EREDETI KÖZLEMÉNY

ORIGINAL ARTICLE

Angiographic classification of chronic subdural hematoma

Michael Josef KUPKA[1, 2], Patrick THURNER[1, 2], Tilman SCHUBERT[1, 2], Nicolin HAINC[1, 2], Menno Robbert GERMANS[2, 3], Zsolt KULCSÁR[1, 2]

[1]Department of Neuroradiology, University Hospital Zürich, Zürich, Switzerland
[2]Clinical Neuroscience Center, University Hospital Zürich, Zürich, Switzerland
[3]Department of Neurosurgery, University Hospital Zürich, Zürich, Switzerland

PRINT | English | https://doi.org/10.18071/isz.77.0196 | www.elitmed.hu

Levelező szerző
(correspondent):
Michael Josef KUPKA, MD,
Department Neuroradiology,
University Hospital of Zurich,
Frauenklinikstrasse 10.
8091 Zurich, Switzerland.
E-mail: Michael.Kupka@usz.ch
https://orcid.org/0009-0004-5756-3231

Érkezett:
2023. december 20.
Elfogadva:
2024. január 11.

Background and purpose – Chronic subdural hematoma (cSDH) is a challenging pathology with high recurrence rate after surgical treatment and may seriously affect the patient's quality of life. Membrane formation with angiogenesis plays an important role in the evolution of the disease, providing a promising target for endovascular therapy. Our goal is to categorize angiographic patterns of chronic subdural hematoma for standardized reporting purposes.
Methods – In our retrospective analysis of prospective data collection, we analyzed angiographic properties of all high recurrence risk patients with cSDH, who were treated by embolization in our hospital between February 2019 and June 2020. Altogether 17 patients were included in the analysis.
Results – Based on superselective angiography of the middle meningeal artery (MMA) in the two standard, AP and lateral views, three distinct categories of dural supply were defined: normal vascular pattern (Grade I), cottonwool appearance without enlargement of the MMA branches (Grad II) and strong cottonwool like staining with dilatative remodelling of the MMA branches (Grade III).
Conclusion – The proposed grading system of the angiographic appearance of cSDH, representing the pathophysiological evolution of the disease should be correlated to therapeutic success rates and could be applied in future clinical studies.

Keywords: chronic subdural hematoma, embolization, middle meningeal artery, endovascular therapy, cotton-wool enhancement

A krónikus subduralis haematoma angiográfiás osztályozása
Kupka MJ, MD; Thurner P, MD; Schubert T, MD; Hainc N, MD; Germans MR, MD; Kulcsár Zs, MD

Háttér és cél – A krónikus subduralis haematoma (cSDH) patológiája kihívást jelent; a kórkép a sebészeti kezelést követően magas kiújulási aránnyal jár, és súlyosan befolyásolhatja a beteg életminőségét. Az angiogenezissel járó membránképződés fontos szerepet játszik a betegség evolúciójában, ígéretes célpontot biztosítva az endovascularis terápia számára. Célunk a krónikus subduralis haematoma kategorizálása volt angiográfiás mintázata alapján, standardizált jelentéskészítés céljából.
Módszerek – A kórházunkban 2019 februárja és 2020 júniusa között embolizációval kezelt, magas kiújulási kockázatú cSDH-s betegek angiográfiás tulajdonságait elemeztük a prospektív adatgyűjtés retrospektív elemzéseként. Összesen 17 beteget vontunk be az elemzésbe.
Eredmények – Az arteria meningea media (MMA) szuperszelektív angiográfiája alapján a két standard, anteroposterior (AP) és laterális nézetben a duralis ellátottság három különböző kategóriáját definiáltuk: normális vascularis mintázat (I. fokozat), vattaszerű kép megjelenése az MMA-ágak megnagyobbodása nélkül (II. fokozat) és nagy mennyiségű vattaszerű kép megjelenése az MMA-ágak tágulatával (III. fokozat).
Következtetés – A cSDH angiográfiás megjelenésének javasolt osztályozási rendszere, ami a betegség patofiziológiai fejlődését reprezentálja, összefüggésbe hozható a terápiás sikerességgel, és alkalmazható a jövőbeli klinikai vizsgálatokban.

Kulcsszavak: krónikus subduralis haematoma, embolizáció, arteria meningea media, endovascularis terápia, vattaszerű kép

Chronic subdural hematoma (cSDH) is a common and severe neurological condition with an annual incidence in the general population of 1.5-5.3 cases per 100,000, and significantly higher incidence in the elderly population (up to 80 per 100.000)[1, 2]. Comorbidities and the advanced age of the patients make therapy challenging, with relative high recurrence rates after surgical hematoma evacuation of up to 33% in symptomatic patients[2]. The most important risk factors for recurrence and poor outcome are coagulation disorders and anticoagulant treatment, which are both quite frequent in the elderly population. By understanding the pathophysiology of the disease with membrane development, angiogenesis and leaky capillaries, middle meningeal artery (MMA) embolization emerged as a minimal invasive intervention to reverse the pathomechanism, and seems a promising alternative or adjunctive to conservative or surgical treatment[3–6].

Despite accumulating clinical data supporting the beneficial role of therapeutic embolisation[7–9], the importance of angiographic appearance of the dural vascular supply in cSDH and its relation to the success of endovascular treatment remains unclear[10]. Since this dynamic imaging feature is not considered in current research and publications, albeit it may influence the success of embolization, our goal is to propose an angiographic classification of angioarchitectural characteristics of cSDH for reporting purposes.

Patients and methods

Patient selection

This retrospective imaging analysis is based on prospectively gathered data on a consecutive group of symptomatic cSDH patients with a high risk of recurrence who were treated with MMA embolization, either alone or as an adjunctive to surgery at our institution between February 2019 and June 2020. High recurrence risk was defined as either pretreatment anticoagulant or antithrombotic therapy or a pre-existing coagulation disorder. The need for pre- or postembolisation hematoma evacuation was individually assessed by the responsible senior neurosurgeon. The study was approved by the regional ethics committee (BASEC Nr. 2018-01212).

DSA analysis

All interventions were performed using femoral access. Selective angiography of the ECA and superselective microcatheter injection of the MMA was performed on the affected side, in regular AP and lateral views. The embolizations were performed in general anesthesia (GA) if the risks of GA were assessed to be low, otherwise local anesthesia was used.

Angiographic grading system

Based on the angioarchitectural characteristics of the MMA, we developed an angiographic grading system. This classification is based on the pathological dilatative remodelling of the branches of the middle meningeal artery, as well as on the presence of capillary and cottonwool enhancement of hematoma membranes. Pathological dilatative remodelling of the MMA was considered by enlarged diameter of the MMA branches supplying the hematoma with well-defined quarter branches. Cottonwool enhancement was defined as the detection of spotted contrast accumulation in the parenchymal phase during selective MMA angiography, with early venous filling. Based on these, we classified them into three categories **(Table 1)**.

Embolization, safety and efficacy assessment

The superselective imaging and embolization was performed through a microcatheter (Magic 1.2F or 1.5F, Balt International, Montmorency, France) positioned in the MMA, distal from the origin of critical anastomotic branches, such as the meningolacrimal or the petrous branch. Embolization was performed under good antegrade flow conditions with microparticles (PVA 45-150µ and 150-250 µ Boston Scientific), until complete devascularisation of the pathologic enhancement and stagnation of the CM in the main branches was achieved, considered a technical success. Treatment success was determined by symptom improvement, hematoma regression and no recurrence during the follow-up. Periprocedural complications as well as need for surgical evacuation were analyzed. All patients were followed clinically and with CT-scan between 1 and 3 months.

Table 1. *Classification of MMA based on angiographic vessel appearance*

	MMA Grade I	MMA Grade II	MMA Grade III
DSA	Normal MMA angiography *without* dilatative remodelling of the arteries and *without* cotton-wool appearance	Cottonwool appearance *without* dilatative remodelling of the MMA branches	Cottonwool appearance and dilatative remodelling of the MMA branches

Results

Angiography findings

According to angioarchitectural morphology 7 patients were classified as type I, 5 as type II and 5 as type III **(Table 1** and **Figures 1–4)**.

Safety and efficacy

Technical success was achieved in 17 cases. A total of 5 patients (29%) underwent surgical evacuation after treatment; in three patients (18%) (group of Grade II and III) the surgical intervention was performed shortly after embolization (the same day or in 1 or 2 days) according to treatment plan. Two patients (12%) of the group with MMA Grade III required surgical evacuation due to a hematoma recurrence. We did not experience embolization related neurological complications. Complete hematoma resorption was observed in 13 cases (76%) within a mean of 10 weeks. Hematoma thickness > 20 mm was predominantly observed in Group I (largest diameter in axial or coronal slices). Midline shift > 10 mm was present in 3 patients of Group II and one patient in Group I. Three patients of Group I were treated by anticoagulant medication (Xarelto, Plavix, Eliquis, Lixian).

During follow up 2 (12%) patients passed away for reasons independent of subdural hematoma **(Table 2)**. One patient with MMA Grade I successfully treated by embolization and combined surgical evacuation of SDH passed away 3 months later due to a multiorgan failure with septic shock. The other patient with MMA Grade I pattern was successfully treated by embolization only and showed a reduction of the subdural hematoma in the control scans without recurrence. Two years later she passed away due to a liver failure.

Discussion

Based on this series of cSDH embolization, we present a simple angiographic grading scale in cSDH for reporting purposes. Our angioarchitecture analysis suggests that the pathophysiological evolution of the cSDH may be well related to the angiographic

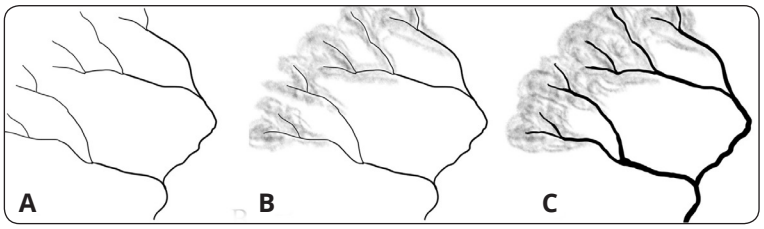

Figure 1. *Schematic represantation of the proposed grading system based on the angiographic appearance: Grade I, with normal appearing vasculature* **(A)**, *Grade II with distal contrast pooling "cotton wool"* **(B)** *and Grade III: "cotton wool" with comcomitant dilatative angiopathy* **(C)**

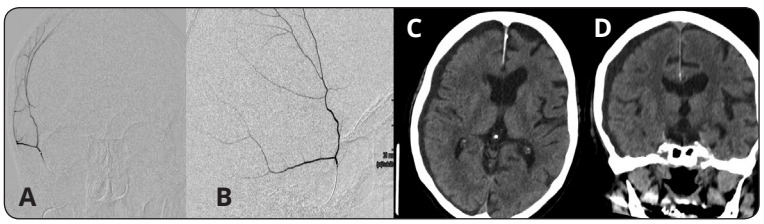

Figure 2. *DSA ap* **(A)** *and lateral* **(B)** *with normal appearance of MMA (Grade I) and computed tomography slices axial* **(C)** *and coronal* **(D)** *from the same patient acquired 2 days prior with evidence of a chronic hypodense subdural hematoma and homogenous architecture*

Figure 3. *MMA angiograms* **(A)** *and* **(B)** *demonstrate a "cotton wool-like" appearance of the distal vasculature (circled) without dilatation (Grade II). CT* **(C, D)** *performed 3 days prior to angiography is provided to demonstrate features of a chronic subdural hematoma with mixed density and high density septa (arrows) running between the inner and outer hematoma membrane (trabecular architecture)*

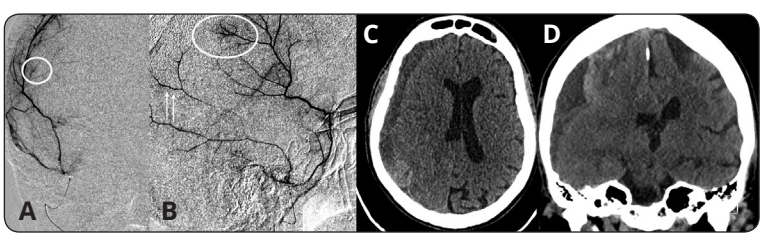

Figure 4. *MMA angiograms with demonstration of "cotton wool appearance" (***A, B,** *circled) and marked dilatation (***B**, *arrows) of a distal frontoparietal branch (Grade III). CT of the same patients* **(C,D)** *shows again a chronic subdural hematoma with mixed density components and trabecular architecture*

Table 2. *Classification of patients according to angiographic pattern and treatment results*

	MMA Grade I	MMA Grade II	MMA Grade III
Total number of patients	7	5	5
Complete hematoma resolution during follow up (mean time 10 weeks)	6	4	3
Combined therapy (embolization/ surgery)	4	4	2
Recurrent hematoma with need of surgical evacuation	0	0	2
Hematoma thickness > 20 mm	4	2	1
MLS > 10 mm	1	3	0
Unrelated death	2	0	0
Anticoagulant therapy	3	0	0

appearance and thus become a biomarker for success prediction of embolization. Patient selection for cSDH embolization should rely on understanding disease evolution and here imaging parameters should have leading role. Imaging criteria for curative embolization are yet to be refined, and as such standardized reporting for imaging patterns is missing, hampering further understanding on the ideal time window for embolization. Similar to the CT criteria[11], DSA would have a role in defining the evolution of the disease.

The rationale behind MMA embolization relies on the current pathophysiological concept of the disease, which has evolved over the last decades based on histological and electron microscopic research[12–14]. According to this concept, the microhemorrhages at the dural border cell layer is at the origin of the hematoma development, leading to inflammation driven angiogenesis and formation of leaky, permeable capillary membranes, these being responsible for repeated rebleedings, fluid accumulation and sustained inflammation[12]. The capillaries being supplied by branches of the MMA, endovascular occlusion of the blood supply may have a benefit in stopping and reversing the disease evolution, leading to hematoma resorption. The current data suggest relatively high efficacy of embolization in cSDH, especially in preventing retreatment rates[4, 15].

Based on the pathophysiological concept of cSDH evolution, with rebleeds and inflammation driven angiogenesis in the hematoma membranes, the adaptive remodelling of the MMA is to be expected, supplying the necessary increased blood supply. This will result in diameter enlargement and increased opacification of the leaky capillary bed as a second stage in the evolution of the pathology. An intervention at different stages of the disease development may have different effects. This may be also influenced by the technique of embolization. Microparticles, penetrating into the capillary bed may have a different effect as compared to liquid embolics, where the whole arterial tree is occluded. A recent systematic review and meta-analysis including twenty-two studies, 382 patients with middle meningeal artery embolization and 1373 surgical patients, showed a recurrence rate of subdural hematoma of 4.1%[6]. Fifty (4.2%) patients underwent a reoperation for a recurrent or residual subdural hematoma. Thirty-six (2.6%) experienced postoperative complications. The rates of good radiologic and clinical outcomes were 83.1% and 73.3%, respectively. Middle meningeal artery embolization was significantly associated with decreased odds of subdural hematoma reoperation (OR = 0.48; 95% CI, 0.234– 0.991; P = .047) compared with surgery. Embolization techniques may vary, with the aim of only occlusion of the leaky capillary bed with microparticles or by complete occlusion of the affected MMA and its smaller branches with liquid embolic agents. Several randomized controlled trials are currently running, from which more understanding of the efficacy and recurrence should be expected. However, the imaging based patient selection criteria for embolization remain unclear.

First *Tanaka* et al. described the cotton-wool enhancement as the appearance of a subdural hematoma during DSA[16]. Later, several studies have demonstrated that this appearance is caused by membrane formation and the appearance of pathological capillaries[12]. Furthermore, research has shown that patients with cSDH have a larger diameter of MMA than healthy ones[17]. This may be an important indicator in determining the stage of the disease because it refers to chronic and eventually increasing hypervascularity of the membranes, requesting more flow and adaptive dilatative remodelling of the MMA branches, similar to the supply of meningiomas. In addition, another research by Nakagawa et al found that the vessels supplying the dura also form a vascular channel in the hematoma and supply the inner membranes, and thus contribute to the recurrence of the disease[18]. They also developed a grading system based on their DynaCT images. Their observations were established in patients with recurrent subdural hematoma after surgery. In contrast, our classification system is based on DSA recordings, there is no need for DynaCT and it can also be observed in patients who have undergone primary MMA embolization.

Embolization may have high potential to become standard of care in combination with surgery or as stand-

alone treatment. For such purpose, a grading system of angiographic appearance of cSDH should be used for reporting purposes, to understand which angiographic patterns have the highest cure or recurrence rates. This would facilitate to improve success of embolization, as well as to help select best therapeutical options for the patients.

The limitations of our study are the retrospective nature and the small patient population as well as a potential selection bias.

Conclusion

From our retrospective study of 17 patients suffering from chronic subdural hematoma and treated by MMA embolization we assessed the angiographic appearance on DSA images and derived a new angiographic grading. The proposed grading system of the angiographic appearance may represent the evolution of the disease and thus may have predictive value in embolization success. Its prospective application in large studies is needed for validation purposes.

———

DECLARATION OF CONFLICTING INTERESTS – The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. FUNDING – The authors received no financial support for the research, authorship, and/or publication of this article.

References

1. *Yadav YR, Parihar V, Namdev H, et al*. Chronic subdural hematoma. Asian J Neurosurg 2016;11:330-42. https://doi.org/10.4103/1793-5482.145102
2. *Ivamoto HS, Lemos HP, Atallah AN*. Surgical treatments for chronic subdural hematomas: A comprehensive systematic review. World Neurosurg 2016;86:399-418. https://doi.org/10.1016/j.wneu.2015.10.025
3. *Link TW, Boddu S, Paine SM, et al.* Middle meningeal artery embolization for chronic subdural hematoma: A series of 60 cases. Neurosurgery 2019;85:801-7. https://doi.org/10.1093/neuros/nyy521
4. *Ban SP, Hwang G, Byoun HS, et al*. Middle meningeal artery embolization for chronic subdural hematoma. Radiology 2018;286:992-9. https://doi.org/10.1148/radiol.2017170053
5. *Ironside N, Nguyen C, Do Q, et al.* Middle meningeal artery embolization for chronic subdural hematoma: a systematic review and meta-analysis. J Neurointerventional Surg 2021;13:951-7. https://doi.org/10.1136/neurintsurg-2021-017352
6. *Ku JC, Dmytriw AA, Essibayi MA, et al*. Embolic agent choice in middle meningeal artery embolization as primary or adjunct treatment for chronic subdural hematoma: A systematic review and meta-analysis. AJNR Am J Neuroradiol 2023;44:297-302. https://doi.org/10.3174/ajnr.A7796
7. *Reith W, Garner M*. [Middle meningeal artery embolization for chronic subdural hematomas]. Radiol Heidelb Ger 2022;62:641-7.
8. *Abdollahifard S, Farrokhi A, Yousefi O, et al.* Particle embolic agents for embolization of middle meningeal artery in the treatment of chronic subdural hematoma: A systematic review and meta-analysis. Interv Neuroradiol J Peritherapeutic Neuroradiol Surg Proced Relat Neurosci 2022;15910199221125976. https://doi.org/10.1177/15910199221125977
9. *Tonetti DA, Thomas AJ, Bulsara KR.* Middle meningeal artery embolization for chronic subdural hematoma: A review. Oper Neurosurg Hagerstown Md 2023;24:469-75. https://doi.org/10.1227/ons.0000000000000656
10. *Mühl-Benninghaus R.* Middle meningeal artery embolization for treatment of chronic subdural hematoma. Radiol Heidelb Ger 2022;62:17-21. https://doi.org/10.1007/s00117-022-01074-8
11. *Miah IP, Tank Y, Rosendaal FR, et al*. Radiological prognostic factors of chronic subdural hematoma recurrence: a systematic review and meta-analysis. Neuroradiology 2021;63:27-40. https://doi.org/10.1007/s00234-020-02597-4
12. *Edlmann E, Giorgi-Coll S, Whitfield PC, et al*. Pathophysiology of chronic subdural haematoma: inflammation, angiogenesis and implications for pharmacotherapy. J Neuroinflammation 2017;14:108. https://doi.org/10.1186/s12974-017-0881-y
13. *Nakaguchi H, Tanishima T, Yoshimasu N*. Factors in the natural history of chronic subdural hematomas that influence their postoperative recurrence. J Neurosurg 2001;95:256-62. https://doi.org/10.3171/jns.2001.95.2.0256
14. *Lee K-S.* Natural history of chronic subdural haematoma. Brain Inj 2004;18:351-8. https://doi.org/10.1080/02699050310001645801
15. *Waqas M, Vakhari K, Weimer PV, et al*. Safety and effectiveness of embolization for chronic subdural hematoma: Systematic review and case series. World Neurosurg 2019;126:228-36. https://doi.org/10.1016/j.wneu.2019.02.208
16. *Tanaka T, Fujimoto S, Saitoh K, et al.* [Superselective angiographic findings of ipsilateral middle meningeal artery of chronic subdural hematoma in adults]. No Shinkei Geka 1998;26:339-47.
17. *Pouvelle A, Pouliquen G, Premat K, et al*. Larger middle meningeal arteries on computed tomography angiography in patients with chronic subdural hematomas as compared with matched controls. J Neurotrauma 2020;37:2703-8. https://doi.org/10.1089/neu.2020.7168
18. *Nakagawa I, Park HS, Kotsugi M, et al*. Enhanced hematoma membrane on DynaCT images during middle meningeal artery embolization for persistently recurrent chronic subdural hematoma. World Neurosurg 2019;126:e473-e479. https://doi.org/10.1016/j.wneu.2019.02.074