PAPER

Coiling and neuroendoscopy: a new perspective in the treatment of intraventricular haemorrhages due to bleeding aneurysms

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Background: Intraventricular haemorrhages (IVHs) caused by bleeding aneurysms are critical conditions that often carry a severe prognosis. Two main problems must be urgently dealt with: the secondary damage caused by intraventricular clotting and the risk of early rebleeding. A protocol of ultra-early endoscopic ventricular evacuation, after securing the aneurysm with coils, is proposed to solve this challenge in the acute phase and within a few hours of onset.
Methods: Ten consecutive patients presenting with haematocephalus from aneurysm rupture were treated in our institute with coiling and endoscopic clot aspiration extended to the whole ventricular system. The only inclusion criteria were the presence of a massive IVH and an aneurysm appropriate for coiling. Computed tomography scans obtained before (within 4 h of symptom onset in all patients) and immediately after surgery were compared for Graeb score and ventriculocranial ratio (VCR); the Glasgow Outcome Scale (GOS) was assessed at 1 year.
Result: All patients were treated within 2 days of onset. The procedure resulted in a mean 58% removal of ventricular blood and decrease of hydrocephalus; the mean (standard deviation (SD)) Graeb score reduced from 11.5 (0.7) to 4.7 (2.2) ($p<0.001$) and mean ventriculocranial ratio from 0.26 (0.06) to 0.17 (0.05) ($p<0.001$). No rebleeding or delayed hydrocephalus needing shunt was observed. Mortality at 1 year was 30%; marked disability (GOS = 3) and good recovery (GOS = 5) were observed in 40% and 30% of patients, respectively.
Conclusions: Early neuroendoscopic removal of blood casting from the lateral to the fourth ventricle after coiling of bleeding aneurysms is a feasible approach, allowing in most instances the rapid improvement of the IVH.

Intraventricular haemorrhages (IVH) secondary to subarachnoid haemorrhage (SAH) from aneurysm rupture often predict an unfavourable prognosis. Their management must urgently and simultaneously deal with two main problems: (1) the mass effect of intraventricular clots, ventricular enlargement and intracranial hypertension,[1 2] leading to rapid neurological deterioration and (2) the high risk of early rebleeding. In the past, clinicians often postponed the clipping of bleeding aneurysms to the positioning of external ventricular drainage so as to at least partially evacuate intraventricular cerebrospinal fluid and blood. Lowering the high intracranial pressure could, however, precipitate rebleeding, especially in severe SAH, although opinions are not in agreement on this point.[3–5] Therefore, to optimise the outcome, exclusion of the aneurysm from circulation and treatments to decrease intracranial pressure should be strictly synchronised. In previous reports,[6 7] we have described a safe and relatively effective endoscopic approach to IVH of various aetiologies. In this work, we report our experience with a combined approach, which deals with both the haemorrhage itself and its recognised cause. The use of coils to embolise the aneurysm, immediately followed by endoscopic removal of the casting clots from the entire ventricular complex, might be the ideal choice to rapidly and effectively deal with this therapeutic conundrum with a minimally invasive approach. If adequately carried out, this protocol could lead to substantial and immediate radiological improvement, interrupting secondary nervous damage.

MATERIALS AND METHODS

Ten consecutive patients (five men and five women, mean age 61 years, range 40–80 years) presenting with SAH and massive IVH from aneurysm rupture were treated in our department with coiling and endoscopic aspiration of intraventricular casting clots (table 1).

The only inclusion criteria were the presence of a massive IVH (Graeb score >10, with complete occlusion of the third and fourth ventricles) and an aneurysm considered appropriate for coiling by our interventional neuroradiologist for either complete occlusion or near-complete occlusion (essentially aneurysm diameter ≥ 2 mm, with suitable neck and position). All patients were clinically evaluated by the Glasgow Coma Scale (GCS) within 3 h of onset of symptoms, and a computed tomography scan was obtained within 1 h of admission to hospital (including cases transferred from other hospitals; figs 1, 2). Cisternal blood was either diffuse or absent in all patients (Fischer group 4). Severity of IVH was graded by the Graeb scale[8]; the degree of hydrocephalus was assessed by calculating the ventriculocranial ratio (VCR), measured as the ratio of ventricular width behind the frontal horns between the caudate nuclei, where the walls are nearly parallel, to the width of the brain at the same level.[9] The percentage reduction in IVH was estimated from the comparison of pre-Graeb and post-Graeb scores. Wilcoxon

Abbreviations: GOS, Glasgow Outcome Scale; IVH, intraventricular haemorrhage; SAH, subarachnoid haemorrhage; VCR, ventriculocranial ratio

Table 1 Demographic, clinical and radiological data of patients

Pt	Age (years)	Aneurysm location	GCS on admission	Graeb pre	VCR pre	Endoscopy day	Previous EVD (days)	WFNS before endoscopy	Endoscopy v coiling timing	Graeb post	Blood removal (%)	VCR post	EVD (days)	Neuro-ICU stay (days)	VP shunt	GOS
1	80	ACoA	7	11	0.35	0	No	4	Endo→coil	1	91	0.20	23	21	No	1
2	53	ACoA +MCA	11	12	0.32	0	No	4	Endo→coil	5	58	0.19	7	16	No	5
3	52	Pericallosal artery	3	12	0.22	0	No	5	Endo→coil	2	83	0.16	15	12	No	3
4	60	Right MCA, giant	4–5	12	0.26	0	Yes (some hours)	5	Coil→endo	4	67	0.17	7	7	No	3
5	40	Left MCA	7	11	0.173	0	No	4	Coil→endo	5	55	0.1	8	22	No	5
6	66	Basilar tip	3	12	0.345	2	Yes (2)	5	Coil→endo	5	58	0.259	20	15	No	1
7	65	ACoA	7	12	0.293	1	Yes (1)	4	Coil→endo	5	58	0.192	10	15	No	3
8	66	Basilar tip	4	10	0.3	0	Yes (some hours)	5	Coil→endo	8	20	0.23	7	7	No	1
9	53	Left PCoA origin	12	11	0.155	2	Yes (2)	4	Coil→endo	4	64	0.094	14	20	No	5
10	75	ACoA	6	12	0.26	2	Yes (2)	5	Coil→endo	8	33	0.18	15	14	No	3

ACoA, anterior communicating artery; BA, basilar artery; EVD, external ventricular drainage; GCS, Glasgow Coma Scale; GOS, Glasgow Outcome Score; ICU, intensive care unit; MCA, middle cerebral artery; PCoA, posterior communicating artery; pre, at admission; post, after operation; Pt, patient; VCR, ventriculocranial ratio; VP, ventriculoperitoneal; WFNS, World Federation of Neurological Surgeons Scale.
Graeb score compounds the amount of blood in the ventricular system in a non-parametric scale from 0 to 12 (0, no blood; 12, all ventricles filled with blood). The higher the VCR, the more severe the ventricular dilatation (normal values are <0.155).

matched-pairs test and the paired t test were applied to evaluate the changes in Graeb score and VCR.

Angiography was obtained in all patients at admission to our department, and showed an anterior communicating artery aneurysm in four patients, a middle cerebral artery aneurysm in two, a basilar tip artery aneurysm in two, a posterior communicating artery aneurysm in one and a pericallosal artery aneurysm in one. Mean aneurysm diameter was 7.5 mm (range 2–22 mm). Coiling was carried out simultaneously with angiography in the last seven patients; in the first three patients, coiling was delayed, and was performed after endoscopic evacuation of intraventricular blood. Angiographic results were assessed immediately and classified as class I (complete occlusion), class II (neck remnant) and class III (sac remnant).[10] For endoscopic evacuation of intraventricular blood, a flexible endoscope (external diameter 3.9 or 4 mm) was used in all patients, with the working channel as a sucker. Access was unilateral in eight patients and bilateral in two, through a 12-mm prefrontal parasagittal burr hole in all procedures. The first goal of the combined procedures considered in this study, besides the securing of the bleeding aneurysms, was the immediate postoperative computed tomography evidence of endoscopic cleaning of clots from the ventricles.

Endoscopic technique

After coiling the aneurysm following the standard Seldinger technique, the intubated patient is taken into the operating theatre and placed in a supine position. The surgical approach is through frontal burr holes 2 cm anterior to the coronal suture and 2 cm from the midline. The direction of the trajectory to reach the ventricles resembles that of ventriculostomy in hydrocephalus—that is, oriented towards the Monro foramen.

Usually, inspection is totally indistinct because only the reddish colour of the clot in the lateral ventricle can be seen. Evidently, this stage of the procedure is to some extent blinded, and thus it is vital to cease aspiration as soon as the reddishness beyond the scope begins to disappear and the white of the ventricular walls becomes visible. If the surgeon follows these simple rules and proceeds carefully and patiently, a large amount of blood can be removed. The procedure can be limited to one side or extended to the other side depending on the Graeb score and on the volume of the

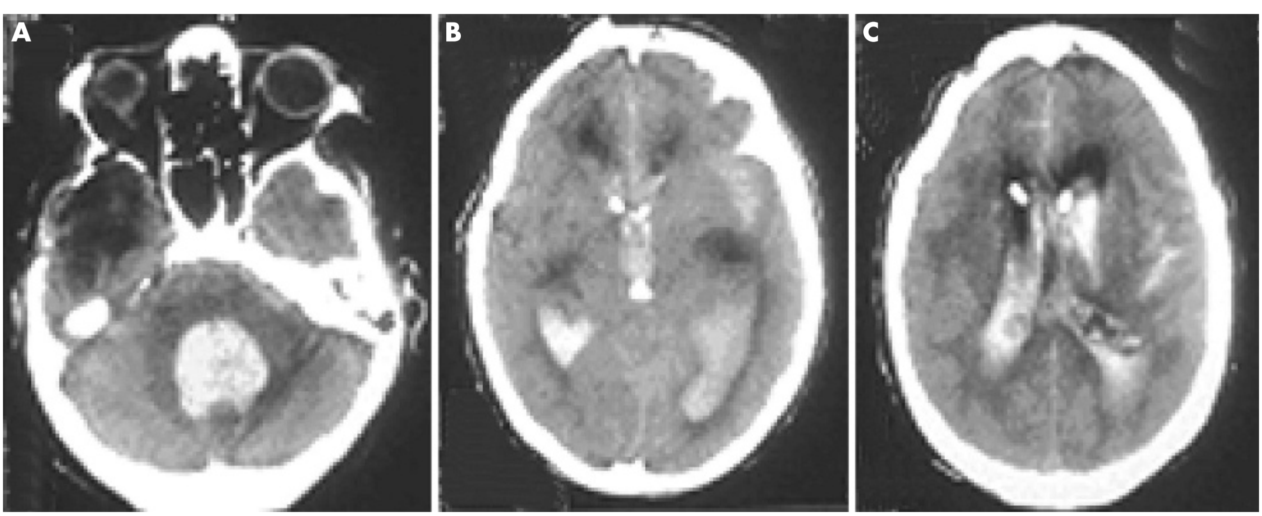

Figure 1 Preoperative computed tomography scan showing the massive intraventricular haemorrhage (IVH), with blood filling the fourth (A), third (B) and lateral (C) ventricles (patient 6).

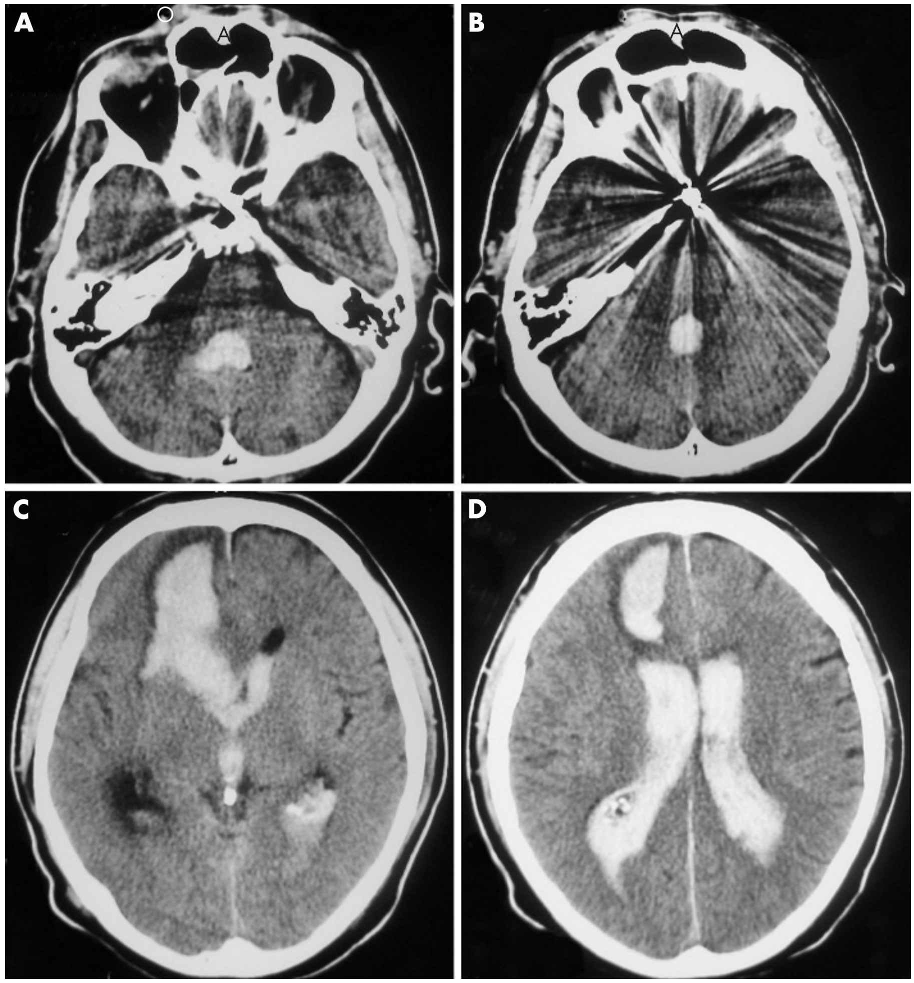

Figure 2 Pre-operative computed tomography scan showing haematocephalus from rupture of the anterior communicating artery (AcoA); coils are evident in (B) (patient 7).

dilated ventricles. The aspiration manoeuvres through the working channel are alternated with rinsing with Ringer's lactate solution and, within a few minutes, the plexus in the lateral ventricle can be seen. This anatomical landmark is important as it immediately orientates the neuroendoscopist and leads toward the Monro foramen. Again, diligent alternate manoeuvres of aspiration and irrigation permit complete clearance of the intraventricular clots, even those impinging on the aditus of the aqueduct and fourth ventricle. Inside the fourth ventricle, irrigations and aspirations must

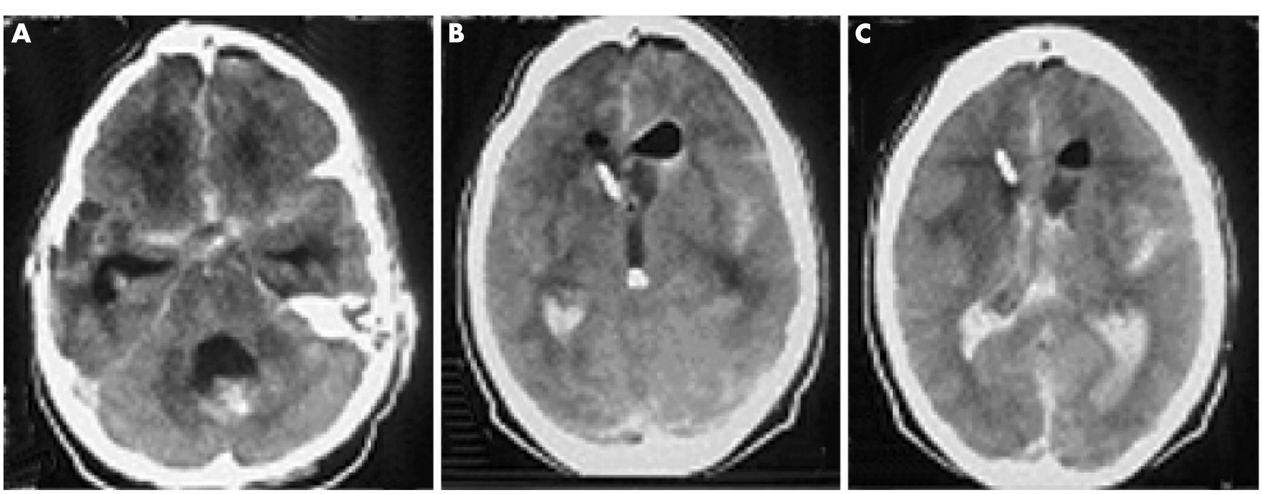

Figure 3 Immediate postoperative computed tomography scan: the fourth and third ventricles are completely free of blood (A, B); a residue of blood in the lateral ventricles (C), which is not considered crucial for circulation of cerebrospinal fluid (patient 6).

be rigorously isovolumetric, as the clots occlude the outlets and the aqueduct is obstructed entirely by the fibrescope. Clot removal from the third and fourth ventricles takes no longer than 5 min per clot and, on inspection, they usually prove to be totally cleared, as confirmed by the control computed tomography scan. When this has been achieved, the surgeon returns to the lateral ventricles and seeks to remove the trigonal and occipital portions of the haematoma. Aspiration of blood from the lateral ventricles is more time consuming, as casts are usually more consistent and voluminous, and repetitive aspirations are thus needed.

RESULTS

All patients underwent complete treatment within 2 days of symptom onset, most of them (6/10) at day 0. In the first three patients, endoscopic evacuation was the initial treatment, followed by coiling of the aneurysm: in the first patient, because of the patient's age and poor GCS, an angiography was not even planned initially, and it was carried out only after the patient survived the endoscopic cleansing; in the second case, an interventional neuroradiologist was not immediately available; and in the third case, the patient was anisocoric with GCS = 3, and a relief of the high intracranial pressure could not be delayed. In the other seven patients, the aneurysm was instead secured immediately before endoscopic aspiration. The entire coiling procedure took on average 80 min (range 40–120 min), and this protocol in our opinion is the best sequence of the combined procedure.

Angiography obtained at the end of coiling procedure showed complete exclusion of aneurysms from circulation in five patients (class 1); in three patients there was a minimum neck remnant (class 2); and in two patients there was a small ''dog-ear'' sac remnant.

In all 10 patients, a ventricular diversion was left after endoscopic evacuation, to measure the intracranial pressure and to be able to immediately manage its possible increase. A control computed tomography scan was always carried out in the immediate postoperative period (figs 3, 4). The endoscopic procedure resulted in a substantial removal of intraventricular blood (20–91%, median 58% of the initial intraventricular blood as judged by the computed tomography scan), and a mean (standard deviation (SD) significant reduction of the Graeb score from 11.5 (0.7) to 4.7 (2.2) ($p<0.001$). Complete clot removal from the third and fourth ventricles, a crucial point of the procedure in our experience, was possible in 9 of 10 patients. Consequently, hydrocephalus also decreased significantly; VCR decreased from a mean of 0.26 (0.06) to 0.17 (0.05) ($p<0.001$). The external diversions were removed 7–23 days after endoscopy (12.6 (5.7) days), and no patient required a permanent shunt. Average stay in the intensive care unit was 14.9 (5.2) days. No rebleeding or delayed hydrocephalus needing shunt was observed. The overall mortality at 1 year was 30% (all three patients died within 3 weeks from admission). In all, 3 (30%) patients had a good recovery (Glasgow Outcome Scale (GOS) = 5) and 4 (40%) showed marked disabilities requiring help in most activities of daily life (GOS = 3).

DISCUSSION

We propose an approach that enables simultaneous resolution of the primary cause of the haemorrhage and of well-known secondary damage caused by intraventricular blood (leading to acute elevation of intracranial pressure, ischaemic encephalopathy and secondary hydrocephalus).[11] The mortality observed in our series was strongly affected by the location of the bleeding aneurysm and GCS at admission: two of the three deceased patients presented with SAH and IVH from basilar tip aneurysm rupture and with very poor admission GCS scores (3 and 4, respectively); the other deceased patient was the first of our series, an 80-year-old woman with GCS = 7 at admission. Death rates reported in the literature range from 33% to 65%,[12–14] and the proposed approach is obviously not the panacea to this dreadful challenge. Nonetheless, an evident rationale exists in the benefits of acutely removing intraventricular blood, as blood and its derivatives have been clearly shown to be pro-inflammatory agents and the cause of secondary neurological damage.[11 15] Accordingly, a packed intraventricular clot on computed tomography scan has a very negative predictive value in patients with high-grade SAH.[13]

The dichotomous distribution of the 1-year outcome in the surviving patients is particularly interesting; three of them showed good recovery with no disability and four showed moderate to severe disability. This result reinforces the view that even patients with very massive IVH from ruptured aneurysms, if treated aggressively and quickly, have a possibility of returning to fully active lives.

Conventional management of IVH consists of external ventricular drain, but catheters invariably become occluded by coagulated blood, which may remain in the ventricles for weeks due to the poor fibrinolytic activity of the cerebrospinal fluid.[16] A recent report on intraventricular infusion of tissue plasminogen activator in IVH after aneurysm coiling or clipping showed efficacy, albeit in a few days, in dissolving

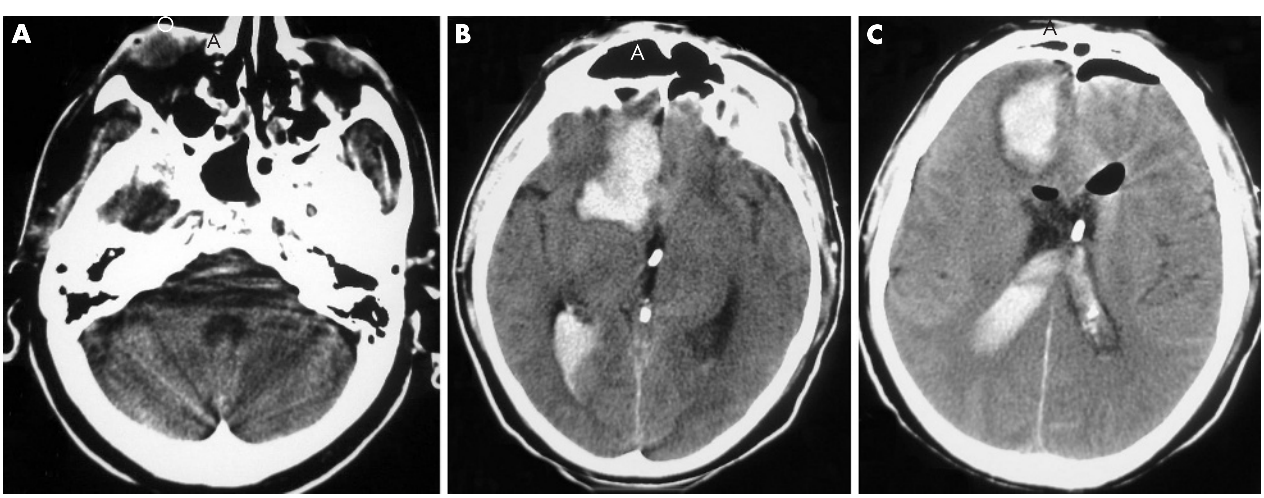

Figure 4 Immediate postoperative computed tomography scan (patient 7).

ventricular casting clots.[14] Furthermore, a potential advantage of our intervention compared with intraventricular thrombolysis is to avoid the risk of exposure to the thrombolytic agent with its associated risk of intraparenchymal bleeding.[17] Mortality in the treated group was 10%, but mean GOS score was 3.2, with only 1 of 10 patients reaching GOS 5. It is difficult to compare these results with ours, as both the mean GCS at admission and the Graeb score of the enrolled patients were substantially more severe in our group. Management of IVH by craniotomy and miscrosurgery has also been described.[18] Such an approach, although clearly more invasive, aims at the same goal as ours: to swiftly remove as much intraventricular blood as possible while securing the vascular source of bleeding.

In the first three cases of our series, the sequence of actions (first endoscopy, next coiling) was dictated by peculiar conditions: poor clinical conditions or advanced age in two cases, and absence of an interventional neuroradiologist in the other case. This last example underlines a possible weakness of our approach. Both selective and effective neuroradiological management of a ruptured intracranial aneurysm, and intraventricular endoscopic navigation in a haemorrhagic field, require dedicated, skilled and experienced teams. The epidemiology of intraventricular haemorrhage, and the organisation and financial cost of maintaining such a team available on a 24-h basis clearly indicate that only major referral centres will be able to efficiently implement and sustain such teams. This in turn calls for an effective networking of referral centres with emergency rooms of smaller hospitals for prompt triage and eventual rapid transfer of putative candidates for intervention. At present, the small number of patients treated thus far does not allow the identification of any relevant outcome predictor, with the possible exception of the posterior location of the aneurysm. The documentation of larger series of treated patients may help clarify this issue.

We expect that our aggressive protocol, besides eliminating the risk of rebleeding, will reduce the secondary damage due to haemorrhage and intracranial hypertension, giving in this way the best chances to our patients.

The critical technical points of the endoscopic procedure lie in the special care that should be paid to clot removal, particularly while navigating through the Monro foramina (from the homolateral frontal horn of the lateral ventricle), the third and the fourth ventricles. Casting clots inside the occipital horns and generally in the lateral ventricles, even if copious, are indifferent and do not affect the outcome and in particular the onset of late hydrocephalus.

A point of criticism in our work is the lack of comparison of the proposed endoscopic evacuation with the standard IVH treatment of external diversion (with or without tissue plasminogen activator infusion). However, the objective of this work was to test the feasibility and to provide preliminary data on the effectiveness of this approach using objective neuroradiological and clinical end points in an observational design. A more structured randomised trial is now warranted to provide comparative indications of efficacy and possibly useful predictive parameters for optimal patient selection.

CONCLUSION

Early neuroendoscopic intraventricular blood aspiration extended towards the fourth ventricle after coiling of bleeding aneurysms seems to be safe and feasible. Through the ultra-early approach adopted in this preliminary experience, acute immediate endoscopic removal of intraventricular clotted blood could be of benefit to patients, because as soon as both the coiling and endoscopic procedures have been completed, the risk of rebleeding and particularly the persistence of tetraventricular haemorrhages do not create an additional burden on what is already a severe prognosis.

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