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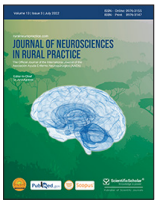

Case Series

Safety and radiologic clearance of chronic subdural hematoma after endovascular embolization using SQUID 18 in patients older than 80 years

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ABSTRACT

The aim of the study was to evaluate radiographic clearance and clinical outcomes in patients over age 80 who undergo SQUID 18 embolization of the middle meningeal artery (MMA) for the management of chronic subdural hematoma (cSDH). From April 2020 to October 2021, data were obtained from patients with cSDH who underwent MMA embolization at our institution. Clinical and radiological data including pre-operative and last follow-up CT scans were analyzed. Six embolization procedures were performed in five patients using SQUID 18, a liquid embolic agent. The median age was 83 years, and three subjects were female. Two of the six cases were recurrent hematomas. MMA embolization was achieved in 100% of cases. The median diameter of the hematoma at admission was 20 mm and at last follow-up was 5.3 mm, demonstrating statistically significant radiographic clearance ($P = 0.043$). There were no intra or post-operative complications. Mortality was not noted during observation period. SQUID MMA embolization safely and significantly reduced the hematoma diameter and offers an alternative treatment in patients older than 80 years with cSDH.

Keywords: Chronic subdural hematoma, Embolization, Middle meningeal artery

INTRODUCTION

Middle meningeal artery (MMA) embolization is an emerging endovascular treatment for the management of chronic subdural hematoma (cSDH). Preliminary data suggest that this minimally invasive therapy may be more effective and safer than conventional therapies.[1-3] Surgical management options include twist drill, burr hole, endoscopic burr hole, craniotomy, or mini-craniotomy, with or without the use of subdural drainage.[4] Conservative (medical) management is also a consideration in certain population and may involve the use of corticosteroids, atorvastatin, and tomographic monitoring.[5] For those who fail non-operative therapy, no consensus for open versus endovascular treatment has been established and additional prospective investigation is warranted to define indications, characterize expected outcomes, and establish long-term treatment durability.[6-8]

While the procedure is frequently performed in the elderly, we present a case series specifically focused on those at highest risk for cSDH recurrence: Patients over the age of 80.[9] Further, there are no reports in the literature reporting on outcomes from MMA embolization using SQUID 18 (Balt, Montmorency, France), a novel embolic agent, in this setting. Given the availability, operator preference, and costs associated with liquid embolic agents, it is critical to share experiences in these different contexts. Meanwhile the SQUID Trial for MMA Embolization for the Treatment of cSDH (STEM) is underway to investigate safety and efficacy of SQUID for the management of cSDH, we offer clinical and radiographic outcomes in a cohort of patients over the age of 80 in this setting.

CASE DETAILS

After human subjects approval was obtained, data were collected from five consecutive elderly patients greater than age 80 who were diagnosed with cSDH who underwent MMA embolization from April 2020 to October 2021 at the Department of Neurosurgery at a major Peruvian academic medical center. Informed consent was obtained from the patients and their relatives before initial treatment. Clinical and radiological variables were analyzed. The diagnosis of cSDH was made by certified neuroradiologists and measured by the

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Received: 01 October 2022 **Accepted:** 15 January 2023 **EPub Ahead of Print:** 23 February 2023 **Published:** 03 May 2023 **DOI**: 10.25259/JNRP_30_2022

presence of a crescent-shaped hypodense subdural collection in an axial section of a non-contrast head CT scan. The decision to treat the patients by endovascular means was based on advanced age and comorbidities. Clinical variables analyzed were age, sex, previous use of antithrombotic drugs, presence of motor deficit, Glasgow Coma Scale (GCS), and the Markwalder Scale. Radiological variables analyzed were the presence of unilateral or bilateral cSDH, the diameter of the hematoma, the type of hematoma according to the Nakaguchi classification and the tomographic controls at 1-month, between the 4th and 6th month, and at 12-month in one of the cases within the study period. The technical details of the embolization included the operative time, the embolic agent used, the type of microcatheter and microwire, perioperative complications, and length of hospital stay. The main outcome of the study was to determine a significant decrease in the diameter of the hematoma at follow-up. The summary of our cases is shown in [Table 1].

Numerical variables were expressed in medians and ranges, whereas categorical variables in percentages. To compare paired variables, the Wilcoxon test was used and $P < 0.05$ was considered statistically significant. Statistical software Stata v.14 was used for analysis.

Five patients were treated with six MMA embolizations. The median age was 83 years (range 82–93 years), and 3 patients (60%) were women. In four cases, a history of head trauma was confirmed before the diagnosis of cSDH. Three patients were under antithrombotic drugs. The median GCS admission was 14 points (range 13–15 points). Two patients presented with mild-to-moderate motor deficit on admission. Four cases presented unilateral cSDH and one case was a bilateral cSDH. Markwalder classification Grade 2 was the most common (three cases). Two cases were recurrent hematomas which underwent previous surgical treatment (one case recurred within the 1 month, and the other case 4 months following surgical evacuation). There were no cases of post-embolization recurrence. The obliteration of the anterior and posterior branches of the MMA was confirmed in all five cases [Figures 1 and 2].

Regarding the technical details of embolization, vascular access was through the femoral artery, supported by a 6-French guide catheter. A Sonic 1.5-French detachable tip

Table 1: Summary of clinical and radiological data of patients who underwent middle meningeal artery embolization.

Case	1	2	3	4	5
Clinical information					
Age/Sex	83/M	82/F	82/F	93/M	90/M
Antithrombotic	No	Yes	No	Yes	No
Hypertension	No	Yes	No	Yes	Yes
Diabetes	No	Yes	No	No	No
Kidney disease	No	No	No	No	Yes
DVT	Yes	No	No	No	No
Dementia	No	No	Yes	No	No
Cranial trauma	Yes	Yes	Yes	Yes	No
Prior stroke	Yes	No	No	Yes	No
GCS at admission	14	15	13	14	13
Motor deficit	Right 4-/5	No	No	Right 4-/5	Left 2/5
Aphasia	No	No	Yes	No	Yes
Initial imaging information					
Side of hematoma	Left	Bilateral	Left	Left	Right
Markwalder grade	Grade 2	Grade 1	Grade 2	Grade 2	Grade 3
Nakaguchi rating	Homogeneous	Separated	Separated	Trabecular	Homogeneous
Diameter (mm)	24	L: 18 R: 12	20	15.7	30
Outcomes					
Peri-operative complications	N/A	N/A	N/A	N/A	N/A
Post-embolization complications	N/A	N/A	N/A	N/A	N/A
GCS at discharge	14	15	13	15	14
GCS at 6-months	15	15	14	15	15
cSDH diameter at 1 month (mm)	6	L: 11.5 R: 9	15	13.7	0
cSDH diameter at 4–12 months (mm)	0	L: 2.7 R: 2	6	8.1	4.3

M: Male, F: Female, GCS: Glasgow Coma Scale, DVT: Deep vein thrombosis, cSDH: Chronic subdural hematoma

delivery microcatheter (Balt, Montmorency, France) was used, over various 0.07–0.10 microwires. The embolic agent SQUID 18 was used in all cases. The median diameter of the hematoma at admission was 20 mm (range 15.7–30 mm), while at the last tomographic follow-up (4–6 months) was 5.3 mm (range 2.3–8.1 mm). When comparing both diameters, a statistically significant decrease in the diameter of the hematoma was observed (P = 0.043). Due to delayed follow-up in one subject, CT scan was obtained 12-months post-procedure, and no recurrence was observed. Distal penetration of the embolic agent into the anterior and posterior branches of the MMA is another predictor of hematoma reduction, which was achieved in our series. An illustrative case with follow-up is shown [Figure 3]. A summary of embolic agents used for MMA embolization is shown in [Table 2].

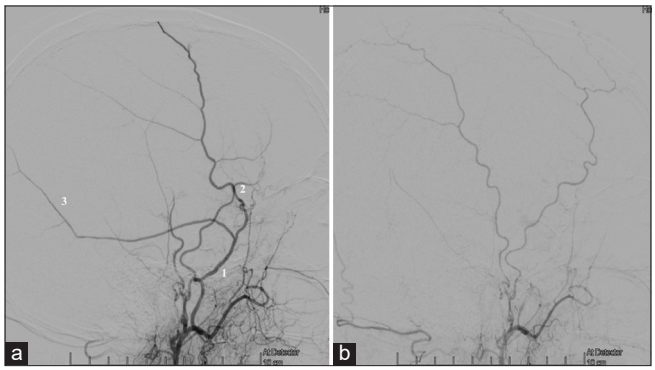

Figure 1: Selective angiography of the right middle meningeal artery (MMA) of illustrative Case 2 (a) pre-embolization angiography shows (1) MMA trunk (2) frontoparietal branch of MMA and (3) parietal branch (b) post-embolization angiography with complete occlusion of frontoparietal and temporal branches.

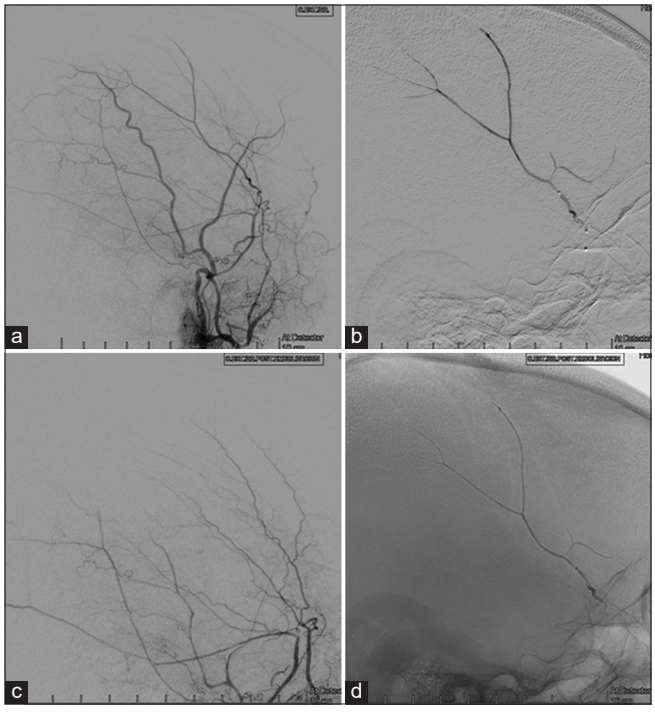

Figure 2: Lateral angiography of the left external carotid artery (ECA) during endovascular intervention in Case 1. (a) Selective angiography of the right middle meningeal artery (MMA) pre-embolization. Atrophic parietal branch is evidenced post first surgery. (b) Superselective embolization of MMA frontal branch. (c) post-embolization. (d) left ECA fluoroscopy.

There were no perioperative complications in our cohort. Transient and/or persistent neurological complications were not observed. The median GCS at hospital discharge was 14 points (range 14–15 points) and the median hospital stay was

Table 2: Embolic agents used for middle meningeal artery embolization in cases of chronic subdural hematomas.

Embolic agent	Main characteristics
NBCA (B. Braun)	Flushing with D5% previous to injection. Occlusion by polymerization. Combined with iodized oil (Lipiodol) for better visualization and reduce speed of polymerization. Depending on the dilution, a better penetration to distal vessels can be achieved. Commonly used with Magic microcatheter.
Polyvinyl alcohol particles	Several sizes, calibers and morphologies. Not opaque by itself, need to be mixed with contrast. Reflux into eloquent branches is difficult to determine. Resorb during time and do not provide a durable and permanent occlusion. Smaller particles result in distal penetration of distal vessels.
Onyx (Medtronic)	EVOH copolymer Previous shaking before use. Tantalum for radiopacity. Occlusion of vessels by precipitation. Flush microcatheter with DMSO. Used with detachable-tip microcatheters (Sonic, Apollo) and non-detachable (Headway Duo, Marathon, Echelon).
Squid (Balt)	EVOH copolymer Previous shaking before use. Tantalum for radiopacity. Occlusion of vessels by precipitation. Flush microcatheter with DMSO. Used with detachable-tip microcatheters (Sonic, Apollo) and non-detachable (Headway Duo, Marathon, Echelon). An extra-low viscosity presentation is available (Squid 12) for better penetration into distal vessels.

NBCA: N-butyl-cyanoacrylate, EVOH: Ethylene-vinyl alcohol, DMSO: Dymethil sulfoxide

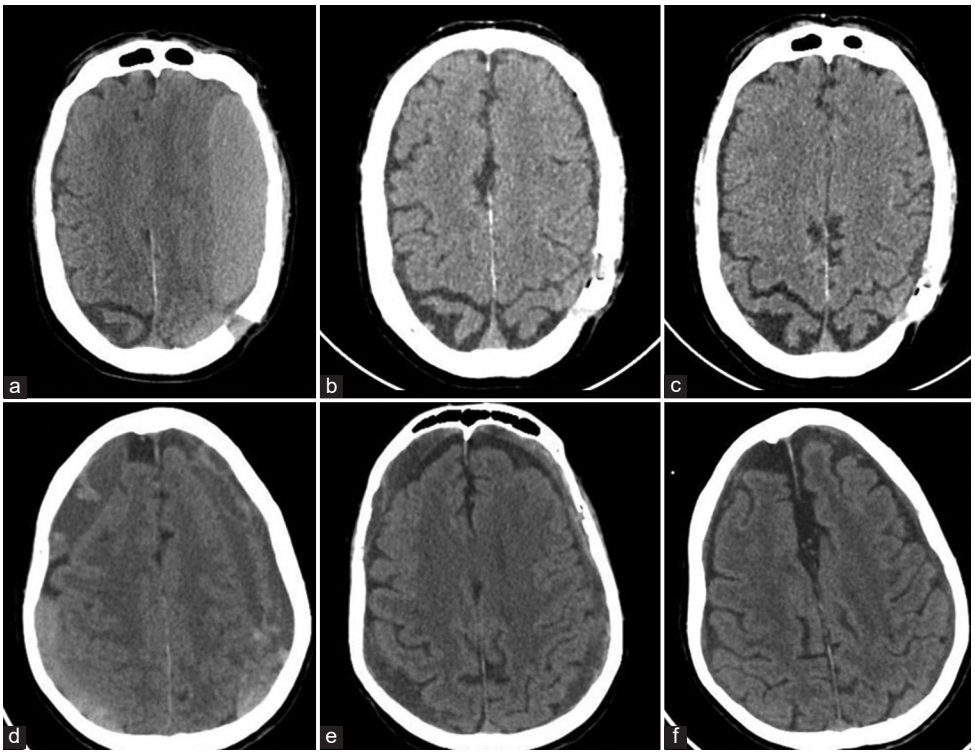

Figure 3: Illustrative Case 1, top panel: (a) Brain computed tomography (CT) scan after 1 month of surgical drainage of Chronic subdural hematoma through a bur hole. (b and c) Follow-up CT scans 6- and 12-month post-embolization; Illustrative Case 2, bottom panel: (d) Head CT scan before middle meningeal artery embolization. (e and f) Follow-up head CT scans 1- and 4-months following embolization.

3 days (range 2–10 days). One of the patients was treated for a urinary tract infection, which prolonged hospitalization. Mortality was not reported.

DISCUSSION

MMA embolization is a novel and less invasive alternative to the classic surgical treatment of cSDH. Favorable clinical and radiological outcomes demonstrate the safety and efficacy of this technique when used appropriately. In our study, we found a statistically significant reduction in the diameter of cSDH at last radiological follow-up in a group of patients older than 80 years with risk factors that would otherwise increase the likelihood of recurrence, morbidity, and mortality. The previous reports have documented safety, as well as reduction of the hematoma diameter at 180-day follow-up.[1,8,10,11] Advanced age of our cohort, at higher risk of recurrence, and use of a novel liquid embolic agent warranted closer follow-up. The absence of morbidity and mortality associated with this procedure further supports safety and feasibility in this cohort. To the best of our knowledge, this small series represents the first report of successful use of SQUID 18 in the endovascular treatment of cSDH in patients over age 80.

One of the main features of our cases was the median age of the patients (83 years), which is higher compared to the previous larger cohorts.[2,10,12] The majority of our patients were under different type of drugs, especially antithrombotic medication. Therefore, given the higher morbidity and mortality risks in this population, MMA embolization was offered to not discontinue their medication, avoid longer hospital stay, and perform a minimally invasive procedure without skin incisions and subdural drainage. Ban *et al.* reported[13] that a significant percentage of complications in the surgical group were due to ischemic events secondary to the reversal or interruption of antithrombotic medications, and hemorrhagic events secondary to thrombocytopenia or inappropriate reversal of antithrombotic medications. In another study, 132 patients with cSDH and antithrombotic drug users were included in the study, finding a lower tendency to surgical reintervention in the group of patients with antithrombotic treatment and MMA embolization compared to the antithrombotic treatment group and evacuation surgery.[14]

Three cases were chronic users of antithrombotic drugs, which had been discontinued due to intracranial hemorrhage. Complications such as thromboembolism did not occur,

and patients resumed within 2 weeks after embolization. In addition, patients on antithrombotic drugs did not present with post-embolization recurrence or the need for emergent re-treatment. More consistent prospective studies are needed to assess risk of thromboembolic complication and timing of restart of antithrombotics.[15] Early resumption (0–30 days) versus late resumption (>30 days) has been shown to confer benefit by reducing frequency of thromboembolic vascular event.[16]

Different embolic agents have been used for the treatment of cSDH: n-butyl cyanoacrylate, polyvinyl alcohol particles, and ethylene vinyl alcohol copolymer (Onyx; Medtronic, Minnesota, USA) are the most widely used with this purpose.[1] The use of Onyx is increasing in the most recent publications due to better penetration, without collateral vessel formation and lower reabsorption and recurrence rates.[2,17] We used SQUID 18 in all cases, without technical difficulty during injection and with adequate distal penetration. Specific clinical differences between the type and/or density of embolic agent used for MMA in not known.[2,10] Petrov *et al*. published a recent case series of cSDH treated with MMA embolization, in a younger cohort (median age 66), using SQUID 12/18 and reported good clinical and radiological results, with total reabsorption of the hematoma at 90-day follow-up.[12]

The study has limitations: The small number of patients and the observational nature of our design limits more robust statistical associations. Because MMA embolizations were done in a specialized endovascular center, an inherent selection bias is present in the study. No comparisons between MMA embolization and other surgical techniques were established prospectively. Therefore, our findings should be interpreted with caution.

CONCLUSION

MMA embolization is a novel and effective technique to treat cSDH in elderly patients, as noted by sustained radiographic clearance of hematoma. Further studies comparing different embolic agents in patients over age 80 may offer more options for those in resource-constrained settings.

Declaration of patient consent

The authors certify that they have obtained appropriate patient consent.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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How to cite this article: Saal-Zapata G, Murga-Villanueva A, Walker M, Ghodke B, Rodríguez-Varela R. Safety and radiologic clearance of chronic subdural hematoma after endovascular embolization using SQUID 18 in patients older than 80 years. J Neurosci Rural Pract 2023;14:336-41.