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Prognostic Factors of Motor Recovery after Stereotactic Evacuation of Intracerebral Hematoma

Rei Enatsu,[1] Minoru Asahi,[1] Masato Matsumoto[1] and Osamu Hirai[1]

[1]Department of Neurosurgery, Shinko Hospital, Kobe, Japan

Spontaneous intracerebral hemorrhage represents 20 to 30% of all stroke patients in Japan. However, the treatment strategy of intracerebral hematoma remains controversial. Stereotactic hematoma evacuation is minimally invasive surgery and is beneficial for clot removal with limited tissue damage. The purpose of this study was to investigate the factors affecting motor recovery after stereotactic hematoma evacuation. This retrospective analysis included 30 patients with spontaneous thalamic or putaminal hemorrhage who underwent stereotactic hematoma evacuation. We compared age, presurgical muscle strength, hematoma volume and removal rate between the patients who showed improvement of motor function (improved group) and the patients associated with no motor improvement (unchanged group). Twenty-one patients were classified into the improved group and nine patients into the unchanged group. Statistical analysis revealed that age in the improved group was significantly younger than in the unchanged group ($p < 0.01$), whereas there was no significant difference in presurgical muscle strength, hematoma volume and removal rate between the two groups. The present results revealed that stereotactic hematoma evacuation is attributable to the improvement of motor function, especially in the younger population, indicating the importance of cortical reorganization during post-surgical rehabilitation. In addition, this procedure could provide functional improvement in severely disabled patients. Proper patient selection to receive this therapy would be beneficial for further advances of this technique. The present result might be useful in elucidating the mechanism of motor recovery and proper patient selection for this technique.

Keywords: cortical reorganization; intracerebral hemorrhage; motor recovery; predictor; stereotactic evacuation
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Spontaneous intracerebral hemorrhage (ICH) represents 8 to 15% of all stroke patients in the United States and 20 to 30% of all strokes in Japan and China (Fayad and Awad 1998). The mortality rates at 7 days and 1 year after ICH are 31-34 and 53-59%, respectively (Flaherty et al. 2006). Furthermore, patients are usually severely disabled; only 10% are capable of living independently after 30 days and only 20% after 6 months (Fayad and Awad 1998). Besides irreversible tissue destruction due to hemorrhage, elevated local pressure, edema and excitotoxicity cause additional secondary brain injury to surrounding areas (Zhou et al. 2011a, b; Little and Alexander 2002; Teernstra et al. 2003). This secondary injury often occurs in the days following the initial hemorrhage and is associated with significant neurological deterioration. Previous reports provide evidence that clot reduction plays an important role in improving brain edema, additional neuronal injury and neurological deficits (Wagner et al. 1999; Teernstra et al. 2003); however, an aggressive open craniotomy may further traumatize brain tissue. It has been reported that there was no significant benefit for surgical treatment over conservative medical treatment for ICH (Mendelow et al. 2005); therefore, the treatment strategy remains controversial. Stereotactic hematoma evacuation is minimally invasive surgery and is beneficial for clot removal with limited tissue damage (Zhou et al. 2011a, b).

The purpose of this study was to investigate the factors affecting motor recovery after stereotactic hematoma evacuation. We compared age, presurgical muscle strength, hematoma volume and removal rate between the group in which motor recovery was observed and the group without motor recovery.

Methods

Patients

Thirty patients [12 women, age: 43-93 years old (median 70 years old)] with a thalamic (15 patients) or putaminal hemorrhage (15 patients) who underwent stereotactic hematoma evacuation between January 2000 and January 2008 were retrospectively included. In our criteria, surgical candidates for stereotactic hematoma evacuation were as follows: (1) spontaneous intracranial hemorrhage without underlining structural abnormality such as tumor and vascular abnormality; (2) hemorrhage volume exceeding 10 ml; (3) muscle strength of the paralyzed limbs: grades 0-3 on the Manual Muscle Testing

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Correspondence: Rei Enatsu, Epilepsy Center, Cleveland Clinic, 9500 Euclid Avenue, Cleveland, OH 44195, USA.
e-mail: enatsur@ccf.org

(MMT). The patient with massive hematoma associated with moderate consciousness impairment [Glasgow Coma Scale (GCS: 5-12)] underwent open craniotomy. The following patients were excluded from surgical treatment and received medical management: (1) hemorrhage less than 10 ml; (2) no or mild neurological deficit (i.e. MMT higher than 4); (3) complicated with serious heart, liver, renal or lung disease or functional failure; (4) severe consciousness impairment (GCS 3-4); and (5) bilateral pupil dilation.

We performed this retrospective study, following "Ethical Guidelines for Clinical Studies" proposed by the Japanese Ministry of Health, Labour and Welfare.

Surgical procedure

Stereotactic hematoma evacuation was performed within 72 hours of ICH onset. All operations were performed under local anesthesia and intravenous sedation. The target points were chosen in the center of the hematoma, based on computed tomography (CT) (Fig. 1). After ipsilateral frontal standard burr hole location (3 cm lateral to the midline and just anterior to the coronal suture) was performed, the hematoma was aspirated with the aid of Komai CT-Stereotactic Apparatus (Mizuho Ikakogyo Co., Ltd. Tokyo, Japan). The puncture needle perforated the predetermined target, then the hematoma was drawn out gently by syringe; thereafter, the needle was removed and replaced by a soft catheter. If the patients were restless or the hematoma volume was small, the catheter was not placed. A CT scan was performed to check the catheter location and residual hematoma volume after the surgery. The catheter was connected to a drainage bag and left for 1-5 days without a fibrinolytic therapy. We removed the catheter within 5 days after the surgery for the early rehabilitation. The CT scan was repeated before catheter removal to evaluate the residual hematoma. After catheter removal, rehabilitation therapy started in the all patients.

Data analysis

The medical records and CT scans were retrospectively reviewed to assess age, presurgical muscle strength (MMT scale), presurgical hematoma volume and removal rate.

The hematoma volume was estimated using a validated practical rule ($ABC/2$, where A: largest diameter of the hematoma on axial CT slices, B: diameter at 90 degrees from A on the same slice, and C: number of slices in which the hematoma is visible multiplied by the slice thickness) (Kothari et al. 1996). This method was applied to measure the volume of hemorrhage preoperatively and postoperatively (before catheter removal). Removal rate was defined as the proportion of hematoma volume reduction [(presurgical hematoma volume - postsurgical hematoma volume) / presurgical hematoma volume].

The MMT scale was compared between admission and 1 month after admission in all patients. If the MMT scale was different between upper and lower extremities, a worse MMT scale was used for further analysis.

Based on these results, we classified the patients into two groups: improved group and unchanged group. The improved group was defined as patients who recovered motor function with improvement of more than one MMT scale, and the unchanged group as patients in which improvement of MMT was less than one.

With respect to statistical analysis, categorical variables were analyzed using Fisher's exact test. The nonparametric Mann-Whitney test was conducted to identify any difference between the groups. For these analyses, PASW (PASW statistics 17.0, SPSS Inc., Chicago, IL) was used and $p < 0.05$ was regarded as significant.

Results

Among the 30 analyzed patients, age, presurgical hematoma volume, postsurgical hematoma volume, removal rate and presurgical MMT scale were in the range of 43-93 years old (median: 70 years old), 10-31 ml (median 18 ml), 3-20 ml (median 8 ml), 25-79% (median 56%) and 0-3 (median 2), respectively.

Twenty-one patients (eight women) were classified into the improved group and nine patients (four women) into the unchanged group (Table 1). The same surgical procedure was performed in the both groups and the intervals from ICH onset to the surgery were not statistically different between the groups (1-3 days (median 2 days) in either group). There were no statistically significant differences in the pre-surgical hematoma volume and removal rate between these groups. CT scans of each group were shown in Fig. 1. The improved group included 11 patients with putaminal hemorrhage and 10 patients with thalamic hemorrhage. On the other hand, the unchanged group included four patients with putaminal hemorrhage and five patients with thalamic hemorrhage. There were no statistically significant differences in sex and the location of hemorrhage between these groups.

The age at onset was 43-83 years old (median: 66 years old) in the improved group, whereas 56-93 years old (median: 74 years old) in the unchanged group (Fig. 2a). Statistical analysis revealed that age in the improved group was significantly younger than in the unchanged group (Mann-Whitney test, improved group: $N = 21$, unchanged group: $N = 9$, $p = 0.007$).

Presurgical MMT scale ranged 0-3 (median 2) and 1-3 (median 1) in the improved and unchanged groups, respectively (Fig. 2b). This difference was not statistically significant.

The volume of presurgical hematoma was estimated to be 10-31 ml (median: 16 ml) in the improved group and 12-21 ml (median: 18 ml) in the unchanged group (Fig. 2c). The volume of postsurgical hematoma ranged 3-20 ml (median: 7 ml) in the improved group and 3-12 ml (median: 8 ml) in the unchanged group. Then, the removal rate was calculated to be 25-79% (median: 60%) and 40-75% (median: 50%) in the improved and unchanged groups, respectively (Fig. 2d). There were no statistically significant differences in the presurgical hematoma volume

Table 1. Patient groups.

Group	Improved group	Unchanged group	*P* value
Number of patients	21	9	
Sex (M:F)	13 : 8	5 : 4	0.833
Location of hematoma (putamen: thalamus)	11 : 10	4 : 5	0.833

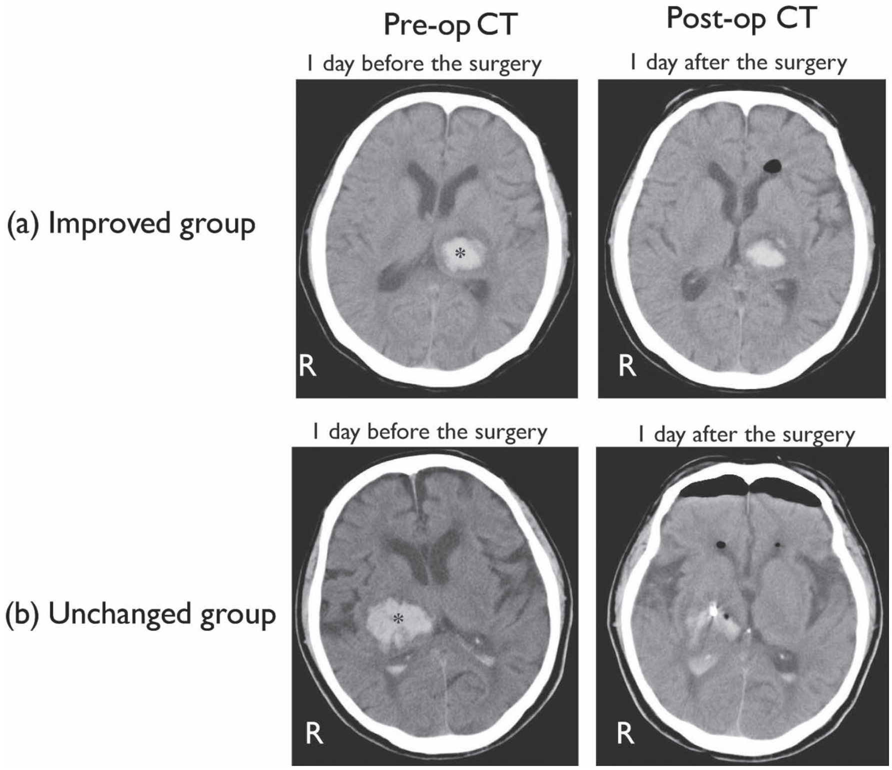

Fig. 1. Pre- and Post-operative CT scans.
Pre-operative (Pre-op) and post-operative (Post-op) CT scans of one patient in the improved group (a) and unchanged group (b). Asterisk represents the predetermined target.

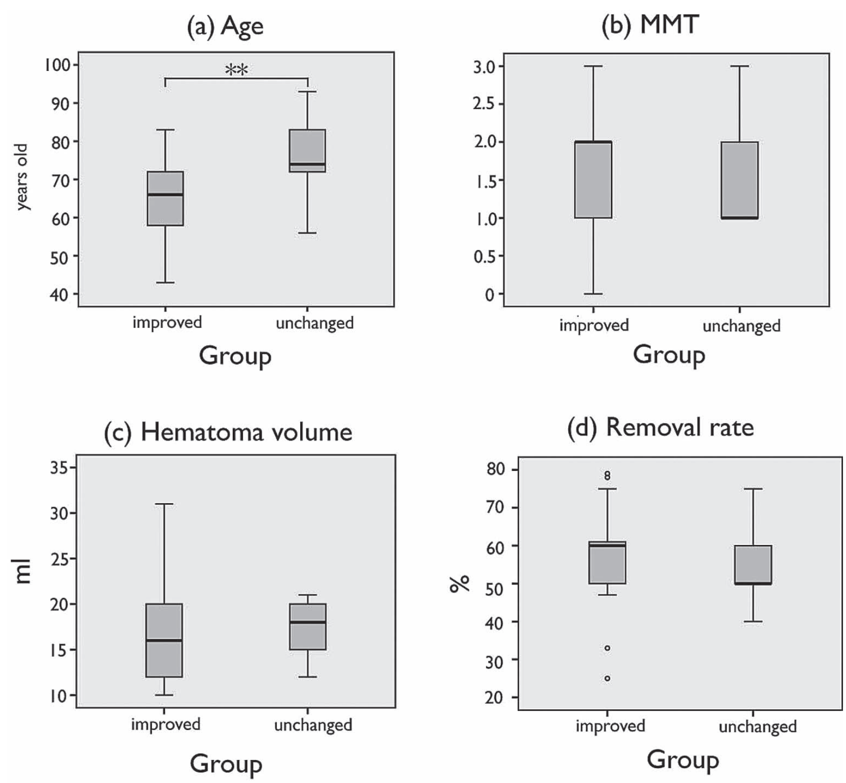

Fig. 2. Box plot of each factor.
Box plots of age (a), Manual Muscle Testing (MMT) (b), hematoma volume (c) and removal rate [(presurgical hematoma volume - postsurgical hematoma volume)/ presurgical hematoma volume] (d) in the improved and unchanged group. $*p < 0.05$, $**p < 0.01$.

and removal rate between these groups.

Discussion

We retrospectively reviewed the medical record of the patients with thalamic or putaminal hemorrhage to investigate the factors affecting motor recovery after stereotactic hematoma evacuation. The finding that emerged from this investigation is that age was the most important factor in motor recovery, and presurgical muscle strength, hematoma volume and removal rate do not significantly influence motor recovery.

Stereotactic hematoma evacuation is minimally invasive surgery and beneficial for clot removal with limited tissue damage. Zhou et al. (2011a, b) suggested the importance of reducing neurotoxic substances released from the hematoma as well as decompression of brain tissue. It has been previously hypothesized that the mass effect caused by hematoma volume is not the dominant injury mechanism, whereas the toxic substances released from the hematoma (i.e. glutamate, hemoglobin) are the most important factor in the pathological mechanism (Huang et al. 2002; Belayev et al. 2003; Miller et al. 2007; Georgiadis et al. 2008). In the present study, presurgical hematoma volume and surgical volume reduction did not significantly correlated with motor recovery. These findings suggest that mass effect of hematoma is not the determinant of motor deficit. In addition, compared with previous reports of stereotactic hematoma evacuation (Teernstra et al. 2003; Zhou et al. 2011a, b), our report includes smaller hematomas associated with motor deficit: 10-31 ml (median 18 ml). This finding also suggested that the other factors such as neurotoxic substances are more associated with the pathological mechanism of neurological deficit than compression by hematoma.

Our result revealed that age is the strongest predictor of motor recovery after stereotactic intracerebral hematoma evacuation, whereas presurgical muscle weakness showed no significant influence on functional recovery over 1 month. Previous studies reported that both age and severity of the neurological deficit are predictors of functional improvement during post-stroke rehabilitation without surgical procedure (Inouye et al. 2000; Kelly et al. 2003; Coupar et al. 2012). It has been suggested that recruiting intact areas of the brain adjacent and connected to the area of primary damage may be responsible for cortical reorganization, leading to functional recovery, and age is one of the factors affecting cortical reorganization (Green 2003; Bayona et al. 2005). The present results suggest that stereotactic hematoma evacuation is beneficial especially for the younger population and cortical reorganization might be the mechanism of functional recovery after this procedure. Based on the hypothesis that clot reduction is beneficial to prevent secondary brain injury, which often occurs in the days following the initial hemorrhage, stereotactic hematoma evacuation could support cortical reorganization and successful post-surgical rehabilitation. Furthermore, functional status on admission was not a determinant of functional recovery after surgery. As severely disabled patients showed comparable improvement, hematoma evacuation should not be withheld from hemorrhagic stroke patients simply because of severe disability.

This study includes certain limitations. First, due to the small number of patients and short-term evaluation, it is difficult to draw definite conclusions on patient characteristics and long-term functional recovery. Next, the motor dysfunction depends on the degree of the internal capsule damages. However, we could not evaluate the internal capsule damages in the present study. Therefore, we cannot exclude the possibility that different extent of the internal capsule damages might cause different functional outcome. The conduction study of the cortical spinal tract through the internal capsule (e.g. motor evoked potential) would be beneficial for the future analysis. Another issue is the evaluation of motor function. We used the MMT scale for functional evaluation, which is practical and easy to perform; however, it could be subjective and fluctuated. A modified NIHSS (National Institute of Health stroke scale) might be more appropriate to measure the motor recovery. In addition, we should note that chronic disease (i.e. coronary heart disease, congestive heart failure, diabetes, hypertension, and dementia) might affect functional recovery, as Inouye et al. (2000) suggested.

In conclusion, we investigated the factors affecting motor recovery after stereotactic hematoma evacuation, and concluded that this procedure is attributable to improvement of motor function, especially at a younger age, indicating the importance of cortical reorganization during post-surgical rehabilitation. In addition, it could provide functional improvement in severely disabled patients. Stereotactic hematoma evacuation is minimally invasive surgery and beneficial for motor recovery, although it has several limitations in its ability to achieve hemostasis and completely evacuate the hematoma. Proper patient selection to receive this therapy would be beneficial for further advances of this technique.

Conflict of Interest

None of the authors has any conflicts of interest to disclose in relation to this work.

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