Stereotaxic evacuation of spontaneous intracerebral hematomas

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The authors describe a new device for removal of intracerebral hematomas, based on the principle of stereotaxic evacuation of these lesions proposed in 1978 by Backlund and von Holst. The optimum parameters of stereotaxic aspiration, including speed of screw rotation and amount of suction, have been determined experimentally. Computerized tomography scanning was used to locate the hematoma site, to assess its volume, and to determine stereotaxic coordinates. A new method of preventing rebleeding is also described. This procedure was used to aspirate hematomas in 32 patients with spontaneous intracerebral hemorrhage, including one case caused by aneurysmal rupture and one secondary to rupture of an arteriovenous malformation. All patients were operated on in a severely comatose or semicomatose state. In all but four cases, the hematomas were almost totally removed. Three patients were operated on twice because of recurrent bleeding. The mortality rate for the series was 22%. A preliminary conclusion is made that this new method is safer and less traumatic than open surgery in most cases of severe intracerebral hematoma.

Key Words: intracerebral hematoma • stereotaxic evacuation • instrumentation • surgical technique

In 1978, Backlund and von Holst proposed a new principle of stereotaxic subtotal removal of intracerebral hematomas in which a special instrument with a mandrel-like Archimedes screw inside a cannula is used to destroy and remove dense clots. We have improved on this promising method and have designed instrumentation for use in this operative procedure. In this paper, we describe the device and its use in 32 cases of spontaneous intracerebral hematoma, including one case caused by aneurysmal rupture and one secondary to rupture of an arteriovenous malformation (AVM).

Description of Device

The main part of our device is a stainless steel cannula 17 cm long and 4 mm in outer diameter (Fig. 1). There are two interchangeable fittings for the cannula: a metal shaft with a blunt tip, and a thin Archimedes screw for fragmenting densely coagulated clots. As determined by experimental studies the tip of the screw was made 1.5 mm shorter than the open end of the cannula, and the screw was made to occupy only 7% of the space inside the cannula, much less than in the device of Backlund and von Holst. This thin screw markedly increases the effectiveness of aspiration. The screw is connected to a miniature electric motor with a variable speed up to 200 rpm, which is fixed on the outer end of the cannula. A transparent plastic tube on the outer end of the cannula is connected to a glass bottle marked with a milliliter scale. A second tube connects the bottle to a conventional surgical aspirator which can remove the pieces of clot (see Fig. 2). The vacuum pressure of the aspirator can be altered from 0 to 2 atm.

We have also developed a new method of preventing recurrent bleeding after hematoma evacuation. A Silastic balloon is fixed to the tip of a thin catheter. After removal of the hematoma, the balloon catheter with a metal shaft inside is introduced through the cannula into the cavity. Following removal of the metal shaft, the balloon is inflated with sterile saline solution under manometric control. Inflation continues until the pressure inside the balloon equals the pressure in the contralateral ventricle.

Experimental Testing

Before the device was used in clinical cases, it was tested in several series of experiments. In a series of experiments on rabbit brain, the optimum rotation speed of the screw and amount of aspirator suction...
Stereotaxic evacuation of intracerebral hematomas

were determined. In these animals, small trephinations were made under general anesthesia, the dura mater was incised, and the cannula tip was introduced into the brain for 5 to 6 mm. With suction of less than 0.5 atm, there was no aspiration of brain tissue. No tissue damage occurred at screw speeds between 60 and 200 rpm, but the optimum speed was about 100 rpm.

The device was also tested on human blood stored without preservatives for 2 to 7 days in order to establish the correct parameters for suction of the clots. From these studies, the optimum speed of screw rotation for dense clots was found to be about 120 rpm, and for less dense clots about 80 rpm. The amount of suction should be about 0.2 atm.

In the second series of experiments, the optimum length relationship between the tip of the cannula and the tip of the screw was determined. It was shown that with the screw tip 1.5 to 2 mm shorter than the cannula.
tip, damage to brain tissue during aspiration is prevented, and aspiration is more effective.

Preoperative Calculations of Lesions

Preoperative computerized tomography (CT) scanning was used to analyze the size and location of the hematoma and its CT density, the degree of brain edema, the presence of mass effect, and whether there was penetration of blood into the ventricles. The volume of the hematoma was estimated from Polaroid photographs of CT scans in two ways: 1) a planimetric method was used to calculate the hematoma area and depth on each scan, so as to establish the total volume of the hematoma from all cuts on which it appears, and 2) by estimating the volume of the hematoma as the volume of an ellipsoid using the following formula:

\[ V = \frac{4}{3} \pi a \times b \times c, \]

where \( a, b, \) and \( c \) are the hemiaxes of the ellipsoid. The difference in hematoma volume as estimated by these two methods is very small. The results are multiplied by a coefficient of 3.5 to obtain the actual volume of the hematoma.

The contours of the hematoma, calculated preoperatively from the CT scans, are then transferred to plain x-ray films taken in both lateral and anteroposterior projections in the operating room according to routine stereotaxic techniques. In taking the x-ray films it is most important to maintain the same perpendicular position of the base plane as was used for CT scanning. To assure this, the base plane used in the CT investigation was checked by metallic marks on the headholder adjacent to the patient’s head. Using television monitoring with electronic amplifiers, it is not difficult to identify the perpendicular plane for both stereotaxic x-ray films.

Next, a target (or targets) within the hematoma must be selected for introduction of the cannula. We usually choose a point 1 to 2 cm posterior to the center of the hematoma, assuming that during stereotaxic aspiration with the patient in the supine position the pieces of clot will sink to the cannula by force of gravity.

Selection of the site for the burr hole depends on the location and volume of the hematoma. As a rule, we drill the hole near the coronal suture. Identification of the brain structures in the path of the cannula was tenbrand and Bailey.\(^{13}\)

Operative Technique

Before the operation, the sagittal line and the point where it crosses the coronal suture are marked on the patient’s head. The site of the burr hole is measured from both marks. The patient is placed in a supine position with his head on a special head rest and fixed to arterial hypertension and cerebral arteriosclerotic bleeds. One case was caused by aneurysmal rupture and one case by rupture of an AVM. Stereotaxic aspiration

Summary of Cases

During the last 3½ years, we have used this method to evacuate hematomas in 32 patients, 18 men and 14 women, aged 27 to 62 years. Thirty cases were secondary to arterial hypertension and cerebral arteriosclerotic bleeds. One case was caused by aneurysmal rupture and one case by rupture of an AVM. Stereotaxic aspiration

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Stereotaxic evacuation of intracerebral hematomas

FIG. 3. Case 1. Computerized tomography scans in a patient with a large lateral hematoma. Left: Before aspiration. Center: Immediately after surgery the cavity is filled with air. Right: One year after surgery a small cystic strip can be seen at the site of the hematoma.

was carried out at different times after the onset of the hemorrhage: 21 operations within the first 3 days, nine within 4 to 9 days, and two after 3 weeks.

All patients were admitted in grave condition: 14 were stuporous and 18 were comatose. All of them rapidly developed severe neurological deficits, including complete or nearly complete hemiplegia, hemianesthesia, aphasia, and hemianopsia. Some patients had cardiovascular and breathing disturbances, and the majority had a very high blood pressure.

The CT scans disclosed hematomas in combinations of basal ganglia, thalamus, or internal capsule in 14 cases, located lateral to or in the globus pallidus or putamen in 16 cases, and located medially in the thalamus in two cases. Massive penetration of blood into the ventricular system was noted in 19 cases. Brain edema was present to some degree in all patients. The hematoma volume, calculated as described above, varied from 24 to 115 ml, being less than 30 ml in nine cases, 30 to 50 ml in nine cases, and more than 50 ml in 14 cases.

In all but four cases the hematomas were removed totally, as confirmed by control CT immediately after surgery. It is important to stress that in a majority of cases it was also possible to remove almost all clots from the ventricles. In most patients the postoperative condition was poor, as is usually true after removal of spontaneous hemorrhages. All patients required a long period of intensive care.

Repeat hemorrhages developed in five patients (16%) in whom total hematoma removal had been confirmed by CT investigation. Three of them underwent reoperation by the same method, and two survived.

There were seven deaths (22%) that occurred between 3 days and 2 weeks after the operation. All but one of these patients had been comatose before surgery. Death was caused by recurrent hemorrhage in three cases, pulmonary thromboembolism in three cases, and renal insufficiency in one. Five of the seven patients who died had been operated on early after stroke: that is, within the first 3 days. It is interesting that the deaths due to rebleeding (three cases) occurred after early operation (up to 3 days after onset), but those due to pulmonary embolism (three cases) occurred after delayed surgery (from 3 to 7 days).

The surviving 25 patients have been followed from 2 months to 3½ years postoperatively. Twenty-three patients have had some resolution of their neurological deficit. Five of them have enjoyed almost complete recovery, and are working full-time at their jobs or at housework. Eighteen patients with hemiparesis can walk with the help of a cane and are relatively independent. Two patients are bedridden. There were no recurrent hemorrhages during the follow-up period.

The following six cases describe the use of the stereotaxic aspiration procedure to evacuate hematomas due to various causes.

Illustrative Case Reports

Lateral Hematomas Due to Hypertension

Case 1. This 51-year-old woman had suffered from arterial hypertension for many years. She was admitted to our clinic in deep stupor, with right-sided hemiplegia and aphasia. The CSF contained much blood. Computerized tomography scanning disclosed a large hematoma (65 ml) in the left hemisphere lateral to the internal capsule (Fig. 3 left).

On the 7th day after hemorrhage complete stereotaxic aspiration of the hematoma was carried out (Fig. 3 center). Five days after surgery, voluntary movements appeared in the right extremities and the patient began to speak a few words. Relatively rapid recovery took place over the next 2 months. One year after operation,
only slight hemiparesis and sensory aphasia remained. The patient can now walk with the help of a cane. On control CT, a small cystic area was noted at the hematoma site (Fig. 3 right).

Case 2. This 58-year-old woman was admitted in a comatose condition with left-sided hemiplegia and signs of secondary brain-stem dislocation. She had suffered for many years from arterial hypertension and cerebral arteriosclerosis. Computerized tomography scanning revealed a medium-sized (35 ml) hematoma in the right hemisphere, lateral to the internal capsule (Fig. 4 left).

The day after the stroke the hematoma was removed by stereotaxic aspiration (Fig. 4 right). Six hours after surgery the patient regained consciousness, and voluntary movements appeared in the left arm and leg. Three months after surgery, strength and motion in the left extremities were restored completely. The patient is walking without help and is fully independent.

Thalamic Hemorrhage

Case 3. This 53-year-old woman had suffered from arterial hypertension for many years. She suddenly developed right-sided hemiplegia with aphasia, and was admitted to our clinic in a deeply stuporous state. Computerized tomography studies disclosed a relatively small hematoma (25 ml) in the left thalamus with involvement of the internal capsule (Fig. 5 left). The lateral and third ventricles contained massive amounts of blood.

Total stereotaxic evacuation of the hematoma and partial removal of blood from the lateral ventricle was carried out on the day after stroke (Fig. 5 right). Two weeks after surgery, motion in the right extremities and spontaneous speech began to return. At 2½ years after surgery, only mild right-sided hemiparesis and light motor aphasia remain. The patient walks with the aid of a cane.

Recurrent Hemorrhage

Case 4. This 42-year-old woman had a long history of renal arterial hypertension with recurrent crises. She was admitted to our clinic in severe coma with nonresponsive pupils. Pathological reflexes were bilateral. A very large hematoma (87 ml) in the region of the internal capsule was observed on CT scans.

The hematoma was removed completely by stereotaxic aspiration 18 hours after the onset of stroke. Postoperatively, the patient's condition improved rapidly. She regained consciousness and responded appropriately to simple commands. Three days later, after a temporary rise in blood pressure to 210/130 mm Hg, her condition worsened rapidly and she became deeply stuporous. Repeat CT scanning showed a recurrent hematoma of the same volume and in the same location as before (Fig. 6 left). A second complete stereotaxic evacuation was performed immediately (Fig. 6 right). The next day the patient was fully conscious, but re-
Stereotaxic evacuation of intracerebral hematomas

Fig. 7. Case 6. Angiograms in a patient with a small arteriovenous malformation (AVM) and a large hematoma. Left: Anteroposterior view showing the AVM (arrow), shift of the anterior cerebral artery to the left, and marked spasm of the middle cerebral artery. Right: Lateral view showing the AVM (arrow).

quired artificial respiration for about 3 weeks. Her condition improved gradually thereafter. One and a half years after surgery the patient is in relatively good condition. She has quite severe hemiparesis, but can walk with a cane.

Aneurysm Rupture

Case 5. This 27-year-old man was admitted in critical condition with a history of acute loss of consciousness. He was deeply stuporous with left-sided hemiplegia and an advanced brain-stem syndrome (that is, with roving divergence movements of the eyeballs, bilateral pathological reflexes, and cardiovascular and respiratory disturbances). Tracheostomy was performed and artificial ventilation was instituted. Angiography revealed a small aneurysm of the middle cerebral artery, and CT disclosed a large hematoma (55 ml) located deep within the right hemisphere.

Stereotaxic evacuation was undertaken a few hours later, and 35 ml of dark blood and clots was removed; the part of the hematoma near the aneurysm was not evacuated, however. The patient's condition improved rapidly, and 1 month later he began to walk. On control angiograms, no filling of the aneurysm was noted. Six months after surgery the patient has only a mild hemiparesis and walks without a cane.

This case represents an extremely rare instance of spontaneous thrombosis of an arterial aneurysm.

Arteriovenous Malformation

Case 6. This 43-year-old nonhypertensive woman suddenly developed left-sided hemiplegia and became stuporous. Bloody CSF was obtained on lumbar puncture after admission. Angiography disclosed a small AVM near the main trunk of the right middle cerebral artery (Fig. 7). Severe spasm of the artery was noted. The right anterior cerebral artery was shifted markedly to the left. A CT scan showed a large hematoma (70 ml) in the frontal and temporal lobes with penetration of blood into the third ventricle (Fig. 8 left).

Two days after the onset of symptoms, about 50 ml of the hematoma was removed stereotaxically. One-third of the hematoma was left near the AVM (Fig. 8 right). The next day the patient was alert, with some voluntary movements of the left extremities. She began to walk 2 weeks after surgery. One month later, movement in the left arm and leg had returned completely. She refused another operation for removal of the AVM. During 2 years of follow-up evaluation, there has been no rebleeding.

Fig. 8. Case 6. Computerized tomography scans in a patient with a small arteriovenous malformation and a large hematoma. Left: Before aspiration. Right: After subtotal evacuation.
Discussion

Surgical treatment of spontaneous intracerebral hemorrhage has improved during the past three decades, but many important problems still remain to be resolved. There are many different and sometimes opposite viewpoints with regard to indications for surgery, timing of the operation, and surgical techniques. The postoperative mortality rate has varied greatly in different reports, ranging from 20% to 80%, with some patients, such as those in deep coma or those with a medial (thalamic) hemorrhage, having a mortality rate as high as 90%.8-10,12,14,15

The classic method of removal of intracerebral hematomas by craniotomy and encephalotomy is not technically difficult but, as clinical experience has shown, the operation is risky in gravely ill patients. This situation has stimulated a search for less traumatic, more tolerable, and safer methods of removal of intracerebral hematomas.

It is known that, a few hours after the onset of symptoms, a hematoma consists of liquid blood (about 20% of its volume) and dense clots (about 80%). In the past, attempts to remove hematomas through a cannula, even one with a large diameter, have often been unsuccessful because evacuation of the dense clots was practically impossible. In 1965, Benes, et al.,2 suggested the aspiration of hematomas through a cannula introduced stereotaxically, but this was ineffective and was not accepted in practice.

The principle of stereotactic evacuation of intracerebral hematomas proposed by Backlund and von Holst1 in 1978 is original and imaginative. The use of an Archimedes screw to fragment dense clots allows them to be removed through a relatively narrow cannula introduced stereotaxically. Obviously, the operation is much less traumatic than the classic open removal of hematomas. The authors reported only one case in which the method was used. In 1982, Broseta, et al.,3 described the use of the method in 16 patients. Eleven of their patients were comatose, and nine had blood in the ventricles. Postoperative mortality was extremely high (81%).

Proper technical equipment is required for the successful use of this method. The original device described by Backlund and von Holst1 has some serious shortcomings. For example, manual rotation of the screw by the surgeon is not only inconvenient but it is nearly impossible over an extended period. Higgins and Nashold4 modified the device by adding a thin tube inside the cannula. That tube was used to maintain suction in cases in which the lumen of the cannula was filled by pieces of clot. It was also possible to inject saline solution through the tube into the hematoma cavity.

The design of our device offers several important improvements. These include rotation of the screw by a small motor; the use of a very thin screw, which provides ample free space inside the cannula; variation in the amount of suction; a straight line of aspiration instead of aspiration into a side tube; a short distance between the tip of the cannula and the end of the screw, which increases the effectiveness of the device; and exact assessment of the volume of hematoma removed.6,7,11

Recurrent bleeding that develops after hematoma aspiration remains an important unsolved problem. Rebleeding occurred in 16% of our cases. Since CT control studies have shown that the hematoma cavity does not collapse immediately after aspiration, negative pressure in the cavity may be one of the main factors predisposing to recurrent bleeding. To prevent this very serious and relatively frequent complication, we have inflated a Silastic balloon in the cavity after evacuation of the hematoma. None of the patients in whom we used this method suffered rebleeding; however, as our experience is still limited, we cannot draw any definite conclusions.

We do not agree with Backlund and von Holst1 that total evacuation of spontaneous hematomas should not be undertaken. As our experience has shown, it is possible and advisable to remove practically the entire hematoma, leaving only a few milliliters of blood. There is no evidence that complete removal of the hematoma increases the risk of recurrent bleeding; however, one must be very careful with the aspiration of hematomas after aneurysm rupture. In such instances the clot near the aneurysm should not be disturbed, as we have shown in our Cases 5 and 6.

Conclusions

Our experience with stereotactic evacuation in 32 cases of hematomas secondary to spontaneous, aneurysmal, and AVM intracerebral hemorrhages has shown that the method described here is effective and offers certain advantages over conventional surgical treatment. With our method it is possible to totally or subtotally evacuate intracerebral hematomas of different sizes and in various locations, and to remove blood clots from the cerebral ventricles. The operation is less traumatic and safer than open surgery, and is a method that may be used in patients who are deeply comatose.

References

Stereotaxic evacuation of intracerebral hematomas


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