Stand-Alone Middle Meningeal Artery Embolization for Treatment of Giant Chronic Subdural Hematoma in Elderly Frail Patients: A Case Series

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BACKGROUND: Previous case series have demonstrated safety and efficacy of middle meningeal artery (MMA) embolization as both adjuvant and stand-alone treatment of chronic subdural hematoma (cSDH). The safety and efficacy of stand-alone MMA embolization for treatment of giant (>150 ml) cSDH in specifically elderly, frail patients is not well studied.

OBJECTIVE: To evaluate the safety and efficacy of stand-alone MMA embolization for treatment of giant cSDH in elderly, frail patients in whom traditional surgical intervention was deemed high risk.

METHODS: We reviewed the records of consecutive patients referred for MMA embolization and identified patients ≥75 yr with modified Frailty Index (mFI) ≥ 2 who underwent stand-alone MMA embolization for cSDH treatment with at least one follow-up imaging study.

RESULTS: A total of 42 patients were referred for MMA embolization with 5 patients meeting inclusion age and frailty criteria. The average age was 82.2 ± 6.8 yr. The median mFI was 3.0 (interquartile range (IQR) 2-4). Four patients were either on aspirin or thrombocytopenic. The average initial cSDH volume was 187.8 ± 31 ml with average initial midline shift of 8.0 ± 2.1 mm. The average length of stay was 4 ± 1.1 d. The average cSDH volume decrease on follow-up imaging was 68.5% ± 11.9%. Follow-up average midline shift decreased by 70% to 2.4 ± 1.4 mm. There were no peri-procedural or in-hospital complications.

CONCLUSION: In frail, elderly patients with giant cSDH, stand-alone MMA embolization was effective in reducing cSDH volume and improving presenting symptoms without complications.

KEYWORDS: Middle meningeal artery embolization, Chronic subdural hematoma, Frailty

Chronic subdural hematoma (cSDH) is a common neurosurgical condition of the elderly and is forecasted to be the most common cranial neurosurgical condition by 2030 as the population ages. Not a benign, isolated diagnosis, cSDH is a potentially recurrent disease process associated with increased mortality even after successful surgical evacuation. In elderly patients above age 75, good outcomes for cSDH are less likely. Frailty, as measured by multiple indices, has been associated with increased complications and mortality following many types of surgical intervention and has been specifically associated with poor outcome following treatment of cSDH.

Recent case series have demonstrated the preliminary safety and efficacy of embolization of the middle meningeal artery (eMMA) as both a stand-alone and adjuvant treatment of cSDH. Importantly, a large proportion of eMMA cases initially reported in the literature were performed as adjuvant therapy in addition to...
surgical management, with only recent case reports and case series demonstrating efficacy of stand-alone eMMA in the treatment of cSDH.8,9 The series presented by Link et al8,9 of stand-alone eMMA in 50 cSDH cases led to a > 50% reduction in 31 (68.9%) patients with cSDH recurrence in 4 (8.9%) patients. Compared with traditional surgical management, eMMA is a minimally invasive treatment option and can be performed without general anesthesia. The safety and efficacy of stand-alone eMMA, especially in elderly, frail patients, has not been well-studied. We reviewed the clinical and radiographic outcomes of elderly (age > 75 yr) patients with modified frailty index (mFI) ≥ 2 who underwent stand-alone eMMA for treatment of giant (>150 ml) cSDH to better understand the safety and efficacy of stand-alone eMMA for giant cSDH in this vulnerable population.

METHODS

This retrospective study was conducted with Institutional Review Board approval for reviewing management and treatment of subdural hematoma including middle meningeal artery embolization. (HP-00 087486). This study was a retrospective, consecutive, single-center case series. We reviewed the records of all consecutive patients referred for eMMA treatment of cSDH during the period of January 2019 to March 2020 and identified patients ≥ 75 yr, with mFI ≥ 2, and who underwent follow-up imaging ≥ 3 wk post-procedurally, and excluded patients who underwent any adjuvant surgical treatment (Figure 1). Patient information including demographics, clinical history, and imaging data was collected. For medical management, any preadmission antiplatelet or anticoagulant medications were held and there was no addition of statins or steroids for management of cSDH. The patients’ presenting symptoms and neurological exams were evaluated and a Markwalder score was assigned according to the previously described scale.10 The pre- and postprocedural volume of the cSDHs was calculated using the previously validated ABC/2 formula.11 The 5-factor mFI was calculated for all patients as described previously.12 Complication was defined as any adverse event related to the procedure, including new neurologic deficit, or evidence of new ischemic or hemorrhagic findings on post-procedure imaging studies. For retrospective data collection, informed consent was waived due to the minimal risk to patients involved.

All patients underwent procedures according to standard institutional protocols. Patient selection for eMMA was based on findings of noncontrast computed tomography (CT) scan, patient clinical status, and treatment consensus among the neuro-interventionalist and referring neurosurgeon. Stand-alone eMMA was performed for symptomatic cSDH with significant but not life-threatening mass effect. Consent was obtained from the patient or their legally authorized representative prior to the procedure. Procedures were performed in a biplane neuroangiography suite (Artis Zee; Siemens, Munich, Germany) by 1 of 4 attending neurointerventional surgeons. Procedures were completed under moderate/conscious sedation (comprised of intravenous fentanyl and/or midazolam). Embolization was performed with either polyvinyl alcohol (PVA) microparticles, Embosphere

![Figure 1: Patient flow chart demonstrating criteria for patient inclusion in case series.](https://academic.oup.com/neurosurgeryopen/article/2/1/okaa025/6118489)
### TABLE. Summary of Demographics, Clinical, and Radiographic Data for Patients Undergoing Stand-Alone eMMA

| Age/Sex | 90/M | 76/M | 77/M | 77/M | 91/M |
|---------|------|------|------|------|------|
| Markwalder grade | 2 | 1 | 1 | 1 | 1 |
| Blood Thinners/Coagulopathy | ASA 81mg | ASA 81mg | ASA 81mg | ASA 81mg | none |
| Statin on admission? | Yes | No | Yes | Yes | No |
| Co-morbidities | CAD, Colon Cancer, CVA, HTN | CAD, Dilated Cardiomyopathy, MI, ESRD, Liver failure | DM, HTN, former smoker | DM, HTN, HLD, AFIB, CVA, MI, CAD | DM, HTN, CHF, COPD, CAD, HLD, Alzheimer’s |
| mFI | 2 | 3 | 2 | 3 | 5 |
| Length of stay (d) | 2 | 4 | 4 | 5 | 5 |
| Discharge disposition | Home | SAR | TBI Rehab | VA hospital | SAR |
| Follow up CT timing (days) | 88 | 23 | 41 | 90 | 138 |
| Initial midline shift (mm) | 6 | 11 | 7 | 6 | 10 |
| Follow up midline shift (mm) | 1 | 5 | 2 | 2 | 2 |
| Initial cSDH volume (ml) | 152 | 238 | 209 | 177 | 163 |
| Follow up cSDH volume (ml) | 57 | 116 | 39 | 31 | 57 |
| cSDH volume decrease | 62.5% | 51.2% | 81.3% | 82.4% | 65% |

Microparticles (Merit Medical), Gelfoam pledgets, or a combination of the above according to preference of performing neuro-interventional surgeons. Femoral access was utilized for all procedures. The patients followed up in outpatient clinic with a head CT and clinical exam with the exception of a single patient who passed away before follow-up.

### RESULTS

A total of 42 patients were treated with eMMA in the period reviewed. There were 15 patients treated who were above age 75. Ten patients over age 75 were treated with stand-alone eMMA. There were 5 patients with cSDH volume > 150 ml and mFI ≥ 2 with average mFI of 3.0 (IQR 2-4). The patients had an average presenting cSDH volume of 187.8 ml ± 31 ml causing an average midline shift of 8.0 ± 2.1 mm. All patients had follow-up CT scans ≥ 3 wk postprocedurally with an average follow-up CT timing of 76 ± 40.5 days postprocedurally. Each patient in this series experienced a 50% reduction in cSDH volume with an average reduction in cSDH volume of 68.5% (127.8 ml). There were no complications. The average hospital stay was 4 ± 1.1 d. A summary of the included patients’ demographics, presenting clinical status, radiological findings, and outcomes is shown in Table.

**Case 1**

A 90-yr-old male with a mFI of 2 presented to an outside hospital with worsening gait, word-finding difficulties, and progressive right-sided weakness. A head CT demonstrated a giant left cSDH with membranes (Figure 2A). The referring neurosurgery service initially offered craniotomy with membranectomy to the patient and his family, but, due to the risk involved, they chose to pursue conservative management. The patient represented to our emergency department with worsening weakness one month later. The patient's family elected for stand-alone eMMA at this time. eMMA was performed via femoral approach under conscious sedation using Embospheres (300-500 um) and a Gelfoam pledget. The patient was discharged to home the morning after the procedure. A 3-mo follow-up head CT demonstrated a 62.5% reduction in cSDH volume with significantly decreased mass effect on the left motor cortex (Figure 2B). The patient's right-sided weakness began to improve in the week following the procedure. Eventually, the patient returned to full strength with marked improvement in speech and cognition.

**Case 2**

A 76-yr-old male with an extensive past medical history and a mFI of 3 (see Table) presented to the trauma unit after a fall with speech perseveration and 1 wk of worsening mental
status. A head CT demonstrated a giant left membranous cSDH with 11 mm of midline shift (Figure 3A). Due to the patient’s low cardiac ejection fraction (15%) and chronic thrombocytopenia (platelet count 59k), surgical intervention was deemed high risk. eMMA was offered and subsequently performed via femoral approach under conscious sedation with multiple Gelfoam pledgets only to avoid risk of microparticle reflux as the patient was intermittently noncooperative during the procedure. The patient’s mental status improved the following day, and he was discharged on post-procedure day 4 to a sub-acute rehabilitation facility. A total of 2 wk later, while at rehab, the patient became profoundly hypoglycemic and was admitted to an outside hospital. A head CT performed at that time, 23 d after eMMA, showed a 51.2% decrease in cSDH volume with resolution of membranes and decreased mass effect with midline shift improved to 5mm (Figure 3B). Unfortunately, due to patient’s worsening overall medical condition, the patient’s family elected for hospice care and he subsequently passed away.

Case 3
A 77-yr-old male with a mFI of 2 on aspirin presented with unsteady gait, confusion, and mild aphasia. A brain magnetic resonance imaging (MRI) demonstrated a giant left cSDH with membranes (Figure 4A). The patient and his wife elected for stand-alone eMMA. The left middle meningeal artery (MMA) was embolized with PVA microparticles (150-250 um) and a Gelfoam pledget via femoral approach under conscious sedation. The patient was discharged to a rehabilitation facility on post-procedure day 4. A 6-wk follow-up head CT showed an 81.3% reduction in the cSDH volume with decreased mass effect on the cerebral cortex (Figure 4B). The patient’s speech and gait returned to normal.
**Case 4**

A 77-yr-old male with a mFI of 3 on aspirin presented after a fall with unsteady gait and mild headache. A head CT demonstrated a giant left cSDH (Figure 5A). The patient elected for stand-alone eMMA. The left MMA was embolized with Embospheres (300-500 um) and a Gelfoam pledget via femoral approach under conscious sedation. The patient was discharged on postprocedure day 4. A 3-mo head CT demonstrated an 82.4% reduction in cSDH volume with resolution of presenting symptoms (Figure 5B).

**Case 5**

A 91-yr-old male with a mFI of 5 and Alzheimer’s dementia presented with worsening aphasia and confusion according to his caretaker. A head CT demonstrated a giant left cSDH (Figure 6A). Due to the patient’s advanced age and medical co-morbidities, surgical intervention was deemed to carry high risk of complication. The patient’s wife elected for stand-alone eMMA. The left MMA was embolized with Embospheres (300-500 um) and a Gelfoam pledget via femoral approach under conscious sedation. The patient was discharged to a sub-acute rehabilitation facility on postprocedure day 4. A 4.5-mo follow-up head CT demonstrated a 65% reduction in cSDH volume (Figure 6B). The patient’s caretaker reported improvement in mental status to patient’s prior baseline following eMMA.

**DISCUSSION**

The incidence and prevalence of cSDH will continue to increase over the next decade with increasingly older and high-frailty patients presenting with this formidable disease.1 Our series supports the safety and efficacy of stand-alone eMMA for treatment of giant membranous cSDH in the elderly, frail population with relative surgical contraindications including use of anti-platelet agents. The above factors have been associated with increased morbidity and mortality following surgical intervention for cSDH.6,13
The patients in this series had cSDH that were > 150 ml, which we classified as “giant” and caused ≥ 5 mm of midline shift. While mass effect and midline shift are concerning markers and should generally be treated quickly, in our series, all patients had a reduction in midline shift (70% average improvement from presenting midline shift) with an average follow-up midline shift of 2.4 ± 1.4 mm. Traditionally, cSDH causing mass effect and significant midline shift have been managed with relatively urgent surgical intervention. Given the chronicity of cSDH mass effect, it may be warranted to first attempt less invasive management prior to surgical intervention, especially in the elderly, frail population. Associated with the reduction in cSDH volume and midline shift was an improvement in patients’ mental status and presenting symptoms postprocedurally with some patients improving within one week of treatment. Although all patients had a sizeable reduction in the cSDH volume, complete resolution of the cSDH was not seen in any case. The absence of complete resolution can potentially be attributed to a lack of brain re-expansion due to chronic mass effect in the setting of significant cortical atrophy.

Supporting the efficacy of cMMA, it was noted that, in all cases, membranes appeared to resolve on a follow-up CT. While this may offer hope for a lasting treatment effect, ultimately extended follow-up of these patients is necessary.

Our series represents a subset of patients in whom treatment alternatives are limited. Surgical intervention was relatively contraindicated in all cases. Relative contraindications to surgical intervention included patient frailty, use of antiplatelet agents or thrombocytopenia, as well as the appearance of the cSDH. Three patients were on daily aspirin, which was held prior to our embolization and for 2 wk after embolization. No adverse events occurred related to holding aspirin. All patients had a trabecular appearance of the cSDH, with evidence of hyperdense areas within the collection consistent with developed membranes which is a relative contraindication for the less invasive surgical options including twist drill craniostomy or burr holes. The most invasive alternative of craniotomy with membranectomy, with increased risk including morbidity and complications rates of up to 20%, was also contraindicated.14,15
Experience with medical management of cSDH remains limited. Atorvastatin has been shown to reduce volume of cSDH after 8 wk compared to placebo in a randomized, controlled trial.\textsuperscript{16} However, the average initial cSDH volume in the trial was approximately 60 ml, a dramatically smaller average volume than the present series. No patient in our series would have qualified for statin use as a stand-alone medical treatment using the aforementioned trial’s inclusion criteria due to either age, prior statin use, or liver disease.

The evidence for use of steroids such as dexamethasone for management of cSDH has been inconclusive to date and consists primarily of low-level, retrospective single-center evidence.\textsuperscript{17} A recent small trial which examined dexamethasone in combination with atorvastatin for cSDH showed significant benefit compared to atorvastatin alone for cSDH volume reduction at 5 wk; however, the average cSDH volume in this study was approximately 60 ml.\textsuperscript{18} Again, no patient in the present series would have been eligible for inclusion according to their criteria. Additionally, the known significant medical adverse effects of high-dose steroids may serve as a relative contraindication in the frail, elderly population.

Despite advanced age and high-frailty, no patient in our series experienced peri-procedural or in-hospital complications. The use of embolic material type was heterogeneous in our series and included PVA, Embospheres, and Gelfoam pledgets, both alone or in combination. Importantly, as a protocol in all eMMA cases, the size and course of the lacrimal branch of the MMA was noted, and effort was made to minimize the risk of embolic material penetrating unseen ophthalmic collaterals. Thus, we generally favored larger particles and Gelfoam pledgets to minimize this risk. Although larger embolic materials may adversely impact efficacy by not penetrating the cSDH membrane distally, it remains a question how best to balance distal penetration of cSDH membrane against risk of off-target embolization. In our small series, all patients had a > 50\% reduction in cSDH volume, suggesting that complete distal penetration of membranes may
not be essential, but further investigation of proximal versus distal penetration is warranted in larger samples.

The ability to perform eMMA under conscious sedation provides distinct advantages over traditional and more invasive surgical strategies by nullifying risks of general anesthesia and the risk of postsurgical complications including seizure and surgical site infection. The present series supports that selected cases can be performed safely and effectively without general anesthesia. Following eMMA, patients generally do not require increased analgesics including opioids and can mobilize hours after the procedure. Early mobility and avoidance of opioids can decrease the likelihood of common hospital complications including delirium, ileus, deep venous thrombosis, and infection and increase the likelihood of shorter length of stays.

While preliminary series describing eMMA for treatment of cSDH have been promising with good reported safety and efficacy, most reported cases have employed eMMA as an adjuvant treatment to surgical intervention rather than a stand-alone therapy. This is the first series to describe the safety and efficacy of stand-alone eMMA in elderly, frail patients with giant (>150 ml) cSDH with midline shift ≥ 5 mm. Further prospective, controlled trials are warranted to examine the efficacy of stand-alone eMMA for treatment of cSDH in elderly, frail patients.

**Limitations**

This report includes selected cases from our institution meeting prespecified inclusion criteria. All data was collected prospectively but reviewed retrospectively. The patients represent a biased sample to the extent that they were not optimal candidates for
surgical intervention or medical management, therefore there was no possibility of a control group. The natural history for the cases above cannot be known, and although the authors felt this was unlikely, there is a possibility the cSDHs would have resolved spontaneously without any treatment.

**CONCLUSION**

Stand-alone eMMA for treatment of symptomatic, giant cSDH was safe and effective in a series of 5 elderly, high-frailty patients carrying high risk of surgical complications. Further prospective, controlled trials examining stand-alone eMMA are warranted to better establish eMMA as an efficacious, lower risk alternative to surgery for an increasingly older, and frail patient population.

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