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Efficacy of Hypertonic Saline Solution to Achieve Persistent Intraoperative Intracranial Hypotension in Endoscopic Endonasal Transsphenoidal Surgery

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ABSTRACT The use of endoscopic transsphenoidal access is an effective and safe method for the surgical treatment of pituitary adenomas (PA). In endoscopic transsphenoidal surgeries, there is a need to control intracranial pressure (ICP) for reposition and expansion of the tumor capsule. Currently, the main method for reducing ICP in transsphenoidal surgery is installation of an external lumbar drainage, which is associated with a number of complications.

AIM OF STUDY To improve the results of surgical treatment of patients with hypertension using hypertonic saline solution (HSS).

MATERIAL AND METHODS The study included 89 patients, who were devided into two groups: Group A — control group (n=25), where the lumbar drainage was installed for invasive intraoperative measurement of the dynamics of ICP parameters at the main stages of the operation (HSS was not administered in these patients); Group B — study group (n=64), where the efficacy of non-invasive regulation of the tumor capsule position using intravenous HSS was assessed, in addition, lumbar drainage was installed in 25 patients of group B, as well as in group A, for invasive measurement of ICP (the dynamics of ICP changes at the main stages of the operation was measured), and the dynamics of changes in the electrolyte composition of the plasma during the first days after the administration of the HSS was monitored as well.

RESULTS In Group B, there was a more significant decrease in ICP in the course of HSS (on average by 22.49 mm Hg) compared to Group A, where the decrease in ICP was 14.23–8,46 mm Hg (from 13.62±1.36 mm Hg, $p<0.05$). After intravenous administration of HSS, the plasma composition changed as expected (the concentrations of Na+ and Cl- increased on average to 150±0.71 mmol/L and 118.3±1.06 mmol/L, respectively, which slightly exceeded the average statistical norm, K + slightly decreased within the average statistical norm), during the first day there was a normalization of the above laboratory parameters .

This technique was used to obtain patent No. 2669924 “A method for regulating the position of a tumor capsule in endoscopic transsphenoidal surgery of pituitary adenoma”.

CONCLUSION The use of HSS is a safe non-invasive technique for expansion of the tumor capsule during operations to remove pituitary adenomas using transsphenoidal endoscopic access. It should be noted that this method is most appropriate in situations not associated with the risk of developing intraoperative liquorrhea.

Key words: pituitary adenoma, endoscopic endonasal transsphenoidal access, lumbar drainage, hyperosmolar colloid- crystalloid solution, intracranial pressure

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PA - pituitary adenomas
ICP - intracranial pressure
HSS - hypertonic saline solution
CSO - chiasmatic-sellar area
CPP - cerebral perfusion pressure

INTRODUCTION

Currently, the treatment of patients with tumors of the chiasmatic-sellar region (CSR) in connection with the introduction of endoscopic transnasal technique into transsphenoidal surgery is one of the most urgent tasks in neurosurgery [1–3].

The history of transsphenoidal surgery at the Center for Neurosurgery named after acad. N.N. Burdenko is over 30 years old. Since 2007 transsphenoidal operations have been performed entirely under the control of an endoscope, which has a number of significant advantages over microscopic techniques [4]. To date, more than 6,000 transsphenoidal endoscopic operations have been performed. Approximately 70% of tumors removed by transsphenoidal access are pituitary adenomas (PA) [5].

Almost from the very beginning of using the transsphenoidal approach for the removal of PA, the need for adequate control of the position of the suprasellar section of the tumor for its effective removal and prevention of the development of intra / postoperative liquorrhea became obvious. To do this, initially (immediately before the operation, after induction into anesthesia), only lumbar punctures were used with the introduction of 20–30 ml of air, which made it possible to correlate the position of the instrument and the suprasellar section of the tumor capsule on the lateral craniography performed on an electron-optical converter. Due to the fact that the operating microscope made it possible to observe in the operating field only the Turkish saddle cavity, to improve the visualization of the suprasellar sections of the tumor, a method of controlled intracranial hypertension was developed, which made it possible, as a result of endolumbar injection of saline through the external lumbar drainage, to bring the upper sections of the tumor capsule from its leftovers [6–8].

The transition to performing operations under the control of an endoscope revealed the opposite need, since the tumor capsule sagging into the saddle cavity did not allow examining the entire cavity, detecting and removing the remnants of the tumor, while the risk of damage to the capsule itself increased. A simple and effective way to solve the problem of the most adequate provision of expansion and view of the entire surface of the tumor capsule was the technique of reducing intracranial pressure (ICP) by installing a lumbar drainage and removing the cerebrospinal fluid through it in combination with "half-sitting" positioning the patient on the operating table [2].

With obvious positive advantages of lumbar drainage, it should be borne in mind that this technique is invasive and is associated with a number of rather serious complications, such as: cerebrospinal fluid and dislocation disorders, infectious complications, the development of pneumocephalus, changes in the composition of the cerebrospinal fluid, post-dural syndrome, hemorrhagic complications and trauma of the nearest anatomical structures. For example, the risk of postoperative meningitis, the participation in the development of which also of lumbar drainage as an infection gate cannot be ruled out, varied from 1.2% to 8% depending on the size of the tumor and the characteristics of the operations [9].

In addition to invasive techniques for controlling intracranial volumes to regulate the position of the tumor capsule, there are also non-invasive ones. One of them can be considered hyperventilation, in which hypocapnia occurs, leading to a decrease in cerebral blood flow and ICP. However, hyperventilation is far from always effective and almost never gives a lasting effect.

The presented work describes a technique for non-invasive regulation of the position of the capsule of the suprasellar part of the tumor using ICP control due to intravenous infusion of hypertonic saline solution (HSS).

MATERIAL AND METHODS

During endoscopic transsphenoidal removal of hypertension, a study was carried out of the effectiveness of using a non-invasive technique for lowering ICP due to rapid intravenous infusion of HSS - in our study, it was 200 ml of 10% sodium chloride solution with a theoretical osmolarity of 3400 mosmol / L.

To determine the effectiveness of ICP regulation using this technique, a total of 89 patients were studied (operated on by the same team of neurosurgeons), from which two groups were formed: group A (n = 25) - a comparison group in which all patients received lumbar drainage (only for invasive monitoring of ICP, but not for removal of cerebrospinal fluid), HSS was not used, and all patients underwent visual endoscopic assessment of the position of the tumor capsule; group B (n = 64) - study group, in which all patients were injected intravenously with HSS and a visual endoscopic assessment of the position of the tumor capsule. Lumbar drainage was installed only in 25 patients of group B (patients were selected sequentially, as they entered the operating room, without using any special criteria), which was sufficient to compare the data obtained in both groups.

Patients of both groups underwent similar operations for the removal of hypertension using endonasal transsphenoidal endoscopic access.

In both groups, ICP indices were assessed at four main stages of the operation: stage 1 - the beginning of the operation before the patient was planted; 2nd stage - immediately after landing the patient (at 25–35º); 3rd stage - access and removal of the tumor; 4th stage - immediately after the end of the operation in the sitting position of the patient. Invasive ICP monitoring was carried out as follows: at the level of the lumbar spine, a lumbar drain was installed, which was connected to a continuous invasive pressure control sensor (in our case, ICP was measured in mm Hg) located in the projection of the Monroe hole (earlobe). The measurement was carried out using an invasive pressure measurement module connected to a Philips M1013A monitor, which displayed ICP values in digital form and in the form of a graphical curve (Fig. 1).

Fig. 1. An example of an invasive measurement of intracranial pressure through a lumbar drainage (photo of the screen of an anesthetic monitor). The blue arrow indicates the intracranial pressure in mm Hg, the red arrow indicates the graphical trend of the intracranial pressure

Reduction of ICP and regulation of the position of the tumor capsule in group B was carried out using a rapid intravenous drip (into a peripheral vein) injection of HSS within 10-15 minutes after the beginning of general anesthesia (the interval of administration corresponded to stages 1 and 2 and the beginning of the 3rd stage - access tumors).

In addition, in 25 patients of group B, given the high osmolarity of the studied HSS, laboratory control of the plasma electrolyte composition was carried out (patients were selected sequentially, as they entered the operating room, without using any special criteria), namely, the concentration of Na +, K + and Cl- in plasma at three stages: preoperatively, immediately after the administration of the HSS and 24 hours after the administration of the HSS.

For the statistical processing of the data obtained as a result of our research, the following programs were used IBM SPSS, Microsoft Exel. The validity criterion was chosen $p<0,05$.

RESULTS

In group A, at the 1st stage of the operation, ICP was within the average statistical norm (3–15 mm Hg) and amounted to 11.53 ± 0.83 mm Hg. At the 2nd stage, immediately after the patient's landing, ICP decreased to - 2.87 ± 1.45 mm Hg, and during the removal of the tumor (3rd stage) and at the end of the operation (4th stage) there was only a slight tendency towards its further decrease to -3.1 ± 1.32 and to -2.7 ± 1, 16 mm Hg respectively. On average, for the entire operation in group A, ICP decreased by 14.23 mm Hg. It should be emphasized that in this group there was no significant decrease in ICP when comparing stages 2-4 of the operation (Table. 1).

In group B at the 1st stage of the operation, ICP, as well as in group A, was within the average statistical norm and amounted to 13.62 ± 1.36 mm Hg, which was comparable to ICP indicators at a similar stage in group A. At the 2nd stage, there was a decrease in ICP to -0.4 ± 0.14 mm Hg, which was also comparable with similar indicators in group A. At the 3rd stage, against the background of the onset of the action of HSS, there was already a more distinct decrease in ICP - to -7 ± 0.7 mm Hg. At the 4th stage, ICP remained rather low (- 8.87 ± 0.84 mm Hg). Thus, in group B, against the background of the use of infusion of 10% NaCl solution during the operation, a noticeably more pronounced decrease in ICP was recorded (on average by 22.49 mm Hg, $p <0.05$) (Table 1, Fig. 2).

Table 1

Comparison of intracranial pressure in groups A and B at different stages of the operation

Patient groups	Intracranial pressure, mm Hg			
	1st stage	2nd stage	3rd stage	4th stage
Group A, n = 25	11.53 ± 0.83	-2.87 ± 1.45	-3.1 ± 1.32	-2.7 ± 1.16
Group B, n = 25	13.62 ± 1.36	-0.4 ± 0.14	-7 ± 0.7	-8.87 ± 0.84

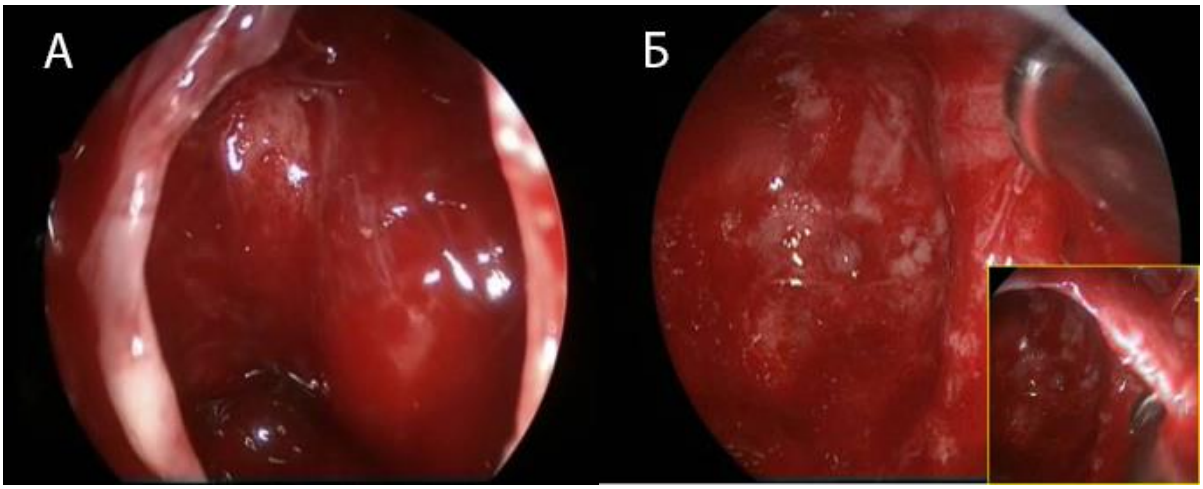

Fig. 2. The degree of expansion of the tumor capsule (intraoperative photo, 45; endoscope): A — incomplete expansion of the tumor capsule (group A); B —expansion of the tumor capsule (group B)

The preoperative level of plasma electrolytes in the studied patients did not exceed normal values: Na+ -142.95 ± 0.55 mmol / L, K+ -4.36 ± 0.09 mmol / L and Cl- 105.45 ± 0.54 mmol / L. After intravenous infusion of HSS, the electrolyte composition of plasma changed as expected: immediately after infusion of HSS, Na+ plasma increased by 5 mmol / L (on average above normal) and amounted to 150 ± 0.71 mmol / L, the Cl- level increased by an average of 12 mmol / L and amounted to 118.3 ± 1.06 mmol / L, the K+ level decreased, but remained within the normal range -3.64 ± 0.09 mmol / L.При лабораторном наблюдении у всех больных после операции все электролитные изменения возвращались к нормальным показателям в течение первых суток. After 24 hours, the indices were: Na+ -144.15 ± 0.61 mmol / L, K+ -4.15 ± 0.11 mmol / L and Cl- 102.55 ± 0.56 mmol / L. In group B, apart from the study of instrumental and laboratory parameters, the analysis of the main neurosurgical pathology was carried out. The vast majority of patients in this group - 62 (96.8%) underwent removal of various hypertension, in one case (1.2%) intracapsular removal of endosuprasellar craniopharyngioma was performed, and in one case (1.2%) chordoma was removed (Table. 2). Suprasellar spread of hypertension was observed in 56 (87.5%) of 64 patients.

Table 2
Analysis of the underlying neurosurgical disease in group B

Underlying disease	Number	%
Endosellar pituitary adenomas	6	9.3
Adenomas with endo-suprasellar growth	56	87.5
Chordoma	1	1.5
Craniopharyngeal cyst	1	1.5
Total	64	100

Visually, during endoscopic transsphenoidal surgery in group B, in all 64 cases (with the help of intraoperative endoscopic assistance), there was a clear positive effect - the tumor capsule rose suprasellar, which provided conditions for a complete examination of all its sections and removal of tumor remnants, and the hypotensive effect (decrease ICP) persisted throughout the operation, there was no additional need to lower the ICP by removing the cerebrospinal fluid through the lumbar drainage.

In 2018, a patent of the Russian Federation No. 2669924 "A method for regulating the position of a tumor capsule in endoscopic transsphenoidal surgery of a pituitary adenoma" was obtained for this technique.

DISCUSSION

From 2014 to the present, a number of solutions have been introduced in our clinic for intraoperative reduction of ICP and regulation of intracranial volumes: 10% NaCl solution (theoretical osmolarity 3400 mosmol / L), 15% mannitol solution (theoretical osmolarity 1131 mosmol / L). It should be noted that before the introduction of a 10% NaCl solution into the practice of our work, this technique was successfully routinely used in neurotraumatology and neuroresuscitation as an effective non-invasive tool that allows you to quickly reduce ICP. Initially, in the period from 2014 to 2016, to reduce ICP in our operations, we used the combined plasma-replacing hypertonic isooncotic solution HyperHAES, which is a combination of hydroxyethyl starch with a degree of molar substitution of 0.5 and an average molecular weight of 200,000 Da and 7.5 % NaCl solution. This combined solution had a sufficiently high theoretical osmolarity - 2464 mosmol / L and its intravenous administration at the beginning of the operation led to a rapid and sufficient decrease in ICP for the expansion of the tumor capsule [8].

Currently HyperHAES is out of production. Considering this, to reduce ICP and expand the tumor capsule, the use of HSS seems to be available and important, which has a higher efficiency in reducing ICP and has no serious complications in its use. Based on the studies carried out comparing

various solutions that can reduce ICP, it can be concluded that 10% NaCl solution, when compared with 15% mannitol solution, has established itself as a more effective means of reducing ICP. Today, the use of HSS is gaining increasing popularity in world practice. [10, 11].

The mechanism of the effect of HSS on ICP is reduced to the following stages: rapid intravenous administration of HSS leads to the creation of plasma hyperosmolarity; fluid, mainly from the intercellular space, quickly moves into the blood vessels and thereby increases the volume of circulating blood, as a result of which arterial pressure and cardiac output increase rapidly, blood viscosity decreases, which leads to a transient increase in cerebral blood flow and an increase in cerebral perfusion pressure (CPP). In turn, an increase in CPP in conditions of intact autoregulation of cerebral vessels leads to their reflex constriction and a decrease in the volume of blood circulation in the brain. As a result of these mechanisms, a decrease in ICP occurs, leading to the expansion of the tumor capsule and its elevation suprasellar, which is a necessary condition for examining the entire intracapsular space and complete removal of the tumor. [12].

CONCLUSION

The results of the study convincingly showed the feasibility of using intravenous administration of hypertonic saline (10% NaCl solution) to achieve stable intraoperative intracranial hypotension sufficient for the operation of transsphenoidal endonasal endoscopic removal of endo-suprasellar adenomas of the pituitary gland - tumors of the chiasmatic-sellar region with a well-formed capsule, at the low risk of developing intraoperative liquorrhea. The laboratory tests carried out revealed the safety of the method presented in the article for the patient's homeostasis system.

In fact, the use of HSS allowed us to completely abandon the potentially risky use of external lumbar drainage when performing standard transsphenoidal endoscopic operations.

In cases where there is a likelihood of the formation of a significant defect in the base of the skull and the need to perform multilayer plasty is high, for example, when performing extended approaches, the use of external lumbar drainage is justified and has no alternative yet.

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