Review
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Minimally Invasive Endoscopic Interventions in the Treatment for Traumatic Intracranial Hematomas

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ABSTRACT Traumatic brain injuries are a global problem, with more than 50 million people suffering from brain injuries every year. A frequent consequence of severe traumatic brain injury is intracranial hematoma (ICH), causing mortality, disability, post-traumatic epilepsy. ICH has different clinical manifestations and physical characteristics. Standard treatment for ICH includes conservative monitoring for small volume hematomas or surgical evacuation of the hematoma. Craniotomy is often used to remove hematomas, because acute and subacute hematomas contain clots, and drainage of the hematoma cavity alone is not enough. In chronic hematomas, drainage through a hole is usually used, but this is effective only if the hematoma is represented by one cavity and its contents are completely liquid, which is not always the case. Thus, widely used techniques do not always meet modern requirements for effectiveness and low invasiveness of surgical treatment.

The review considers endoscopic methods of surgical treatment for all variants of traumatic ICH; 31 publications have been found on this topic, mentioning 602 interventions. Differences in patient selection criteria make it difficult to compare the methods and outcomes. From the technical point of view, the procedures were also very diverse. The article analyzes the main features of different authors' methods.

None of the authors comes to the conclusion about outcome worsening after endoscopic intervention. With regard to acute and subacute hematomas, there are currently no reliable statistical data, but the results obtained can generally be assessed as positive.

In acute and subacute hematomas, endoscopic intervention is perceived by the authors not as providing more opportunities, but only as a less invasive replacement for conventional craniotomy. In chronic hematomas, endoscopic intervention is considered to have more opportunities and advantages over the standard treatment.

At present, the widespread use of endoscopic minimally invasive methods of surgical treatment for traumatic hematomas is hampered mainly by the lack of clear criteria for selecting patients and well-established methods of intervention. More high-quality research is needed to determine the role of these methods in general clinical practice.

Keywords: endoscopy, minimally invasive surgical procedures, brain injuries, subdural hematoma, epidural hematoma, intracranial hematoma

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ASH - acute subdural hematoma
CSH - chronic subdural hematoma
GCS—Glasgow Coma Scale
ICH - intracranial hematomas
ICP - intracranial pressure
SCT - spiral computed tomography
SSH - subacute subdural hematoma
TBI - traumatic brain injury

INTRODUCTION

Traumatic brain injury is a global problem, affecting more than 50 million people annually [1]. It is also necessary to note the great social significance of this pathology, since the average age of victims is, according to various studies, from 22 to 49 years [2]. Overall, mortality from traumatic brain injury (TBI) in Europe is 10.5 per 100 000 population per year [2]. Bruises and compression of the brain occur with an incidence of 30–40 cases per 100,000 population per year [3]. A common consequence of severe TBI is intracranial hematomas (ICHs) which cause the most serious consequences of the injury: mortality, disability, post-traumatic epilepsy [4,5]. Trauma is the cause of 94.7% of cases [6] of intracranial hemorrhage. In 2/3 of deaths after TBI, autopsy reveals an intracranial hematoma [3]. Intracranial hematomas are very diverse in their clinical manifestations and physical characteristics. This is due to both – their location and the changes occurring in the hematoma over time.

Regarding the location in the cranial cavity, subdural hematomas located between the dura mater and the arachnoid membrane are most common; their incidence at autopsy is 20–63% [7], the incidence in the population according to data from different regions of the Russian Federation is from 15.5 to 32.9 cases per 100,000 population per year [8]. Among victims with head trauma, the incidence of acute subdural hematomas is 1–5% [6].

Epidural hematomas located between the skull and the dura mater are much less common (5–20% according to autopsy data) [7]. Intracerebral hematomas occur in 15% of cases (also according to autopsy data) [7].

However, the location of the hematoma is not the main characteristic, since the severity of clinical manifestations depends more on the volume of the hematoma. It is generally accepted that supratentorial hematomas with a volume of more than 30 ml (or 15 ml for subtentorial ones) are potentially dangerous and require surgical treatment. But the volume of the hematoma does not fully characterize it either.

An important factor is how long the hematoma lasts, especially in the case of subdural localization. Subdural hematomas are divided into acute (up to 5 days) (ASH), subacute (from 5 days to 3 weeks) (SSH) and chronic (more than 3 weeks) (CSH). Chronic hematomas differ so greatly in their clinical manifestations and treatment methods that they are most often considered separately. The overall incidence of CSH in the population ranges from 1.72 to 20.6 per 100,000 for the general population and 58.1 per 100,000 in the group over 65 years of age [9]. However, the incidence is expected to double by 2030 [10].

Standard treatments for ICH include conservative observation for small hematomas or surgical evacuation of the hematoma. Conservative management of the patient is possible if the hematoma volume is less than 30 ml, thickness is less than 15 mm, displacement of the midline structures is less than 5 mm and the level of wakefulness is the Glasgow Coma Scale (GCS) above 8, subject to observation in a neurosurgical hospital [11]. There are currently no drugs with proven effectiveness that speed up hematoma resorption. To improve the resorption of hematomas, the use of statins is being considered, but their effectiveness has not yet been proven [12]. In the case of epidural hematomas, conservative treatment can lead to complete resolution of the hematoma, but prolonged hospitalization is required (average 4.5 weeks), multiple repetitions of spiral computed tomography (SCT) [13]; and, yet, 15% of patients will still require a craniotomy [14]. Administration of urokinase through a drainage tube for epidural hematomas is only applicable for chronic hematomas [15] due to the risk of rebleeding.

Surgical methods for removing hematomas vary significantly depending on the type and location of the hematoma. To remove acute and subacute hematomas, the standard method is craniotomy or craniectomy if decompression is necessary. The need for wide access is due to the fact that acute and subacute hematomas contain clots, and drainage of the hematoma cavity alone is not enough. It is important to note that decompressive interventions do not show advantages over osteoplastic ones [1,11,16–18] due to a significantly higher number of complications that occur after such interventions in 49-73% of cases [19]. Modern treatment methods in most cases involve closure of the bone defect after removal of the hematoma [20]. Chronic subdural hematomas usually have liquid contents, so craniotomy is rarely used for their removal. The main methods of surgical treatment for chronic subdural hematomas are burr hole evacuation in the operating room or twist drill craniostomy which can be performed in the ward. Both methods are effective only if the hematoma is represented by one cavity, and its contents are completely liquid. However, chronic hematomas are often divided by septa into several cavities or contain clots from secondary, more recent hemorrhages. Forty-six percent of hematomas are "complex"— containing either septa or fresh clots [21]. This leads to a significant number of complications and the need for repeated interventions - according to some data, from 25.4% [22] to 31.6% [23]. Male gender, age over 60 years, a high Markwalder functional score, preoperative displacement of midline structures less than 10 mm, and hematoma duration less than 20 days are predictors of recurrent CSH [24]. Thus, classical methods of surgical treatment for traumatic ICH, despite extensive experience in their use, have been still far from perfect. General trends in the development of surgery, and in particular neurosurgery, are the desire to reduce surgical aggression, minimize trauma, and at the same time improve the final outcomes of treatment.

In our review, we tried to consider endoscopic methods of surgical treatment for all types of traumatic intracranial hematomas. Publications on this topic are sparse; we were able to find 31 articles on this topic (Table).

Table

Some characteristics of endoscopic interventions according to publications of different authors

Year	Author	Number of patients, n	Age	Type of hematoma	Trepanation size, mm (B – burr hole)	Type of endoscope (F - flexible, R - rigid, S - special, T - tube)	Medium (A - air, L - liquid)	Special tools	Drainage	Duration (min or +end. stage)	Anesthesia (G - general, L – local)	Conversion to open	Relapse	Mortality
1994	*Karakhan V.B. et al.* [33]	180	n/a	Any type	20–25	F	L	dissector	yes	–	G	9	2.5%	18%
1995	*Rodziewicz G.S. et al.* [37]	2	75	CSH	30×40	R 0–30°, 4 mm		forceps	48h	–	G			no
1996	*Hellwig D. et al.* [38]	14	32–81	CSH	2 B	F	n/a	endoscope fixture	yes	–	–		7%	no
1997	*Gruber D.P. et al.* [39]	7	Up to 2	CSH	B	F	L	endoscope fixture	no	42	G			no
2003	*Masopust V. et al.* [40]	3	75–86	CSH	2 B	R	n/a	–	yes	–	L		33.3%	no
2009	*Mobbs R. et al.* [24]	10	67	CSH, SSH	25–35	30°, 4 mm	A	–	yes	+22	G	2		no
2012	*Ohshima T. et al.* [44]	1	74	EH	B	F	A	–	–	+45	G			no
2012	*Huang A.P.H. et al.* [52]	6	25–45	EH	20–28	R 30°	A	coagulation and suction cannula	no	38–68	G			no
2013	*Kon H. et al.* [49]	1	87	ASH	15	T 10 mm	L	coagulation and suction cannula	no	47	L			no
2013	*Codd P.J. et al.* [56]	1	86	ASH	1–2 25 mm each	R 4 mm 30°	A	coagulation and suction cannula	no	120	G			no
2014	*Yokosuka K. et al.* [28]	11	73–92	ASH, SSH	20–30	R 4mm 0°	A	coagulation and suction cannula	no	85	L		9%	no
2015	*Ueba T. et al.* [51]	1	88	SSH	B	R 30°	A	coagulation and suction cannula, curette	no	–	L			no
2015	*Suat B. et al.* [47]	8	n/a	SSH, CSH	20–35	R 0-30° 4mm	A		yes	+20	–			no
2016	*Miki K. et al.* [57]	12	μ 78,8	ASH, SSH	n/a	n/a			–	–	–			
2016	*Tamura R. et al.* [27]	2	81 and 73	ASH, ICH	25	R 2.7mm, T 10 mm	A	Neuroport tube	–	–	L			no
2016	*Májovský M. et al.* [29]	34	μ 71,2	CSH	B	F	A		yes	43	L		11.3%	2.9%
2016	*Ansari I. et al.* [13]	7	17–64	EH	19–29	R 0°, 30°, 70°	A	coagulation and suction cannula	no	45–100	–			no
2017	*Kuge A. et al.* [43]	1	31	ASH	20	R	A	coagulation and suction cannula	no	–	L			no
2017	*Yan K. et al.* [41]	24	66	CSH	25	R 0° 3 mm	A		yes	76	G		8.3%	4%
2018	*Maruya J. et al.* [26]	2	71 and 51	ASH + Brain contusion	40	F and R 2.7 mm 0°	A	coagulation and suction cannula, retractor	yes	90–150	L, G			no

2018	*Matsumoto H. et al.* [58]	6	>80	ASH	3	R 4 mm 0–30°	A	endoscope fixture, suction cannula, tweezers, coagulator	no	91	L			no
2018	*Kawasaki T. et al.* [30]	17	μ 79.2	ASH, SSH, CSH	30×40	F 5mm	L	coagulation and suction cannula	no	107.8	L, G		11.7%	no
2018	*Zhang J. et al.* [9]	42	μ 74.3	CSH	15	R 30°	A	coagulation and suction cannula, microscissors and tweezers	yes	56.5	L			no
2019	*Ichimura S. et al.* [42]	5	μ 87.4	ASH	30	R 0–30°	A		yes	–	L, G			40%
2020	*Hwang S.C. et al.* [25]	13	μ 78.6	ASH	30×40	R 0° 3 mm	A	suction cannulas with different angles	yes	90	L, G			23%
2020	*Katsuki M. et al.* [35]	15	μ 86	ASH	20–30	R 0–30° 4 mm	A	coagulation and suction cannula	–	91	L			33,3%
2020	*Du B. et al.* [22]	45	μ 73.2	ASH, SSH	20–30	R 0–30°, T 7.7 mm	A, L	suction cannula, scissors, tweezers, forceps, coagulator	yes	60	G			no
2021	*Miki K. et al.* [34]	26	>65	ASH	30×40	R 0–30°	A	coagulation and suction cannula	yes	–	G			no
2021	*Khattar N.K. et al.* [48]	3	41–51	ASH	24	S	L	special device for irrigation-aspiration	yes	206	G			no
2021	*Amano T. et al.* [21]	97	μ 77.1	CSH	B	R 0°, 30°, 70°	A	suction cannula, tweezers	yes	59.4	L		9.3%	no
2021	*Katsevman G.A. et al.* [50]	1	40	EH	B	S		special device for irrigation-aspiration		–	–			

Notes: ICH — intracerebral hematoma; ASH — acute subdural hematoma; SSH — subacute subdural hematoma; CSH — chronic subdural hematoma; EH — epidural hematoma

INDICATIONS AND CONTRAINDICATIONS

Not all the authors selected patients based on certain criteria; often the use of endoscopy was determined by the ability to perform such an intervention. In other cases, there were significant differences in approach. For example, administration of antiplatelet agents and anticoagulants is considered by some authors as an indication specifically for endoscopic intervention, since less invasive intervention reduces the risk of bleeding [39, 42, 46]. Other authors, on the contrary, include an increased risk of bleeding in the list of contraindications for endoscopic intervention [35, 40, 44, 51], since the possibilities of surgical hemostasis during endoscopic intervention are limited. A cited study showed that taking antiplatelet and anticoagulant medications did not increase the risk of reoperation or death after removal of acute subdural hematoma [52].

A number of authors indicate only contraindications [25, 47, 48] for endoscopic intervention, considering the indications to be the same as for open intervention. This is true for acute and subacute hematomas, where minimally invasive endoscopic intervention may reduce the surgeon's options compared with the traditional intervention of craniotomy [53]. In the case of chronic hematomas, where traditional intervention – craniostomy and drainage - is performed “blindly”, the use of endoscopy, on the contrary, increases the surgeon’s capabilities. Therefore, in the case of chronic hematomas, more complex variants, such as septated, multi-layer, with secondary hemorrhages and hematomas that recur after previous interventions are suggested as an indication for the use of endoscopy [21, 26–29, 51].

All the researchers recognize the key feature of endoscopic intervention - the need for a cavity to work. Therefore, most authors, in one way or another, have criteria for selecting patients that suggest preservation of the cavity upon removal of the hematoma. This possibility is provided, for example, by the chronic stage of a subdural hematoma (11 out of 31 articles, see table), or severe brain atrophy associated with old age or other reasons (22 out of 31 articles, see table). Cerebral edema and its rapid expansion are indicated as a clear contraindication to continue intervention [24, 30, 42, 48].

An important criterion for choosing a minimally invasive endoscopic intervention for many authors is the possibility of performing it under local anesthesia (14 articles out of 31, see table), which makes it possible to operate in the absence of the anesthesiologist [41, 45], or in the presence of contraindications to general anesthesia [31, 39, 54].

TECHNICAL FEATURES OF ENDOSCOPIC INTERVENTIONS

From a technical point of view, the methods used by different authors have significant differences. Some features of the interventions used are presented in the table. Both burr hole and mini-craniotomy are used as access. The defining parameters of both approaches have long been formed in the literature - the burr hole is from 0.5 to 30 mm, mini-craniotomy - from 3 to 4 cm [13, 55]. In 12 of the sources studied, the authors use craniotomy (trepanation size 3 cm or more); the minimum dimensions of access are not reported, since the authors do not indicate the exact dimensions of the burr holes. More often, large accesses are used to remove acute and subacute hematomas [44, 46, 48]; sometimes resection of the edges of the bone defect is performed to increase the angle of insertion of the endoscope and tools [35, 37, 49]. Most techniques involve burr hole or opening placement above the hematoma, but four publications describe the access above the edge of the hematoma [24, 26, 37, 54] to facilitate insertion of a straight endoscope and instruments into the cavity

The next important technical component of the intervention is the type of the endoscope used. Rigid endoscopes are most often used (23 out of 31 publications), and flexible endoscopes are used less often (7 articles). There may be potential benefits to the flexible endoscope [29]. However, to achieve its full benefits, the flexible endoscope must have a working channel for instruments and should not be used solely for visualizing the surgical field. In addition, the image quality of the flexible endoscope must be improved [46]. Interestingly, flexible endoscopes were used more often in older studies. 8 researches mention passing instruments through the tube or working channel of the endoscope; in the rest ones, instruments are passed next to the endoscope. The rigid endoscopes used had a 0 (mentioned in 15 articles) or 30 degree viewing angle (also mentioned in 15 articles), with diameters ranging from 2.7 to 6.5 mm. One publication mentions the use of a 70-degree endoscope when removing epidural hematomas [13]. Some techniques used a tube to hold an endoscope and instruments with a diameter of 7.7 mm and 10 mm [33, 39]. Custom-made endoscopes and devices were used in three techniques — in the oldest available publication [25] and in the newest ones [22, 49, 50].

The methods used to remove a hematoma strongly depend on the optical medium, but when describing the technique, the authors often do not directly indicate whether visualization is performed through liquid or air, and this has to be determined by indirect signs or is difficult to determine at all [27, 29]. Most often, air is used as a working medium, and only in 7 publications the authors use liquid as an optical medium.

The process of hematoma removal is not described in all the publications. Most use aspiration and washing with either saline or artificial cerebrospinal fluid (Japanese authors) [35, 41]. A significant proportion of researchers use aspirator cannulas with the possibility of mono- or bipolar coagulation, either directly or by passing the coagulator through the suction cannula. As a rule, the authors do not disclose details of the design of the aspirators used - their bends, sizes, diameters and other features are not mentioned. The aspirator cannula is often described as soft or bendable (see table). Two reports mention a curette [36, 42], similar to that used in the removal of pituitary adenomas [36]. In surgical intervention for epidural hematoma, dural sutures are mentioned [32], which can only be made in the central part [13]. Custom-made instruments are rarely used. The first description of a special dissector was published in 1994 [25]. Two other technologies using special devices and instruments are described in 2020 [22] and 2021 [49, 50].

The fact that drainage improves treatment results and, in particular, contributes to a significant reduction in the incidence of relapses, has been convincingly proven [56, 57] and is generally accepted. In our review, after endoscopic removal of the hematoma, drainage was used by the authors of 14 out of 31 publications (table), and there is no noticeable connection with the type of hematoma and its duration. Apparently, the decision to drain or not is determined by the personal preferences of the author; no reasons are given for this. Not infrequently, the authors of the publication do not indicate at all whether drainage was used after the intervention (in 5 publications). The most often mentioned duration of drainage is 2 days.

When assessing the outcomes, it is necessary to take into account that most publications describe very few cases of endoscopic interventions for traumatic ICH. Thus, as for acute subdural hematomas, a maximum of 26 cases appear in publications [48], and 2 articles describe samples of 15 patients [44, 47]. The largest published experience with the removal of epidural hematomas is 7 cases [13], and traumatic ICHs were removed, according to the published data, in 2 cases [42]. Unfortunately, there is no question of statistically significant differences and evidence. More extensive studies are found only in endoscopic surgery for CSH, where there are publications with a control group and statistical data processing [9, 21, 24]. The outcomes in general can be called encouraging, since none of the authors provided data that could discredit endoscopic interventions for traumatic ICH, although a statistically significant improvement in outcomes was not always obtained [24]. The largest study (97 patients and 283 control patients) of the use of endoscopy for CSH showed a statistically significant reduction in the incidence of hematoma recurrence (from 25.1% after classical intervention to 9.3% after endoscopic one), and a reduction in the frequency of re-interventions (from 9 .2 to 0%) [21].

DISCUSSION

Traumatic brain injury (TBI) continues to be one of the main causes of mortality and disability in working age. ICHs are often the main factor determining the severity of the injury, and, at the same time, they are potentially treatable, since quick and complete removal of the hematoma can significantly reduce the mortality and disability of patients with TBI. It has been believed that classical surgical approaches, such as craniotomy and craniectomy, can provide rapid and complete removal of the hematoma, but recent studies show a significant number of complications (up to 49–73%) [19]. A similar situation is observed with minimally invasive burr hole procedures for chronic hematomas, where the frequency of re-interventions in some cases reaches 25% [22]. These data demonstrate the need for further improvement of approaches to surgical treatment of patients with traumatic ICH. One of the areas of development is the use of minimally invasive endoscopic interventions. Such techniques have not yet become widespread, but a number of authors have published their experience of such interventions (table). A total of 602 endoscopic interventions for traumatic ICH are mentioned in publications from 1994 to 2021; but due to the large differences in patient selection, intervention techniques, and publication format, a summary assessment of this experience is impossible; only the most frequently mentioned features are available for analysis. Thus, not a single study provides precise quantitative characteristics of hematomas [58]. In acute and subacute hematomas, researchers do not mention indications for endoscopic intervention, using general indications for ICH removal and some conditions that allow endoscopic intervention. The main condition is the presence of a cavity - the predicted absence of rapid expansion of the brain, - this also includes advanced age [34, 35, 38, 39], brain atrophy [41], large thickness of the hematoma [43], absence of bruises and cerebral edema, as well as low intracranial pressure (ICP) [42]. It is likely that endoscopy is better suited for patients with a more distant period after injury, in the absence of significant cerebral edema and elevated ICP [48]. Another common condition for the use of endoscopy is the need to perform surgery under local anesthesia (due to the high risk of general anesthesia or the absence of the anesthesiologist) [39, 41, 44–47, 54]. Thus, in case of acute and subacute hematomas, this technique is not perceived by the authors as an intervention with broader capabilities, but only as a less invasive replacement for conventional craniotomy. As for CSH, conditions are mentioned when the intervention should be only endoscopic one, as having wider possibilities and advantages over the standard treatment. Thus, the advantages of endoscopic surgery are confirmed in septated CSHs [24, 26, 27], and in case of failure of previous treatment [28].

From a technical point of view, interventions are very diverse, this applies to all stages. Accesses of various sizes and locations are used. Despite the fact that the main advantage of endoscopic interventions should be their low invasiveness, in many cases the authors use craniotomy (30 mm or more in size) as the access [26, 37, 42, 44, 46, 48]. Such access sizes largely neutralize the advantages of endoscopic intervention. The location of the access is also varies greatly - the hole is located both at the edge of the hematoma, and vice versa, in the center; even a cadaver study has been carried out on the optimal location of the access [59]. Various types of endoscopes are used, viewing occurs in both liquid and air medium. The process of hematoma removal differs to a lesser extent - most use aspiration, some authors use a curette, scissors and forceps. Thus, at present there is no common understanding of the technique of endoscopic intervention for traumatic ICH, and therefore we can say that the technique is at the development stage. There is no established, proven intervention technique. Perhaps this is what is holding back the widespread use of endoscopic interventions for ICH.

Since a well-established and time-tested technique have not been developed, and numerous studies have not been performed, the use of endoscopic methods in the treatment of TBI is limited. It is not always possible to determine in advance whether the cavity will be sufficient during the intervention; some publications directly indicate that in some patients the intervention could not be performed [30]. Many authors point to a significant risk of damage to the cerebral venous cortex by the endoscope or instruments [9, 30, 37, 43], although no such incident has been described in any publication. There may also be difficulties in organizing endoscopic intervention and time for preparation, the need to familiarize operating room staff with the technique and instruments [45].

None of the authors comes to the conclusion that treatment outcomes are worse when endoscopic intervention is used. Regarding the results obtained in relation to acute and subacute hematomas, reliable statistical data is currently not provided, but in general they can be assessed as positive. The cost-effectiveness compared to large craniotomy is also positively assessed; it was shown in a small group of patients, that the duration of the operation was shorter, and the costs were significantly lower in endoscopic surgery [43]. In case of CSH, the authors provide more convincing statistical evidence of the benefits of the endoscopic technique in the form of reduced incidence of hematoma recurrence and the frequency of re-interventions [21], but these are also isolated studies. For example, 25 clinical studies have been conducted using the classical method of CSH removing through the burr hole, and more than 700 articles have been published [60]. Our review of published data on endoscopic techniques for the removal of intracranial hematomas examined 31 publications; in total, in 602 operated patients, the mortality rate was 3.6% (table).

CONCLUSION

Endoscopic surgery for intracranial hematomas is a promising direction in neurosurgery. The published outcomes are largely preliminary but show a number of benefits and no significant risks when using minimally invasive endoscopic techniques in the treatment of traumatic brain injury. However, their use is limited due to the lack of clear patient selection criteria and well-established intervention techniques. Research is required to determine the role of these methods in widespread clinical practice.

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