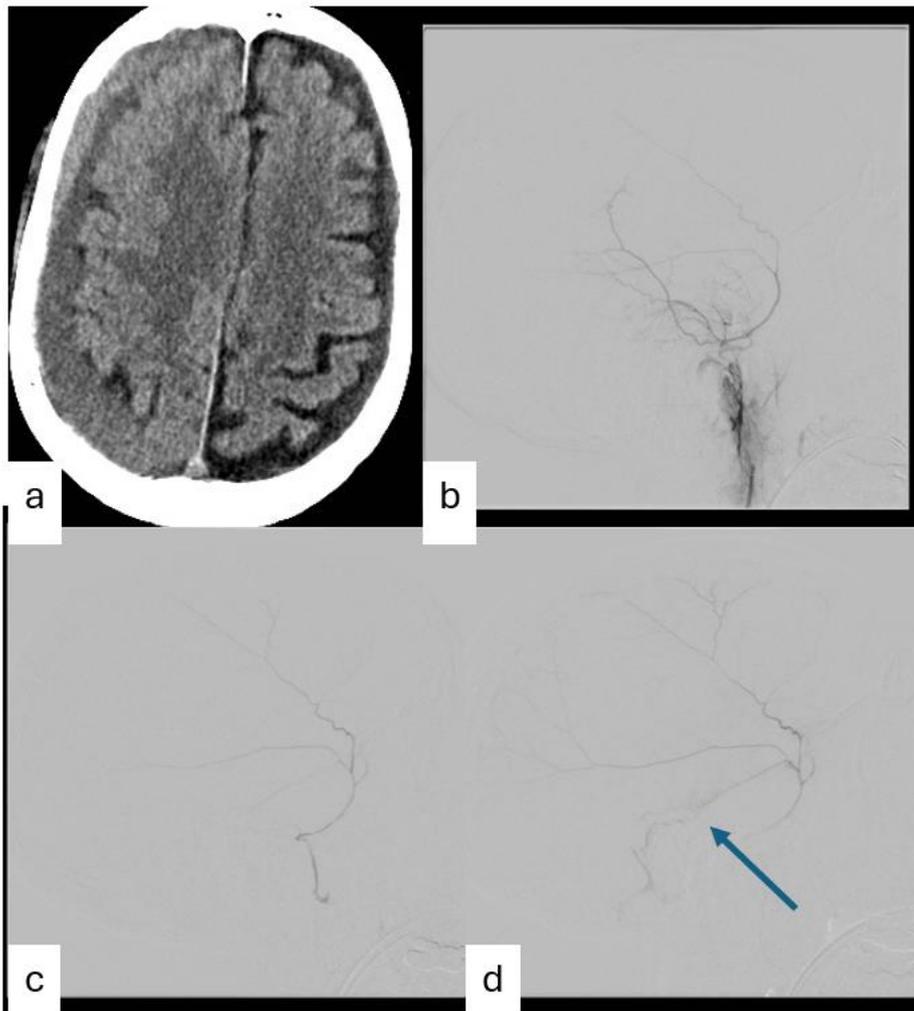


Fig 1. a) A patient in their 80s with a right-sided non-acute subdural hematoma underwent embolization of the middle meningeal artery. **b)** The angiogram of the right external carotid artery revealed no evidence of an arteriovenous fistula (AVF). **c)** A selective angiogram with the microcatheter positioned at the

origin of the right middle meningeal artery (MMA) showed no AVF. **d**) However, when the microcatheter was advanced just proximal to the bifurcation of the right MMA, a fistula (arrow) was observed, supplied by the posterior division of the MMA and draining into the right sigmoid sinus.

Table 1. Demographic and Angiographic Characteristics of the Study Cohort.

Characteristics	Number (%)
Total number of patients	55
Female	12 (21.8)
Male	43 (78.2)
Age (years)	
≤60	34 (61.8)
>60	21 (38.2)
cSDH Location	
Bilateral	15 (27.3)
Right Hemisphere	19 (34.5)
Left Hemisphere	21 (38.2)
Surgical drainage Prior to-EMMA	
Yes	41 (74.5)
No	14 (25.5)
EMMAs	64
Right Hemispheres	31 (48.4)
Left Hemispheres	33 (51.6)
Patients with ≥1AVF	18 (32.7)
Hemispheric Angiograms with AVF	21 (32.8)
Hemispheric Angiograms with more than one AVF	4 (6.3)
2 AVF	3
3 AVF	1
Visualization of AVF	
Global angiography	0
Microcatheter angiography	21 (100)
During liquid embolic injection	4 (19.0)
Arterial Supply of AVFs*	
Accessory MMA	1 (3.8)
Anterior Division of MMA	7 (26.9)
Posterior Division of MMA	18 (69.2)
Venous Drainage of AVFs*	
Osteo-dural Vein	18 (69.2)
Sigmoid Sinus	2 (7.7)
Superior Sagittal Sinus	3 (11.5)
Transverse Sinus	3 (11.5)

Values are reported as n (%) unless otherwise stated.

*Percentages calculated per total number of AVFs (n = 26).

AVF: Arterio-Venous Fistula; cSDH: Chronic Subdural Hematoma; EMMA: Embolization of Middle Meningeal Artery; MMA: Middle Meningeal Artery.

The most common arterial supply was from the posterior division of the MMA (18/26, 69.2%) and the most common venous drainage was into the osteodural veins (18/26, 69.2%). No residual AVFs were observed on post-embolization control angiograms. No patient experienced recurrence of cSDH during the follow-up period. Table 2 presents

various demographic and clinical factors associated with AVFs. Prior surgical drainage was associated with lower prevalence of AVFs (32% vs 53%, $p=0.028$). Inter-rater agreement was moderate ($k=0.42$). In five patients, the AVFs were deemed iatrogenic and excluded from the analysis.

Table 2. Association Between Demographic and Angiographic Characteristics and Presence of Arteriovenous Fistula.

Characteristics	Total (n)	Without AVF (n)	With AVF (n)	p-value
Angiograms performed	64	43	21	0.659
Right Hemispheres	31	20	11	
Left Hemispheres	33	23	10	
Gender				0.200
Female	12	10	2	
Male	53	34	19	
Age				0.114
≤60-years	40	24	16	
>60-years	24	19	5	
EMMA performed	61			
Embolic Agent				0.729
Onyx	22	15	7	
Particle	8	6	2	
Squid	31	19	12	
Surgical drainage before EMMA				0.028
Yes	45	34	11	
No	19	9	10	

AVF: Arterio-Venous Fistula; EMMA: Embolization of Middle Meningeal Artery.

4. Discussion

Our study demonstrates that the non-iatrogenic AVFs are present in approximately one-third of patients with cSDH undergoing EMMA, with multiple AVFs observed in 6.25% of patients. Prior surgical drainage was associated with a lower prevalence of AVFs. Most AVFs were supplied by posterior division of MMA and drained into osteo-dural veins. Prior literature has reported AVFs in association with cSDH primarily through isolated case reports and small series, limiting accurate estimation of prevalence [12, 14, 15]. Proposed mechanisms included congenital dural shunts becoming patent after hemodynamic changes or angiogenesis following craniotomy. However, these mechanisms alone do not fully explain our findings, as AVFs were present in only one-third of patients and were less prevalent in those who had undergone surgery.

Importantly, AVFs in our cohort were often visible only on microcatheter angiography, supporting the hypothesis that these may represent physiological dural shunts (< 12 μm) not visible on global DSA [12, 14, 16]. This observation suggests that such shunts may be underrecognized during routine angiography. Although procedural iatrogenesis remains a concern, cases suspicious for iatrogenic AVFs were systematically excluded, strengthening the validity of our prevalence estimate. Consistent with prior case reports, no patient experienced cSDH recurrence following embolization, even in the presence of AVFs [12, 18]. Given the potential role of both MMA flow and dural AVFs in sustaining cSDH, systematic evaluation for AVFs during EMMA is warranted. When AVFs are identified, liquid embolic agents may be preferable, as they allow effective fistula occlusion without venous migration.

This single-center study is limited by sample size and potential selection bias, as three patients did not undergo embolization. Nevertheless, this

study represents the first prospective assessment of non-iatrogenic AVF prevalence in cSDH patients undergoing EMMA.

5. Conclusion

Non-iatrogenic AVFs were observed in approximately one-third of patients with cSDH undergoing EMMA. Prior surgical drainage was associated with a lower incidence of AVFs. Larger, multicenter studies are needed to validate these findings and further elucidate the role of AVFs in cSDH pathophysiology and recurrence.

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Author Contributions

JS- conceptualized the study, monitored the study conduct, analyzed the data and finalized the manuscript.

Conflicts of Interest

JS is PI for EMMA Can study funded by Medtronic Canada.

Disclaimer

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