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COMPARATIVE ANALYSIS OF THE RESULTS OF ENDOSCOPIC SURGERY AND EXTERNAL VENTRICULAR DRAINAGE IN PATIENTS WITH INTRAVENTRICULAR HEMORRHAGE

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The aim of the study is to perform comparative analysis of external ventricular drainage and endoscopic surgery results in patients with intraventricular hemorrhage.
Materials and methods. A retrospective analysis was performed in 29 patients with intraventricular hemorrhage who underwent surgery at the N.V. Sklifosovsky Research Institute of Emergency Medicine, Moscow, and the Yaroslavl Regional Clinical Hospital. Endoscopic surgery for intraventricular hemorrhage was performed in 15 cases (treatment group), and in 3 cases endoscopic removal was accompanied by external ventricular drainage. External ventricular drainage without endoscopic surgery was performed in 14 cases (control group), and in 3 of these cases local fibrinolysis was also performed. In the treatment group, mean age was 59.6 ± 16.7 years, level of consciousness per the Glasgow Coma Scale prior to surgery was 9.9 ± 3.3, severity of intraventricular hemorrhage per the Graeb Scale was 7.3 ± 2.5. In the control group, mean age was 52.8 ± 9.6 years, level of consciousness per the Glasgow Coma Scale prior to surgery was 10.7 ± 3.2, severity of intraventricular hemorrhage per the Graeb Scale was 5.0 ± 2.6. Outcomes were assessed on the 30th day after hemorrhage using the modified Rankin Scale (mRS).
Results. Endoscopic method allows to effectively remove clots from the lateral and 3rd ventricles, decreasing the volume of intraventricular hemorrhage from 7.3 ± 2.5 to 3.9 ± 2.5 points per the Graeb Scale. Comparative analysis showed no difference in hydrocephalus resolution in the treatment and control groups. There were no intracranial infectious complications in the treatment group, but in the control group bacterial meningitis was diagnosed in 2 (14.3 %) of the 14 patients. Favorable outcome (score 0–2 per the mRS) was observed in 40.0 % of patients in the treatment group and 28.6 % in the control group. Mortality was 13.3 % in the treatment group and 57.1 % in the control group ($\chi^2 = 8.6$, $p < 0.01$).
Conclusion. Endoscopic surgery is an effective and safe method for intraventricular hemorrhage management and third ventriculostomy for occlusive hydrocephalus resolution, allowing to achieve better functional results and decrease mortality in patients with nontraumatic intraventricular hemorrhage.

Key words: intraventricular hemorrhage, endoscopic removal, third ventriculostomy, outcomes

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INTRODUCTION

Intraventricular hemorrhage (IVH) is a severe form of intracranial hemorrhages caused by hypertensive disease. In most cases, IVH is a consequence of blood breakthrough into cerebral ventricles during formation of intracerebral hematoma (ICH). It is established, that IVH can lead to increased intracranial pressure, occlusion hydrocephalus (OH) in the first days after hemorrhage, and communicating hydrocephalus in the long term [1–3]. If the signs of OH are present, surgical treatment usually consists of external ventricular drainage (EVD) which can be accompanied by local fibrinolysis (LF) of blood clots [2–4]. Endoscopic surgeries for IVH are still uncommon, though earlier studies showed that endoscopic surgeries can affect outcomes by reducing mortality, frequency of communicating hydrocephalus and suppurative intracranial complications [3, 5–7].

The study objective is to compare our own results of external ventricular drainage and endoscopic operations in patients with intracranial hemorrhage.

MATERIALS AND METHODS

Retrospective analysis of the results of surgical treatment of patients with IVH was performed at the N.V. Sklifosovsky Research Institute of Emergency Medicine, Moscow, and the Yaroslavl Regional Clinical Hospital. The treatment group consisted of 15 patients with IVH who underwent treatment using endoscopic technologies. In 12 of 15 patients, only endoscopic aspiration (EA) was performed, both with and without third ventriculostomy (TVS). In 3 of these 15 patients, EA (with and without TVS) was accompanied by EVD. All 15 patients were included in the treatment group because for all of them the following actions were performed during surgeries:

1) using endoscopic technologies, blood clots of varying sizes were removed which decreased the amount of blood and, in the long run, products of its decay, and decreased mass effect on the paraventricular structures of the brain;
2) most of the patients underwent TVS as prevention for OH in the postoperative period.

The control group consisted of patients who in 11 observations received EVD, in 3 observations received EVD and LF for IVH.

Patients were examined per the common scheme in accordance with the guideline protocol for treatment of patients with hemorrhagic stroke. At hospitalization, CT of the brain was performed. In case of dynamic observation for 1 or more days, brain CT was repeated prior to surgery. After surgery, brain CT was performed in most cases on the first day and dynamically to exclude hydrocephalus.

There were no significant differences between the treatment and control groups in in-hospital length of stay, operative time, age, sex, OH severity, condition. Mean in-hospital length of stay of patients in the treatment group was 1.7 ± 1.1 days. Mean patient age was 59.6 ± 16.7 years. Level of consciousness per the Glasgow Coma Scale (GCS) [8] at hospitalization was 10.9 ± 3.5. IVH severity per the Graeb scale [9] was 7.3 ± 2.5. Most patients were diagnosed with OH, 2nd ventriculocranial ratio (VCR-2) was 23.0 ± 3.8 %. Surgeries were performed at day 2.9 ± 1.4. Mean score per the GCS prior to surgery was 9.9 ± 3.3. Mean in-hospital length of stay in the control group was 1.4 ± 1.1 days. Mean age was 52.8 ± 9.6 years. Level of consciousness per GCS at hospitalization was 11.1 ± 3.1. IVH severity per Graeb was 5.0 ± 2.6. All patients of the control group had OH, mean VCR-2 was 23.1 ± 4.4 %. Surgeries were performed at day 2.1 ± 1.8. Mean GCS score prior to surgery was 10.7 ± 3.2 (Table 1).

In most patients, IVH was caused by blood breakthrough from the forming ICH into ventricle cavities. IVH was verified more frequently in ICH of the thalamus and cerebellum (sometimes of other locations), and in isolated IVH without ICH formation (Table 2). Types of endoscopic operations depending on IVH location in the treatment group are presented in Table 3.

Outcomes were assessed at day 30 after hemorrhage per the modified Rankin Scale (mRS) [10].

Table 1. *Characteristics of patients with intraventricular hemorrhage who underwent different types of surgery*

Parameter	Parameter in groups				Number of patients
	Treatment (EA)		Control (EVD)		
	without EVD	with EVD	without LF	with LF	
Age, years	58.3 ± 18.0	65.0 ± 10.6	52.3 ± 10.3	54.7 ± 7.5	–
Level of consciousness per GCS, score at hospitalization prior to surgery	 11.2 ± 3.7 9.9 ± 3.5	 9.7 ± 3.2 9.7 ± 3.2	 10.3 ± 3.0 9.9 ± 3.1	 14.0 ± 1.0 13.7 ± 0.6	 – –
ICH volume, cm^3	9.4 ± 10.9	7.2 ± 7.0	11.3 ± 7.5	16.7 ± 12.5	–
IVH severity per Graeb, score	6.9 ± 2.5	8.8 ± 2.3	4.4 ± 2.4	7.3 ± 2.5	–
Occlusion no occlusion foramen of Monro cerebral aqueduct IV ventricle	 2 0 10 0	 0 0 3 0	 0 0 5 6	 2 1 0 0	 4 1 18 6
VCR-2, %	22.8 ± 4.2	23.7 ± 2.1	24.6 ± 3.6	17.7 ± 2.1	–
Operation time, days	3.2 ± 1.3	1.7 ± 0.6	2.1 ± 2.0	2.0 ± 1.0	–
Total	*12*	*3*	*11*	*3*	*29*

***Note.** Here and in tables 2–6: EA – endoscopic aspiration; EVD – external ventricular drainage; LF – local fibrinolysis; GCS – Glasgo Coma Scale; ICH – intracerebral hematoma; IVH – intraventricular hemorrhage; VCR-2 – 2nd ventriculocranial ratio.*

Table 2. *Locations of intracerebral hematoma and intraventricular hemorrhages (n = 29)*

ICH location	Number of patients with different localization of blood clots, ventricles				Total
	Lateral, III	Lateral, III, VI	III, VI	VI	
Lobar	1	0	0	0	1
Lateral	1	2	0	0	3
Thalamic	1	8	0	0	9
Mixed	0	2	0	0	2
Cerebellar	0	4	4	1	9
Brainstem	0	2	0	0	2
No ICH	0	2	1	0	3
Total	*3*	*20*	*5*	*1*	*29*

Statistical analysis was performed using the Statistica 12.0 (StatSoft, Inc., USA) software; comparative analysis was performed using nonparametric methods with χ^2-test, Fisher's exact test, Kruskal–Wallis test, and Mann–Whitney U test. Intergroup differences were considered statistically significant at $p \leq 0.05$.

Table 3. *Endoscopic surgeries depending on intraventricular hemorrhage location (n = 15)*

Surgery type	Number of patients with different localization of blood clots, ventricles			Total
	Lateral, III	Lateral, III, IV	III, IV	
EA	1	3	1	5
EA + TVS	0	5	1	6
EA + TVS + DC PF	0	1	0	1
EA + TV + EVD	0	3	0	3
Total	*1*	*12*	*2*	*15*

Note. *TV – third ventriculostomy; DC PF – decompressive craniectomy of the posterior fossa*

RESULTS

Radicalness of blood clot removal in endoscopic surgeries

Only in the treatment group radicalness of IVH resolution was evaluated. In the control group, EVD was the most common surgery, IVH was not managed, therefore IVH volume did not change after surgery. In the treatment group, effectiveness of blood clot removal was evaluated (per the Graeb scale) by comparing IVH severity before and after surgery: prior to surgery it varied between 4 and 10, mean value was 7.3 ± 2.5; after surgery it varied between 0 and 10, mean value was 3.9 ± 2.5. Considering that in most patients standard access to the ventricles from the Kocher point was used, during operation clots from the anterior horn of the lateral ventricle (or from the anterior horns of both lateral ventricles), as well as 3rd ventricular cavity (which allowed to access its floor and perform TVS), were removed. Therefore, decrease in hemorrhage severity in EA was achieved through clot removal from the anterior horns of the lateral ventricles and anterior 1/2 or 2/3 of the 3rd ventricle. As a result, hemorrhage severity decreased by 4 points per the Graeb scale. In IVH in the 3rd and 4th ventricles, access through a burr hole made frontally from the Kocher point could be used to remove clots from the cavity of the 3rd ventricle through the aqueduct after aspiration. It is a less common operation which in favorable conditions allows to almost completely remove clots from the ventricular system.

Intraoperative complications

Intraoperative complications were observed in 3 (20 %) of 15 patients, who underwent EA of IVH. In 2 patients, arterial hypertension was observed, possibly associated with excessive irrigation of the ventricular cavities. In 1 patient, hemorrhage from the perforating artery branching from the basilar artery bifurcation was observed. Hemorrhage occurred during TVS and was stopped through expansion of Fogarty balloon catheter for 2 minutes. Outcomes in patients with intraoperative arterial hypertension were of types 4 and 5 per the mRS. In 1 patient after hemorrhage during TVS, convergence failure due to the left oculomotor nerve was observed. It could be caused by traction pressure on the 3rd nerve during Fogarty catheter expansion or ischemia of the oral segments of the brain stem after hemorrhage into the 3rd, 4th ventricles and development of tegmental syndrome. In the control group, no intraoperative complications were observed.

Effectiveness of surgical resolution of occlusion hydrocephalus

Prior to surgery, mean VCR-2 value in the treatment group (endoscopic surgery) was 23.0 ± 3.8 %, after surgery per CT data (performed on day 1 after operation) it was 18.5 ± 4.0 %. In the control group (with EVD) VCR-2 prior to surgery was 23.1 ± 4.4 %, after surgery (per CT data) it was 18.2 ± 5.2 %. Results show no differences in the treatment and control groups which demonstrates effectiveness of endoscopic surgeries in OH resolution.

Postoperative complications

Frequencies of postoperative complications in the treatment and control groups were similar but their structures were different. In 15 patients from the treatment group, 1 patient had IVH recurrence without consequences (she was discharged with favorable outcome), in 1 patient massive cerebellar infarction was caused by OH and axial brain dislocation which subsequently led to patient death. In the control group of 14 patients, 2 developed suppurative meningitis which caused death of 1 of them. The remaining complications in both groups were not surgical (Table 4).

Table 4. *Postoperative complications in patients of the treatment and control groups*

Postoperative complication	Number of patients in groups		Total
	Treatment (EA)	Control (EVD)	
No complications	9	9	18
Recurrence of IVH	1	0	1
Ischemic cerebellar stroke	1	0	1
Meningitis	0	2	2
Pneumonia	4	2	6
GIB	0	1	1
Total	*15*	*14*	*29*

***Note.** GIB – gastrointestinal bleeding.*

Outcomes

Outcomes of the patients after EVD and EA were significantly different. In patients after EA, functional outcomes were better with lower mortality compared to patients after ECD (Table 5). Mortality after EVD was 57.1 %, after EA it was 13.3 % ($\chi^2 = 8.6$, $p < 0.01$). Causes of death are presented in Table 6. Of 15 patients of the treatment group, 2 died. Death of 1 patient was caused by massive ischemic cerebellar stroke which led to edema-ischemia, brain dislocation (outcome was reached at day 10 after hemorrhage). One patient with massive IVH in the lateral, 3rd and 4th ventricles with volume of 28 cm^3 (Fig. 1) who underwent endoscopic removal of blood clots and TVS, died on day 30 after hemorrhage due to multiple organ failure. Autopsy showed minimal morphological changes in the periventricular brain matter at the level of lateral ventricles (Fig. 2).

For patients in the control group (EVD), deaths were primarily caused by cerebral edema and dislocation, less frequently due to brain stem hemorrhage, meningitis, pneumonia, and multiple organ failure. Causes of death in the control group should be considered closer.

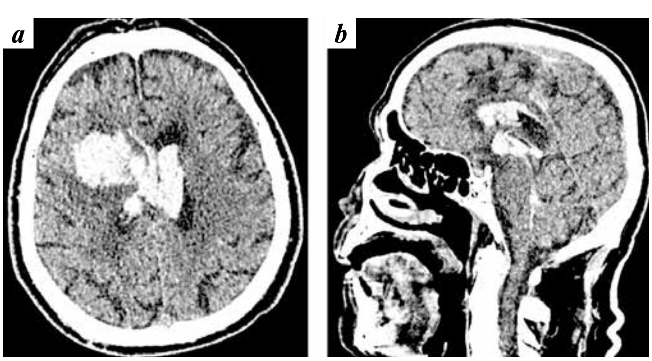

Fig. 1. *CT scan of the patient N., 78 years old. Intracerebral hematoma of basal ganglia – 35 cm^3, intraventricular hemorrhage in lateral, III and IV ventricles – 28 cm^3: a – axial plain; b – sagittal reconstruction*

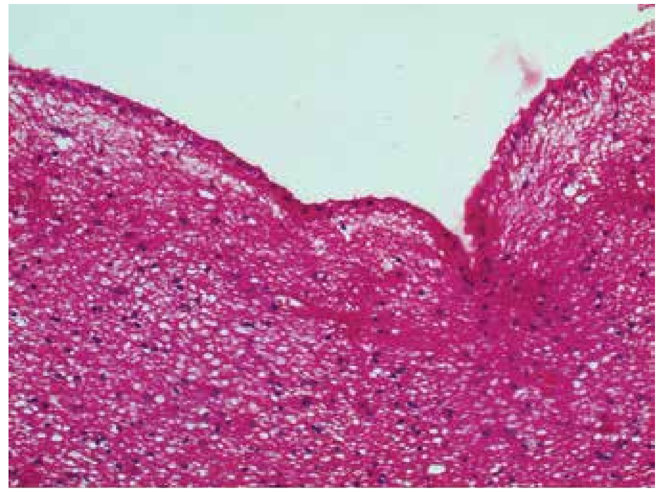

Fig. 2. *Morphological research of lateral ventricle wall (hematoxylin and eosin, × 200) on the 30th day after intraventricular hemorrhage and on the 27th day after endoscopic intraventricular clot removal from the lateral ventricle. Changes of the lateral ventricle wall are visualized, cuboidal epithelium of ependyma is preserved, no periventricular edema and ischemia*

Table 5. *mRS outcome after surgery in the treatment and control groups (n = 29)*

Surgery type	mRS outcomes			Total, *n* (%)
	0–2	3–5	6	
EA	6 (40.0)	7 (46.7)	2 (13.3)	15 (100)
EVD	4 (28.6)	2 (14.3)	8 (57.1)	14 (100)
Total	*10 (34.5)*	*9 (31.0)*	*10 (34.5)*	*29 (100)*

***Note.** mRS – modified Rankin Scale.*

Table 6. *The structure of causes of death in patients from treatment and control groups*

Cause of death	Group		Number of patients
	Treatment (EA)	Control (EVD)	
Cerebral edema and dislocation	1	4	5
Brainstem hemorrhage	0	1	1
Meningitis	0	1	1
Pneumonia	0	1	1
Multiple organ failure	1	1	2
Total	*2*	*8*	*10*

Edema-ischemia and brain dislocation caused deaths of 4 patients in the control group (after EVD). These patients passed on average on day 15.3 after hemorrhage. In 3 of 4 patients, OH was resolved after EVD, in 1 patient it was not. The last patient was hospitalized with ICH with volume of 21 cm^3, complicated by IVH in the 3rd and 4th ventricles with their tamponade which led to OH. At hospitalization the patient was in deep obtundation (GCS score was 11). Patient underwent EVD (2 lateral ventricles were drained) but ICH was not removed. During patient emergence from anesthesia, his condition had negative dynamics (GCS score was 4). CT data showed increased axial brain dislocation. Patient had been receiving intensive care for 3 weeks but despite all attempts, he could not be saved. In 3 other patients, EVD helped resolve OH but it did not prevent cerebral ischemia after brain dislocation, and cerebral edema and dislocation were stated as causes of death. In 1 patient of the control group, death was caused by primary hemorrhage in the brain stem which was the cause of OH and subsequent surgical intervention.

DISCUSSION

Nontraumatic IVH can occur as an isolated form of hemorrhage or as a result of blood breakthrough into the ventricular system during parenchymatous hemorrhage. Isolated IVH is observed in 3–15 % of cases [6, 11]. This IVH which in itself worsens prognosis in patients with hemorrhagic stroke [12, 13], is often complicated by acute OH with risk of death [1, 14]. Acute OH is an emergency condition requiring emergency surgical intervention. Depending on hospital facilities, patient can undergo EVD, LF with subsequent ventricular drainage, TVS, and endoscopic blood clot removal accompanied by TVS.

The first group to perform endoscopic IVH resolution were L.M. Auer et al. (1988). In their work [5], they presented results of successful endoscopic removal of 77 intracerebral and 13 intraventricular hemorrhages: in 12 % of observations, more than 90 % of clot volume was removed, in 88 % cases more than 50 % of the initial volume of clots. Technique of clot removal comprised of clot irrigation with physiological solution and its aspiration through endoscopic trocar. In the study by Z. Horvath et al. (2000), a biportal technique of ventricular clot removal in a patient with primary hemorrhage into the lateral ventricles and tamponade of the 3rd and 4th ventricles was proposed. Clot removal was performed by constant irrigation with physiological solution and aspiration with two endoscopes which allowed to better orient in the conditions of hemorrhage and poor visibility, and to remove clots from the lateral, 3rd ventricles and perform TVS without complications under "double visual control" [6].

Technique of hemorrhage resolution in the ventricular system depends on the volume, density, and location of blood clots. Loose clots can be removed by irrigation and soft aspiration using multichannel trocar with a possibility to regulate inflow and outflow of irrigation liquid. Denser clots are removed with microforceps through trocar channels [11, 15]. Using a multichannel trocar for breakage of dense clots, J.M. Oertel et al. (2006, 2008) also used ultrasound aspirator and water jet burr compatible with the Gaab trocar [16–18]. After clot breakage, clots could be aspirated thorough relatively narrow channels of a multichannel trocar. P. Longatti and L. Basaldella (2013) successfully removed massive IVH of the lateral, 3rd and 4th ventricles using a flexible endoscope with diameter of the working channel of 1.2 mm which allowed for better maneuvering in the cavities of the lateral and 3rd ventricles [18].

As we have seen in our own experience, endoscopic aspiration of clots using a rigid endoscope is possible for the anterior horns, lateral ventricles, and cavity of the 3rd ventricle. Removal from the 4th ventricle is a technically complex but accomplishable task [19]. In this study to remove clots from the cavity of the 3rd ventricle and cerebral aqueduct, one-channel trocar of the Gaab ventruloscope and Certofix 14F catheter were used. Hard metal tips of a vacuum aspirator are less fitting for this kind of operation – removal of clots through a trocar – as endoscope cone at its base does not allow to manipulate the aspirator. For this task, only a flexible tip can be used. However, use of a transparent endoscopic port with diameter of 8 mm in some cases allowed us to effectively and quickly remove clots of varying density from the anterior horns and bodies of the lateral ventricles using a metal canula of a vacuum aspirator (Fig. 3). Removal of clots from the cavity of the 3rd ventricle technically remained the same: only through a trocar which can be inserted through the foramen of Monro.

The published studies show high effectiveness of endoscopic surgery, low complication risk, and favorable outcomes in most of the patients (on average, in 76 %) [3, 7, 11, 15, 20]. According to meta-analysis by Y. Li et al. (2013), which included 680 of operated patients, local clot fibrinolysis with EVD is less effective than endoscopic clot aspiration with EVD: in this case clot removal by 60 % and more can be achieved by endoscopic aspiration and EVD in 88.9 % of cases, while by local fibrinolysis and EVD only in 29.4 % of cases. Mortality after fibrinolysis and EVD, according to meta-analysis, is 14.1 %, after endoscopic aspiration and EVD – only 4.9 %. Effectiveness of EVD after successful endoscopic clot removal is not confirmed and selection of the approach to external drainage is left to the surgeon [3].

In this study we showed that endoscopic technique provides the following benefits:

- significant decrease in clot volume in the ventricular system (from mean score of 7.3 ± 2.5 to 3.9 ± 2.5 per the Graeb scale) which can frequently cause significant damage to the periventricular segments of the brain stem [21];
- allows to resolve OH;
- allows to increase the number of favorable outcomes and decrease mortality compared to outcomes in the control patient group.

One of the advantages of endoscopic operations is ability to perform TVS which removes the necessity of external draining or shortens the time of drain presence in the

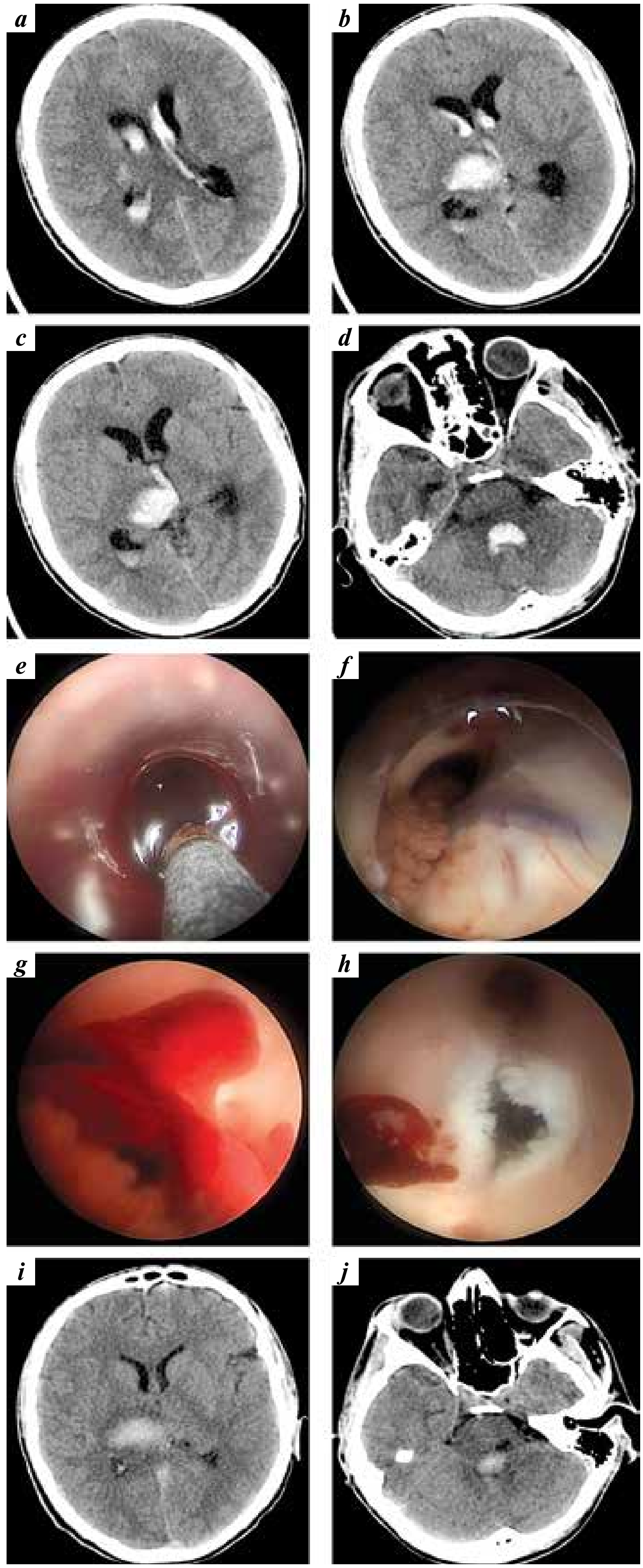

Fig. 3. *Endoscopic intraventricular hemorrhage resolution and third ventriculostomy in patient A., 24 years old, on the 3d day after hemorrhagic stroke. CT scan of the brain: a–d – intracerebral hematoma (6 cm³), intraventricular hemorrhage in lateral, III and IV ventricles (12 cm³) (Graeb score – 6); e, f – intraventricular hemorrhage resolution from lateral ventricles; g, h – intraventricular hemorrhage resolution in the III ventricle and ventriculostomy; i, j – CT scan of the brain 7 days after surgery*

ventricles and allows to decrease the frequency of ventriculitis from 10–17 to 0–2.9 % [22]. However, some authors state that endoscopic aspiration should be accompanied by external ventricle drainage, especially if intracranial pressure should be controlled and corrected with ventricular draining [2, 7]. This study did not include evaluation of long-term treatment results, therefore the question of advisability and risks of EVD after endoscopic aspiration of IVH should be studied further.

CONCLUSION

Endoscopic surgery is an effective and safe method of intraventricular hemorrhage management and 3rd ventriculostomy for occlusion hydrocephalus resolution. The study shows that this method allows to achieve better functional results and decrease mortality in patients compared with external ventricular drainage. Selection criteria for supplementation of endoscopic surgery with external ventricular drainage require further investigation.

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A.V. Elfimov: research idea of the study, scientific editing of the article;
V.A. Khamurzov: obtaining data for analysis;
A.A. Grin: research idea of the study, scientific editing of the article;
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