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REVIEW ARTICLE

Middle meningeal artery (mma) embolization for recurrent hematoma after chronic subdural hematoma surgery: A short review

Kronik subdural hematom cerrahisi sonrasında tekrarlayan hematomda middle meningeal arter (mma) embolizasyonu: Kısa bir inceleme

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Abstract

Chronic subdural hematoma (CSDH) is a frequent neurosurgical disorder, particularly in elderly patients and those receiving antithrombotic therapy. Although burr-hole drainage remains the standard treatment, recurrence occurs in 10–15% of cases. Middle meningeal artery (MMA) embolization has recently emerged as a minimally invasive technique targeting the vascular pathophysiology underlying hematoma persistence and recurrence. This review summarizes the rationale, technique, embolic materials, and clinical outcomes associated with MMA embolization for recurrent CSDH, with reference to a representative clinical case from our institution. A 63-year-old female with recurrent CSDH following burr-hole drainage underwent MMA embolization using polyvinyl alcohol (PVA) particles. The literature on the pathophysiology and endovascular management of CSDH was reviewed to contextualize this case. CSDH formation is driven by fragile neocapillaries and inflammatory cascades within vascularized membranes supplied by the MMA. Embolization interrupts this pathological cycle by reducing neovascular perfusion and inflammatory activity. Recent studies report recurrence rates of 4–5% after MMA embolization substantially lower than those following surgery along with low complication rates and earlier resumption of antithrombotic therapy. In our case, complete radiological resolution was achieved without adverse events. MMA embolization represents a paradigm shift in CSDH management by directly addressing the vascular mechanisms responsible for recurrence. It offers a durable, safe, and minimally invasive alternative or adjunct to surgery, particularly valuable for elderly or high-risk patients. Further randomized controlled trials are warranted to confirm its efficacy as a first-line or adjunctive therapy.

Keywords: Chronic subdural hematoma, middle meningeal artery embolization, recurrence, polyvinyl alcohol particles, minimally invasive neurosurgery.

Özet

Kronik subdural hematom (KSDH), özellikle ileri yaş hastalarda ve antitrombotik tedavi kullanan bireylerde sık karşılaşılan bir nöroşirürji sorunudur. Burr-hole drenajı standart tedavi olmakla birlikte, olguların yaklaşık %10–15'inde nüks görülmektedir. Orta meningeal arter (OMA) embolizasyonu, hematomun devamlılığı ve tekrarlamasında rol oynayan damar kaynaklı patofizyolojiyi hedef alan, giderek daha fazla kabul gören minimal invaziv bir yöntemdir. Bu derleme, rekürren KSDH olgularında OMA embolizasyonunun gerekçesini, uygulama basamaklarını, kullanılan embolik ajanları ve bildirilen klinik sonuçları özetlemeyi; ayrıca kurumumuzdan bir örnek olgu ile yöntemi klinik açıdan somutlaştırmayı amaçlamaktadır. Burr-hole drenajı sonrası tekrarlayan KSDH nedeniyle PVA partikülleri kullanılarak OMA embolizasyonu uygulanan 63 yaşındaki kadın hasta sunuldu. Olgu, KSDH'nin patofizyolojisi ve endovasküler tedavisine ilişkin mevcut literatür doğrultusunda değerlendirildi. KSDH'nin devamlılığı; OMA tarafından beslenen dış membranda gelişen kırılgan neokapiller ağ ve buna eşlik eden inflamatuvar süreçlerle sürdürülmektedir. Embolizasyon, bu neovaskülarizasyonu devre dışı bırakarak hematomun kronikleşme döngüsünü keser. Güncel çalışmalar, OMA embolizasyonu sonrasında nüks oranlarının %4–5'e kadar düştüğünü ve cerrahi tedaviye kıyasla anlamlı avantaj sağladığını göstermektedir. İşlem genellikle düşük komplikasyon oranlarıyla uygulanabilmekte ve antitrombotik tedavinin daha erken yeniden başlanmasına olanak tanımaktadır. Sunulan olguda işlem sonrası herhangi bir istenmeyen olay izlenmemiş ve tam radyolojik düzelme elde edilmiştir. OMA embolizasyonu, KSDH'nin tekrarlamasından sorumlu damar temelli mekanizmaları hedeflemesiyle tedavi yaklaşımında önemli bir yenilik sunmaktadır. Özellikle yaşlı, komorbiditesi yüksek veya cerrahi açıdan riskli hastalarda cerrahiye alternatif ya da tamamlayıcı etkili ve güvenli bir seçenektir. Yöntemin birinci basamak tedavi olarak kullanımını desteklemek için daha fazla randomize kontrollü çalışmaya gereksinim vardır.

Anahtar Kelimeler: Kronik subdural hematom, orta meningeal arter embolizasyonu, rekürrens, PVA partikülleri, minimal invaziv nöroşirürji.

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INTRODUCTION

Chronic subdural hematoma (CSDH) is a common neurosurgical condition, particularly in elderly patients, and its incidence increases with age and the use of anticoagulant or antiaggregant medications (1,2). Although surgical evacuation is the standard treatment, recurrence after burr-hole drainage remains a significant challenge, occurring in approximately 10–15% of cases (3). Recently, middle meningeal artery (MMA) embolization has emerged as a minimally invasive alternative or adjunctive therapy that targets the underlying pathophysiology of CSDH formation and recurrence (4,5).

A 63-year-old female patient in our clinic with recurrent CSDH following burr-hole drainage achieved complete hematoma resolution after MMA embolization using polyvinyl alcohol (PVA) particles. Before embolization, the patient presented with mild left-sided weakness and persistent headaches, and CT imaging demonstrated a right sided, mixed-density hematoma with membrane formation; follow-up CT scans at three months confirmed complete radiological resolution with full neurological recovery. This clinical observation reflects growing evidence that MMA embolization can be an effective treatment option for recurrence, especially in patients on antiaggregant therapy or those who refuse reoperation.

Pathophysiology of Chronic Subdural Hematoma

The development of CSDH involves repeated microhemorrhages and inflammatory cascades in the subdural space. Blood accumulation triggers local inflammation and angiogenesis, leading to the formation of vascularized outer and inner membranes that perpetuate hematoma expansion (6). The outer membrane is particularly rich in fragile neocapillaries derived primarily from branches of the MMA. These vessels, lacking proper autoregulation, are prone to leakage, thereby sustaining a cycle of bleeding and resorption imbalance (6,7).

Histopathological studies demonstrate that pro-inflammatory cytokines and angiogenic factors such as vascular endothelial growth factor (VEGF) are upregulated in the hematoma membranes. This insight has shifted the understanding of CSDH from a purely mechanical lesion to a dynamic, inflammatory condition suggesting that therapies targeting its vascular supply may reduce recurrence (6,7).

Rationale for Middle Meningeal Artery (MMA) Embolization

The MMA provides the main arterial supply to the outer membrane of a chronic subdural hematoma. Embolizing this artery aims to reduce perfusion to the fragile neovessels within the membrane, thereby suppressing inflammatory and angiogenic activity that promotes hematoma persistence and recurrence (4,5,7). Compared with surgery, which directly evacuates the hematoma but does not address its source, MMA embolization interrupts the pathological blood supply at its origin. Several studies have demonstrated its efficacy not only as a rescue therapy for recurrent cases but also as a preventive adjunct to initial surgery (5,7,8). Moshayedi and Liebeskind highlighted that understanding CSDH pathophysiology has paved the way for trials incorporating MMA embolization as both a primary and adjuvant treatment (7).

Techniques and Embolic Materials

MMA embolization is typically performed under fluoroscopic guidance via transfemoral or transradial access. A microcatheter is navigated into the MMA branch of the external carotid artery, followed by selective embolization (4). The goal is to achieve occlusion of the distal MMA branches feeding the hematoma membranes while preserving adjacent meningeal and orbital circulation.

Various embolic agents have been utilized. Solid materials include polyvinyl alcohol (PVA) particles (250–500 μm), Embosphere® microspheres (tris-acryl gelatin), and coils, whereas liquid agents such as N-butyl cyanoacrylate (NBCA) and ethylene vinyl alcohol copolymer (EVOH) provide deeper and more permanent penetration (4,5). Selection of embolic material depends on operator experience, vessel anatomy, and the degree of collateral circulation. In our case, 355–500 μm PVA particles were selected because larger particles are effective in achieving distal MMA branch occlusion while minimizing the risk of unintended penetration into anastomotic channels. Using this approach, complete

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radiographic resolution of the hematoma was achieved on follow-up imaging.

Clinical Outcomes and Recurrence Rates

The reported incidence of CSDH varies widely: 3.8 per 100,000 in individuals under 65 years and 8–54 per 100,000 in those over 65 years (3). Traditional surgical evacuation remains the standard of care; however, recurrence rates range from 8% to 20%, depending on hematoma characteristics, postoperative pneumocephalus, and continuation of anticoagulant or antiaggregant therapy (1–3).

MMA embolization offers significantly lower recurrence rates. Schmolling et al. reported recurrence in only 4.3% of patients treated with MMA embolization compared with 11% after surgery. In a U.S. national database study of 191 patients, Nia et al. demonstrated that MMA embolization was both safe and effective, with a low complication rate and shorter hospital stays (5,8). Moreover, embolization may allow for earlier resumption of antithrombotic medications, which is a major advantage for patients at cardiovascular risk.

Recent literature supports the use of MMA embolization not only for recurrent cases but also as a first-line or adjunctive therapy to prevent recurrence after burr-hole drainage (4,5). Mühl-Benninghaus emphasized that the minimally invasive nature of this approach makes it particularly suitable for elderly or medically fragile patients for whom surgical intervention carries high risk (4).

DISCUSSION

Chronic subdural hematoma remains a clinically significant condition in older adults, and its management continues to evolve as the underlying pathophysiology becomes better understood. Traditional burr-hole drainage effectively removes the accumulated hematoma but does not directly address the inflammatory and angiogenic processes that sustain recurrence (1–3). As described in previous studies, the outer membrane of a CSDH is characterized by fragile neovascular networks originating primarily from the middle meningeal artery. These vessels contribute to persistent microhemorrhage, cytokine release, and membrane expansion, creating a cycle that predisposes patients to recurrence even after technically successful surgery. This pathophysiological insight forms the basis for the increasing use of middle meningeal artery embolization as a targeted, disease-modifying treatment (4-7).

In the present case, MMA embolization was performed following recurrence after burr-hole drainage, and complete radiographic resolution was achieved using PVA particles. This clinical course aligns with the growing evidence suggesting that embolization may be particularly useful in patients at high risk for recurrence, including those receiving antithrombotic therapy or those who decline repeat surgery (4,5). Literature indicates that MMA embolization not only reduces recurrence by interrupting the vascular supply to the outer membrane but may also mitigate the inflammatory cascade that contributes to hematoma persistence (6–8). In this context, the technique offers a biological advantage over surgery alone, which does not affect the vascularized membranes responsible for ongoing bleeding. Although MMA embolization is generally safe, potential complications include non-target embolization, cranial nerve palsy, and skin necrosis (4,5,8). In our case, these risks were minimized through selective catheterization of distal MMA branches and continuous fluoroscopic monitoring, and no adverse events were observed.

Although prospective trials remain limited, these findings support the growing consensus that embolization can function effectively as both a standalone option and an adjunct to surgery. In particular, the minimally invasive nature of the procedure and its compatibility with patients who must continue anticoagulant or antiaggregant therapy make it a valuable option in medically complex cases (4,5,8).

Another important consideration is the variety of embolic materials that can be used. As highlighted in previous publications, solid and liquid agents differ in penetration depth, permanence, and operator preference. In this case, PVA particles provided satisfactory occlusion, consistent with reports that these agents are effective in achieving distal MMA branch embolization and promoting hematoma resolution. While some studies suggest potential advantages of liquid embolics due to deeper penetration, current evidence does not conclusively favor one material over another, indicating

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that multiple embolic strategies remain viable depending on anatomical and clinical factors (4,5).

Overall, the present findings reinforce the concept that addressing the vascular source of hematoma maintenance is crucial for reducing recurrence. The successful use of MMA embolization in this patient supports its role as a safe and effective treatment alternative or adjunct in recurrent CSDH, particularly for individuals with elevated surgical risk. Although further randomized studies with larger populations are necessary to define standardized protocols, the existing literature provides a strong rationale for integrating MMA embolization into contemporary CSDH management algorithms (4–8).

CONCLUSION

MMA embolization represents a paradigm shift in the management of chronic subdural hematoma. By addressing the inflammatory and vascular mechanisms responsible for hematoma persistence, it provides a targeted, durable, and minimally invasive treatment alternative. The markedly lower recurrence rates, favorable safety profile, and compatibility with antithrombotic therapy make MMA embolization a valuable option for recurrent or high-risk CSDH cases. Ongoing clinical investigations continue to explore whether MMA embolization can reduce recurrence when used as a first-line or adjunctive strategy.

Future prospective randomized studies with larger sample sizes are warranted to further define its role as a standalone or adjunctive treatment. Nevertheless, current evidence supports MMA embolization as an effective and safe approach, especially in patients with recurrence after surgery or contraindications to reoperation.

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