Endoscopically observed outer membrane of chronic subdural hematoma after endovascular embolization of middle meningeal artery

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ABSTRACT

Background: Embolization of the middle meningeal artery (MMA) has been established for chronic subdural hematoma (CSDH). Neuroendoscopic observation of the outer membrane of the hematoma was carried out after embolization. The treatment mechanism of embolization is discussed, focusing on the vasculature and inflammation of the membrane.

Methods: Four patients with recurrent CSDH were included in this study. The MMA was embolized using Embosphere® particles in three patients. The outer membrane was observed with normal and narrow band images (NBIs).

Results: The net-like vessels were not obstructed in the whole area of the outer membrane, but in a patchy fashion of embolized areas surrounded by nonembolized areas. In two patients, the nonembolized areas showed a hemorrhagic inflammatory red color. Histopathological examination confirmed hypertrophic dura with leukocyte infiltration. Dilated dural arteries and proliferated sinusoid arteries were located in the deep and superficial border cell layers. These arteries were visualized as green and brown on NBI, respectively. In the embolized area, the red membrane turned pink, indicating ischemia and subsiding inflammatory hyperemia. In the third patient, the outer membrane was white in both the nonembolized and embolized areas in endoscopic view, and the net-like vessels were sparse in both endoscopy and histology, indicating a scar inflammatory phase. The membrane transition was not observed in the patient that did not undergo embolization.

Conclusion: Endoscopic observation revealed that embolization of the MMA blocked both the dural and sinusoidal arteries. Ischemic transformation causing the suppression of inflammation of the outer membrane is a suggested mechanism of MMA embolization.

Keywords: Chronic subdural hematoma, Embolization, Inflammation, Neuroendoscope, Outer membrane

INTRODUCTION

Chronic subdural hematoma (CSDH) is categorized as a traumatic brain disease; however, pathophysiologically, it may be included as an inflammatory disease.[5] CSDH is observed to occur in the wound healing process after a tear of the dural border cell layer due to minor head trauma. Hematoma contains inflammatory cytokines, kinins, leukotrienes, and prostaglandins. The mass lesion and symptoms spontaneously turn to the resolution phase, which is promoted by corticosteroids.[10]
The active healing processes of CSDH are observed and staged by histopathology\[9,18\] and endoscopy\[13,26\]. Nagahori et al.\[18\] classified the histopathological findings of the outer membrane into four stages: I, noninflammatory; II, inflammatory; III, hemorrhagic inflammatory; and IV, scar inflammatory stages. Nakaguchi et al.\[19,25\] classified the CT findings into four groups, namely, the homogenous, laminar, separated, and trabecular types. They indicated the relationship between the CT findings and hematoma age; the homogenous and laminar types were seen in the early phase of the CSDH, the separated type was seen in the following most active phase, and the trabecular type was seen in the later resolving phase. Katsuki et al.\[13\] observed the outer membrane using an endoscope and suggested that the color of the membrane transitioned according to Nagahori’s histopathological stages: I, white; II, yellow; III, red; and IV, white. All these studies indicated that the postoperative recurrence rate was high in Stage III and low in Stage IV. Endoscopic observation provides information regarding the hematoma age, degree of inflammation, and the risk of recurrence.

The standard treatment of burr hole irrigation with drainage is symptomatic treatment for CSDH. An alternative treatment for embolization of the middle meningeal artery (MMA), the major blood supplier to the outer membrane, using endovascular intervention is a causal treatment. Angiographical hypervascularity of the MMA in CSDH and treatment with MMA embolization was first reported in 2000.\[16\] Since then, the procedure has been widely accepted, and several successful reports have been detailed.\[2,6,12,15,24,27\] Studies investigating its effectiveness and indications have been performed.\[1,4,10\]

The inhibition of local bleeding from the outer membrane by disturbance of the blood supply is a suspected mechanism of embolization;\[23\] however, ischemic changes in the lesion have not been observed directly. The influence of embolization on inflammatory processes has not yet been elucidated. We performed endoscopic observation of the outer membrane after embolization of the MMA in three patients with recurrent CSDH. The differences in the endoscopic images of the membrane between the embolized and nonembolized areas are shown; additionally, the effect of MMA embolization on the vasculature and inflammation is discussed in this study.

Patients

Patients with recurrent CSDH who required surgical decompression met the criteria for MMA embolization at our institute. Patients receiving initial treatment or those with recurrent asymptomatic small-sized hematoma, renal failure, or allergy to iodine contrast medium were not indicated for embolization. Urgent irrigation surgery without embolization was performed for patients with severe symptoms. Four patients with recurrent CSDH with and without embolization between December 2020 and June 2022 were included in the study. All the patients and their families were informed of the purposes, methods, and risks of MMA embolization, burr hole surgery, and endoscopic observation, and agreed with written permission. This retrospective study was approved by the Institutional Review Board of Yamaguchi University Hospital (approved number: H2021-042-2).

MATERIALS AND METHODS

Superselective external carotid angiography was performed using a microcatheter. The MMA was embolized using Embosphere (100–300 micrometers) particles. Surgery was performed 1–7 days after the embolization. The same burr hole made in the previous surgery was enlarged laterally by 5 mm to obtain a specimen of the dura mater. The CSDH was irrigated with artificial CSF; an Olympus videoscope (VEF-V; Olympus Medical Systems, Tokyo, Japan) was inserted. The tip of the scope was angled outward to observe the outer membrane. Subdural drainage was performed until the day after surgery.

The severity of the clinical signs and symptoms before treatment was classified according to the neurological grade of CSDH.\[17\] The preoperative CT findings of the hematoma cavity,\[9,25\] color of the outer membrane in the endoscopic normal band image,\[13\] and histopathological findings of the dura stained with hematoxylin and eosin\[18\] were classified according to the literature [Table 1]. Endoscopic narrow band imaging (NBI) was also performed to observe the vasculature of the outer membrane. The NBI system mounts an optical color separation filter that narrows the bandwidth. Images are produced by the illumination of two bands, which are 415 and 540 nm. The band with 415 nm wavelength provides information about deep and superficial vessels.\[21\]

RESULTS

Three patients, all of whom were men (ages 62, 81, and 88 years), were treated with embolization and irrigation. A fourth patient, a 68-year-old woman, was treated with irrigation alone [Table 2]. The preoperative neurological grades for the four patients were 2, 2, 3, and 2, respectively. Preoperative CT revealed a separated type in Patient 1, trabecular type in Patient 3, and homogenous type in Patient 4. Embolization of the unilateral and bilateral MMA was performed in Patients 1 and 3 and in Patient 2, respectively. Endoscopic observation was performed unilaterally in all patients and irrigation with drainage without observation was performed on the left side in Patient 2. All the patients showed postoperative improvement. The CSDH decreased in size and did not recur. No apparent complications related to embolization or endoscopic observation were found.

Net-like vessels were visualized on the outer membrane using an endoscope. These vessels were not obstructed in the
whole area, but in a patchy fashion in the embolized areas surrounded by nonembolized areas. In Patients 1 and 2, the nonembolized areas showed a red hemorrhagic inflammatory color [Figures 2a and 2b]. Histopathological examination confirmed hypertrophic dura with leukocyte infiltration. Dilated dural arteries and hemorrhage were located between the periosteal and meningeal dura, and proliferated sinusoid arteries were in the dural border cell layer [Figure 2c]. NBI visualizes deep and superficial vessels in green and brown; therefore, the green- and brown-colored vessels correspond to the dural and sinusoid arteries [Figures 2d and 2e]. In the embolized area, the red membrane turned pink [Figures 3a and 2b], indicating ischemia and subsiding inflammatory hyperemia, and the net-like green and brown arteries were obstructed [Figures 3b and 2e]. Endoscopic findings indicated that the hematomas in the two patients were Stage III before embolization and transitioned to Stage IV after embolization [Table 2]. The separated types on CT were compatible with the stage before embolization.

In Patient 3, the outer membrane, seen through a gap between the massive proliferated trabecula, was white in both the nonembolized and embolized areas [Figure 4a]. The sparse vascular network was observed to be brown on NBI, indicating both the dural and sinusoid arteries in the superficial location [Figure 4b]. Histopathological examination confirmed that the white color indicated scar inflammation, and the dura was so thin that the dural artery was located close to the surface and was visualized as brown [Figure 4c]. The hematoma was in Stage IV before and after embolization [Table 2]. The trabecular type on CT was compatible with the stage before embolization.

In Patient 4, the outer membrane was a yellow color on NBI, which indicated inflammation [Figure 5a]. The NBI also visualized net-like brown-colored vessels [Figure 5b]. No areas showed transitions to white color or obstruction of vessels.

**DISCUSSION**

Endoscopic observation of the outer membrane of the CSDH during burr hole irrigation after MMA embolization was performed in three patients. MMA embolization turned the red outer membrane to a pink color and obstructed the net-like vasculature in two patients. In the other patient, both the embolized and nonembolized areas were white. The transition of color or vessel obstruction was not observed in the patient previously treated with the irrigation surgery alone.

The effect of MMA embolization appeared primarily in sporadic ischemic changes in both the dural and sinusoid arteries. The dural arteries receive the embolus, whereas the sinusoid arteries are responsible for bleeding. The NBI showed the green dural arteries and brown sinusoid arteries together in one area and their obstruction of them together in other areas. None of the areas showed one of the remaining green or brown arteries. The results indicated that the sinusoid artery was supplied only from the adjacent dural artery. Therefore, embolization of the dural artery should be a reasonable approach for achieving hemostasis in the sinusoid artery.

**Table 1: Chronological staging of the findings of chronic subdural hematoma.**

| Stage                        | I                          | II                          | III                         | IV                           | References             |
|------------------------------|----------------------------|-----------------------------|-----------------------------|------------------------------|------------------------|
| Histopathology of membrane   | Noninflammatory            | Inflammatory                | Hemorrhagic inflammatory    | Scar inflammatory           | Gandhoke et al. [9]    |
| CT                           | Homogenous laminar         | Homogenous laminar          | Separated                   | Trabecular                   | Nagahori et al. [14] |
| Endoscope color of membrane  | White                      | Yellow                      | Red                         | White                        | Nakaguchi et al. [19] |
|                              |                            |                             |                             |                              | Takei et al. [25]      |
|                              |                            |                             |                             |                              | Katsuki et al. [13]    |
This method is also applied in other fields of treatment, such as vasoconstrictive nasal sprays for rhinitis\textsuperscript{[22]} and geniculate artery embolization for osteoarthritis of the knee joint.\textsuperscript{[11]}

MMA embolization may be helpful, especially in elderly patients. It is difficult to expect the atrophic brain to re-expand itself for clearance of the subdural space.\textsuperscript{[14]} The stabilization of CSDH from the intracranial space into a subdural fluid capsule is another treatment goal. Although intracranial hypotension in elderly patients cannot be compensated by MMA embolization, the recurrence rate should be reduced if the inflammation resolved.\textsuperscript{[10]} MMA

**Figure 2:** Normal and narrow band images (NBI) of the endoscope, and photomicrograph of the dural specimen. (a) Normal band endoscopic image of Patient 1 showing red-colored hypervasculature in the outer membrane where microsphere did not reach. (b) Normal band endoscopic image of the outer membrane of the right-sided CSDH of Patient 2. Red hypervasculature and pink avascular areas are shown in the lower and upper sides of the picture. (c) Photomicrograph of the dural specimen stained with hematoxylin-eosin (HE); original magnification, x40 in Patient 2. The upper part of the picture indicates the osteal side of the dura. The dural arteries are dilated, and inflammatory cells infiltrate the layer between the peristeal and meningeal dura (arrowhead). Hypertrophy of the dural border cell layer and development of sinusoid arteries (arrow). (d and e) NBI of the same area in (a and b). The hypervasculature are obvious in (d) and lower side in (e). The hypovasculature is seen in lower side in (e).

| Patient number | Age | Sex | Past history | CT classification | Endoscope nonembolized area | Endoscope embolize area | Histology |
|---------------|-----|-----|--------------|-------------------|-----------------------------|-------------------------|-----------|
| 1             | 88  | Man | No           | Separated (Stage III) | Red (Stage III) | Pink (Stage IV) | Not available |
| 2 right side  | 62  | Man | ITP, CSF hypovolemia | Separated (Stage III) | Red (Stage III) | Pink (Stage IV) | Hemorrhagic inflammation (Stage III) |
| 3             | 81  | Man | Liver cirrhosis, coagulopathy | Trabecular (Stage IV) | White (Stage IV) | White (Stage IV) | Scar inflammation (Stage IV) |
| 4             | 69  | Woman | Tuberculosis depression | Homogenous Stage I or II | Yellow (Stage II) | Not embolized | Not available |

ITP: Idiopathic thrombocytopenic purpura, CSF: Cerebrospinal fluid
embolization is an optimal option for this purpose\(^3\) as is the oral intake of corticosteroids\(^2\) and Goreisan extract.\(^4\) Endoscopic observation would help a limited number of patients with CSDH in providing information for the treatment of choice. The staging of the outer membrane in combination with CT findings\(^7\) may indicate the risk of recurrence and suggest the necessity of embolization; that is, the white outer membrane and trabecular type on CT in Patient 3 suggested that the CSDH would have improved even if no embolization was performed. On the other hand, it is impossible for endoscopic observation to quantitatively assess the result of embolization when calculating the percentage of the embolized area.

CONCLUSION

Endoscopic observation revealed that embolization of the MMA, the only blood supplier to the outer membrane, obstructed both the dural and sinusoid arteries, and changed the color of the outer membrane of CSDH. Ischemia and suppression of inflammation are suggested treatment mechanisms.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Conflicts of interest

There are no conflicts of interest.

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