Clinical Article

Stereotactic Multiplanar Reformatted Computed Tomography-Guided Catheter Placement and Thrombolysis of Spontaneous Intracerebral Hematomas

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Objective : The authors present their experiences with stereotactic multiplanar reformatted (MPR) computed tomography (CT)-guided catheter placement for thrombolysis of spontaneous intracerebral hematoma (sICH) and their clinical results.

Methods : In 23 patients with sICH, MPR CT-guided catheter placement was used to select the trajectory and target point of hematoma drainage. This group was comprised of 11 men and 12 women, and the mean age was 57.5 years (range, 31-79 years). The patients' initial Glasgow Coma Scale scores ranged from 7 to 15 with a median of 11. The volume of the hematoma ranged from 24 mL to 86 mL (mean 44.5 mL). A trajectory along the main axis of the hematoma was considered to be optimal for thrombolytic therapy. The trajectory was calculated from the point of entry through the target point of the hematoma using reformatted images.

Results : The hematoma catheter was left in place for a median duration of 48.9 hours (range 34 to 62 hours). In an average of two days, the average residual hematoma volume was 6.2 mL (range 1.4 mL to 10.2 mL) and was reduced by an average of 84.7% (range 71.6% to 96.3%). The residual hematoma at postoperative seven days was less than 5 mL in all patients. There was no treatment-related death during hospitalization.

Conclusion : The present study indicates that stereotactic MPR CT-guided catheter placement for thrombolysis is an accurate and safe procedure. We suggest that this procedure for stereotactic removal of sICH should be considered for the optimization of the trajectory selection in the future.

KEY WORDS : Intracerebral hematoma · Stereotactic aspiration · Surgical treatment · Thrombolysis.

INTRODUCTION

Intracerebral hematoma (ICH) is associated with the highest mortality rate of all forms of stroke. The role of stereotactic surgery in the treatment of ICH has gained importance over the past decade. Clot removal is beneficial because it reduces the volume of the hematoma and may therefore also lowers intracranial pressure, reduces the chance of edema formation and improves perfusion in the affected hemisphere[4,12,14,18]. However, the main disadvantage of this technique is slowness in the reduction of hematoma volume, taking many days in some cases, as observed in patients with large hematomas[15]. Among the strategies for stereotactic removal of an ICH, it is important to remove as much of the blood clot as possible. To remove

as quickly blood clot as possible, it is important that the catheter be placed accurately along the predetermined trajectory into the target point of the hematoma. In the past our experiences, the residual hematoma after conventional computed tomography (CT)-guided surgery using only axial CT images was mostly observed at the posterior and inferior portion of the hematoma. In conventional CT-guided methods, an optimal catheter insertion is difficult because the aiming trajectory is calculated from the point of entry through the target point of the hematoma using only axial images of the hematoma. The authors present experiences with stereotactic MPR CT-guided catheter placement for thrombolysis of spontaneous ICH and their clinical results.

MATERIALS AND METHODS

Patient population

Between January 2005 and December 2006, 46 patients with spontaneous supratentorial ICH underwent CT-

guided stereotactic aspiration surgery. This group did not include patients who underwent frameless stereotactic surgery, patents with subcortically extending massive ICH, patients with signs of advanced transtentorial herniation, and patients with subacute or chronic hematomas. All patients had arterial hypertension previously or at admission with normal coagulation parameters. ICH localization and volume estimation were performed with 4- (Lightspeed, General Electronic Medical Systems, USA) and 64- (Brilliance, Philips Medical Systems, USA) channel CT scanners. They had an ICH volume exceeding 20 mL. For patients younger than 60 years of age, CT angiography was performed to rule out the presence of underlying vascular anomalies and revealed no vascular anomaly. Surgery had gone possible within 24 hours after ICH onset.

Twenty-three of the 46 patients treated by stereotactic aspiration surgery underwent conventional CT-guided catheter placement using only axial images of the hematoma. MPR CT-guided catheter placement was performed to select the trajectory for hematoma drainage in another 23 of the 46 patients. This group treated by MPR CT-guided catheter placement was comprised of 11 men and

12 women, and the mean age was 57.5 years (range, 31-79 years). The patients' initial Glasgow Coma Scale scores ranged from 7 to 15 with a median of 11. The demographic data and the findings of the initial CT scans of these 23 patients are described in detail in Table 1. The ICH volume was estimated using a validated practical rule (ABC/2, where A=biggest diameter, B=diameter at 90 degrees from A, C=number of slices; the presence of intraventricular hemorrhage was not included in the equation) and ranged from 24 mL to 86 mL (mean 44.5 mL)[13]. All patients were followed up for a minimum of 30 days. The outcome of the patients was assessed 30 days post-hemorrhage using the Glasgow Outcome Scale (GOS)[9].

Operative technique

The catheter was placed with the aid of a Cosman Roberts-Wells head frame (Radionics, Inc). The operations were performed under general anesthesia. An ipsilateral frontal standard burr hole location (3 cm lateral to midline and just anterior to the coronal suture) was generally used for the treatment of the hematoma. A silicone catheter (Youshin Medical; length 35 cm, 1.6/3.0 mm inner/outer

Table 1. Summary of 23 patients who underwent stereotactic multiplanar reformatted computed tomography-guided catheter placement and thrombolysis of spontaneous intracerebral hematoma

No.	Sex/Age	GCS	ICH volume (mL)	ICH Location Side	ICH Location Deep	ICH Location Subcortical	Fibrinolysis with urokinase Total dose (IU)	Fibrinolysis with urokinase Drainage (h)	ICH reduction (mL)	% of ICH removed	GOS
1	M/42	8	84.6	Lt	Put	Fro	56,000	54	76.3	90.2%	MD
2	F/51	7	24	Lt	Tha		32,000	38	19.5	81.3%	MD
3	M/72	12	31.3	Rt	Put	Fro	40,000	40	22.4	71.6%	SD
4	F/79	13	33.6	Lt	Put		64,000	60	26.4	78.6%	MD
5	F/51	13	42	Rt	Put		48,000	41	34.3	81.7%	SD
6	F/61	9	27	Lt	Put		48,000	53	25.6	94.8%	MD
7	F/73	10	72	Lt	Put	Fro	56,000	56	68.9	95.7%	SD
8	M/37	9	73.4	Rt	Put		56,000	59	63.6	85.6%	SD
9	F/54	9	42	Rt	Put		64,000	58	34.2	81.4%	SD
10	M/57	14	51.6	Rt	Put		48,000	52	43.6	84.5%	GR
11	M/72	14	85.7	Rt	Put−Tha	Par	72,000	62	78.1	91.1%	SD
12	M/31	14	39.7	Rt	Put		48,000	56	35.2	88.7%	MD
13	F/51	14	42	Rt	Put		56,000	48	31.8	74.8%	MD
14	F/66	14	28.9	Rt	Put		40,000	50	26.3	91.0%	MD
15	F/65	10	29.7	Lt	Put		48,000	46	27.7	93.3%	MD
16	F/73	9	28.8	Lt	Put		40,000	40	20.3	70.5%	SD
17	F/64	14	36	Rt	Put		48,000	48	32	88.9%	MD
18	M/44	15	43.2	Rt	Put		24,000	50	41.6	96.3%	MD
19	M/46	14	54.3	Lt	Put	Fro	64,000	56	46.1	84.9%	GR
20	M/68	13	24	Lt	Put		40,000	36	18	75.0%	GR
21	M/67	11	55.5	Lt	Put		56,000	48	49.2	88.6%	SD
22	F/61	9	49.4	Rt	Put		48,000	40	43.1	87.2%	MD
23	M/38	12	25.7	Lt	Put		24,000	34	18.7	72.7%	MD

GCS : Glasgow Coma Scale, Rt : right, Lt : left, Put : putamen, Tha : thalamus, Fro : frontal, Par : parietal, GOS : Glasgow Outcome Scale, GR : good recovery, MD : moderately disabled (independent), SD : severely disabled (dependent on others), VS : vegetative state, D : dead

diameter) with small openings at its proximal end over a length of 1.5 cm was used. The picture archiving and communication system (PACS) automatically generated MPR images, regardless of CT scanner type[10]. The MPR images include coronal and sagittal reformatted images that are generated in axial thin-section source images. The aiming trajectory was calculated from the point of entry through the target point of the hematoma using reformatted images (axial, sagittal, and coronal plane) such as the Cartesian coordinates x, y, and z (Fig. 1, 2). The catheter was trajected along the main axis of the hematoma and the small openings of the catheter were placed in the center of the hematoma. A catheter was inserted to the precalculated depth and target point, followed by careful manual hema-toma aspiration and irrigation with a small volume of normal saline. The catheter was anchored to the skin, and connected to a closed external drainage system.

Immediately after surgery, the postoperative hematoma volume and catheter position were investigated by CT. All catheters were placed exactly at the precalculated target point of the hematoma. Urokinase (8,000 IU/2 mL saline) was administered through the catheter, subsequently flushed with 2 mL of saline and then clamped. After 30 minutes the catheter was unsealed and the liquefied hema-toma was drained naturally. The evacuated volume was recorded after every procedure. This evacuation and uroki-

nase injection procedure were performed several times at 6- or 8-hour intervals until the hematoma was completely drained. The catheter was removed when repeated CT scan revealed less than 10 mL of the ICH volume after surgery.

RESULTS

ICH volumes ranged from 24 to 86 mL with a mean of 44.5 mL. The hematoma catheter was left in place for a median duration of 48.9 hours (range 34 to 62 hours). In an average of two days after surgery, the mean residual hematoma volume was 6.2 mL (range 1.4 mL to 10.2 mL) and the ICH volume was reduced by an average of 84.7% (range 71.6% to 96.3%). The residual hematoma at postoperative seven days was less than 5 mL in all patients. The mean number of urokinase instillations was 6.2 times (range 3 to 9 times) and the mean dose of urokinase instillations was 49,600 IU (range 24,000 IU to 72,000 IU). There were 5 subcortically extended ganglionic ICHs and 18 pure ganglionic ICHs. The selection of an appropriate trajectory and the burr hole site were not restricted by the stereotactic device in most of the patients. But, in 3 subcortically extended ganglionic hemorrhages, a burr hole location was modified to place the tip of catheter in the center of hematoma. The modified burr hole site was located 3 cm lateral to midline and about 1 cm posterior to the
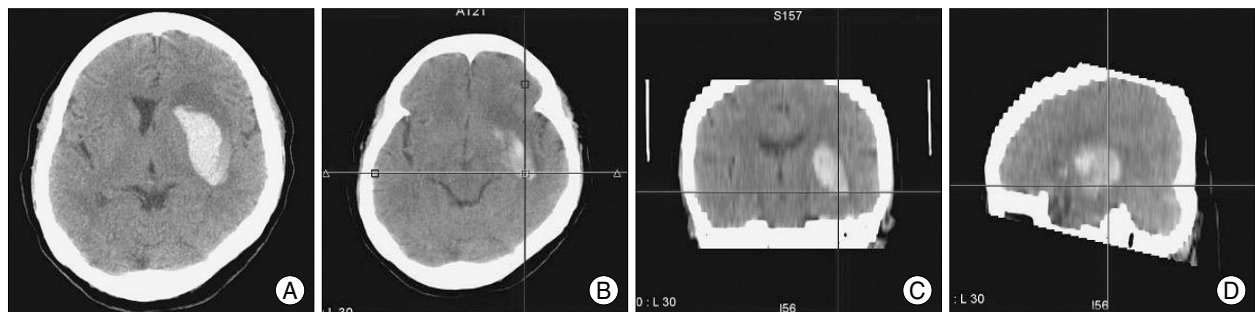

Fig. 1. This 65-year-old hemiplegic patient with a left basal ganglia hematoma (A) underwent stereotactic multiplanar reformatted computed tomography-guided catheter placement for thrombolysis and drainage. We were able to select the optimal trajectory for the catheter along the main axis of the hematoma using reformatted axial (B), sagittal (C) and coronal (D) images.
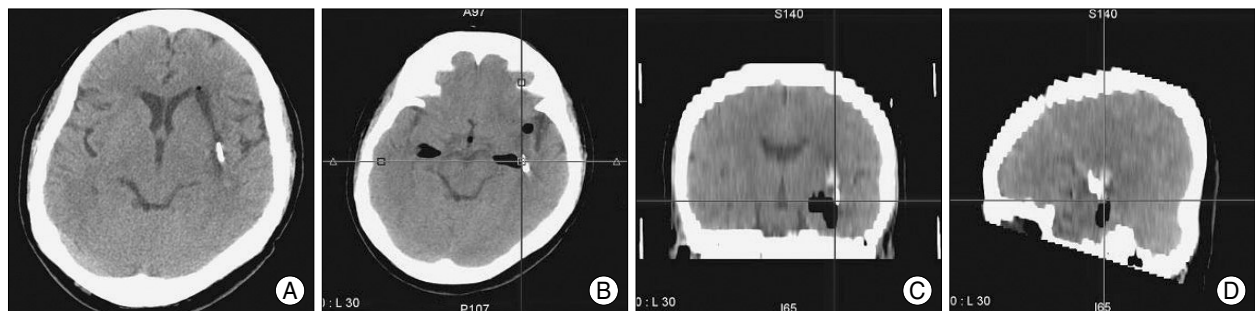

Fig. 2. After the 2-day drainage period, the hematoma was almost completely removed (A). Axial (B), sagittal (C) and coronal (D) reformatted images show the catheter, which is placed along the main axis of the hematoma, as planned preoperatively.

coronal suture.

There were no surgical complications except for 2 minor bleedings around the hematoma catheter, which had resolved on follow-up CT scan. There were no treatment-related deaths during hospitalization. Within the 30 days follow-up period, 8 patients were discharged, but they remained to be dependent because of residual hemiparesis (GOS=SD). Twelve patients suffered a mild neurological deficits (GOS=MD). Three patients achieved good recovery (GOS=GR).

DISCUSSION

Optimal treatment of ICH remains a complex and controversial issue[5,7]. Clinical presentation, age, and the size and localization of the hematoma influence the decision for conservative or surgical treatment[11]. Surgical treatment can be accomplished by several methods, including microsurgical removal after craniotomy with or without ultrasonic guidance, endoscopic hematoma evacuation or the use of stereotactically placed catheters for subsequent fibrinolytic therapy with urokinase, or tPA. Craniotomy has been the standard approach for ICH removal. However, the major disadvantage of an extensive surgical approach is that it may lead to further brain damage, particularly in patients with deep hematomas. Most of the randomized controlled trials have failed to demonstrate a superiority of craniotomy over medical therapy for ICH evacuation[3,16]. Minimally invasive surgical techniques may substantially decrease the volume of a hematoma while avoiding the morbidity associated with major craniotomy procedures, especially in elderly and debilitated patients[1]. Several experimental studies have shown that the infusion of urokinase promotes clot lysis and resorption without producing neurotoxicity, histopathological alterations, or recurrent bleeding[6,17].

The application of stereotactic surgery and minimally invasive therapies to cerebrovascular surgery has led investigators to utilize these techniques to reduce the hematoma volume in the treatment of ICH. The volume of ICH has been consistently shown to be a powerful predictor of poor outcome regardless of clot location, age, or neurological condition[5,7]. The rationale for ICH evacuation is that the reduction of clot volume may improve neurological recovery and clinical outcome. The removal of a focal mass effect may improve perfusion of compromised brain parenchyma and prevent intracranial hypertension. It may also enhance the clearance of blood breakdown products, thereby preventing secondary brain edema and other potential sources of neurotoxicity.

Catheter placement along the main axis in the center of the hematoma was considered to be optimal for effective clot lysis[19,21]. Hondo described the use of a silicone catheter that was inserted into the center of the hematoma after three-dimensional CT images or biplane CT images were taken to determine the coordinates of the target point[8]. Unfortunately, detailed information on how often the adequate selection of the target point allowed optimal catheter positioning was not provided in the already published series on the use of the stereotactic CT-guided method for sICH. Catheter placement is difficult with the conventional CT-guided method because the aiming trajectory is calculated from the point of entry through the main axis of the hematoma using only axial CT images of the hematoma. The selection of the trajectory is based on the experience and spatial orientation capabilities of the neurosurgeon. In the past our experiences, the residual hematoma after conventional CT-guided surgery using only axial CT images was mostly observed at the posterior and inferior portion of the hematoma. Therefore, the target point of the hematoma was generally determined to the posterior and inferior portion of the hematoma. If the entry point should be fixed before the target point is selected, the selection of an appropriate trajectory would sometimes be restricted and the catheter would be placed the outside of the hematoma. The selections of the target point and the trajectory are initially determined and then the proper entry point can be selected. In 3 cases of the extended subcortical lobar hemorrhage, a burr hole location was modified to place a catheter in the center of the hematoma. Catheter placement along the main axis was successful in all cases.

An advantage of this technique is that MPR images are automatically generated, regardless of CT scanner type. And, the selection of the trajectory is not based on the experience and spatial orientation capabilities of the operator but the objective data from MPR CT images. So, catheter placement along the main axis in the center of the hematoma could be achieved with high accuracy and safety using MPR CT-guided methods.

Surgical treatment of ICH using various stereotactic techniques, including fibrinolytic instillation, has evolved over the years, but many investigators have reported aspiration rates ranging from 30% to 80% on average over the first few days[2,8]. Compared with data from the literature, the results obtained using this MPR CT-guided method were highly satisfactory for clot removal. Rhode et al. reported that the development of delayed perifocal edema was intensified by fibrinolytic therapy, which was probably related to the function of tPA as a mediator of edema formation after thrombin release and ischemia[20]. Substantial decompression of the hematoma cavity by the mass effect

from the surrounding edema would have been anticipated in all of the patients in this study, and there were no instances of clinical deterioration due to edema associated with residual hematoma. Early removal of the hematoma allowed the patients to be discharged from the hospital faster and provided a greater chance of neurological recovery. This method appears to be effective at decreasing ICH volume and it is not associated with significant management morbidity. Further applications of this method are being evaluated to clarify whether it provides better neurological and overall recovery than standard craniotomy or conventional stereotactic surgery.

CONCLUSION

The present study indicates that stereotactic MPR CT-guided catheter placement is an accurate and safe procedure for thrombolysis. In comparison with the conventional CT-guided method, the MPR CT-guided method offers objective selection of the optimal trajectory and the appropriate target point for catheter placement. We suggest that this procedure for stereotactic removal of sICH should be considered for the optimization of trajectory selection in the future.

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