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Study of the effectiveness of ventriculosubarachnoid drainage in neonatal hydrocephalus according to the data of the Republic of Crimea for the period 2000–2018

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ABSTRACT

Despite the achieved success in the treatment of neonatal hydrocephalus, the task of restoring circulation, outflow, and absorption of cerebrospinal fluid (CSF) remains urgent.

The aim of the study was to investigate the effectiveness of ventriculosubarachnoid drainage in compensating hydrocephalus without shunt implantation.

Materials and methods. We collected and studied clinical material for the period from 2000 to 2018 according to the data of the Republic of Crimea. We identified groups of premature (n = 184) and full-term (n = 107) infants who underwent standard treatment with lumbar puncture, subgaleal drainage, and ventriculoperitoneal shunting (VPS). In case of ventricular occlusion in 143 premature and 46 full-term infants, at the initial stage of treatment, the option of coronary – lambdoid subarachnoid ventriculostomy (RF Patent No. 2715535) in combination with lumbar punctures was included. With progression of hydrocephalus, ventriculosubarachnoid stenting (RF Patent No. 2721455) with subgaleal drainage was considered as an option.

Results. The inclusion of the proposed options made it possible to increase the rate of hydrocephalus compensation without VPS to 75.5% in premature infants and to 80.4% in full-term infants versus 28.3% and 20.6%, respectively, according to the standard protocol ($p < 0.001$). In other cases, the imbalance between CSF production and absorption persisted, which required integration of a stent with a peritoneal part of the shunt, without replacing the system.

Conclusion. The obtained result allows to consider the inclusion of the proposed options in the modern treatment algorithm for neonatal hydrocephalus.

Keywords: ventriculosubarachnoid drainage, hydrocephalus, infants

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Conformity with the principles of ethics. All legal representatives of the patients signed an informed consent to participate in the study. The study was approved by the Ethics Committee at V.I. Vernadsky Crimean Federal University (Protocol No. 53 of 06.12.2018).

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Изучение эффективности опции вентрикуло-субарахноидального дренирования при неонатальной гидроцефалии по данным Республики Крым за период 2000–2018 гг.

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РЕЗЮМЕ

Несмотря на достигнутые успехи в лечении гидроцефалии неонатального периода, остается актуальной задача восстановления ликвородинамики, оттока и всасывания ликвора.

Цель – изучение эффективности опций вентрикуло-субарахноидального дренирования в компенсации гидроцефалии без имплантации шунтов.

Материалы и методы. Собран и изучен клинический материал за период 2000–2018 гг. по данным Республики Крым. Выделены группы недоношенных (n = 184) и доношенных (n = 107) детей, которым выполнялось стандартное лечение с люмбальными пункциями, субгалеальное дренирование и вентрикуло-перитонеальное шунтирование (ВПШ). При окклюзии желудочков у 143 недоношенных и 46 доношенных детей на начальном этапе лечения включалась опция коронаро-транслябдовидной субарахно-вентрикулостомии (патент РФ № 2715535) в комплексе с люмбальными пункциями, а при прогрессировании гидроцефалии – вентрикуло-субарахноидальное стентирование (патент РФ № 2721455) с субгалеальным дренированием.

Результаты. Включение предложенных опций позволило повысить процент компенсации гидроцефалии без ВПШ до 75,5% у недоношенных детей и 80,4% у доношенных против 28,3 и 20,6% соответственно при стандартном протоколе (p < 0,001). В остальных случаях сохранялся дисбаланс продукции – всасывания ликвора, что потребовало интеграции стента с перитонеальным сегментом шунта без замены системы.

Заключение. Полученный результат позволяет рассматривать включение предложенных опций в современный лечебный алгоритм при неонатальной гидроцефалии.

Ключевые слова: вентрикуло-субарахноидальное дренирование, гидроцефалия, дети

Конфликт интересов. Авторы заявляют об отсутствии явных и потенциальных конфликтов интересов, связанных с публикацией настоящей статьи.

Источник финансирования. Авторы заявляют об отсутствии финансирования при проведении исследования.

Соответствие принципам этики. Все законные представители пациентов подписали добровольное информированное согласие на участие в исследовании. Исследование одобрено этическим комитетом КФУ им. В.И. Вернадского (протокол № 53 от 06.12.2018).

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INTRODUCTION

Current publications on pediatric neurosurgery and neurology describe the principles of treatment for posthemorrhagic hydrocephalus (PHH) in newborns with normalization of the increased intracranial pressure, including lumbar punctures (LP) and ventricular punctures (VP), external and internal ventricular drainage, and artificial ventriculoperitoneal shunts (VPS) [1–14]. A sequence of treatment options according to the "LVV protocol" is considered as guidelines for PHH therapy: LP and VP, ventriculosubgaleal drainage (VSGD), and if they are ineffective – VPS [1–6].

The relevance of the issue is determined by the absence of a generally accepted opinion regarding treatment for decompensated PHH with subarachnoid space (SAS) block and impaired resorption [7–10]. There is a need to personalize treatment tactics [2] aimed at restoring CSF circulation and reducing the frequency of VPS surgery [11–14]. Solution of these issues becomes interdisciplinary in the joint practice of a pediatric neurosurgeon, neonatologist, and neurologist.

The aim of the study was to investigate the effectiveness of ventriculosubarachnoid drainage options for PHH compensation in newborns.

MATERIALS AND METHODS

We have collected, studied, and analyzed clinical data on the treatment of PHH in 480 newborns in the Republic of Crimea for the period from 2000 to 2018. The study was approved by the Ethics Committee at V.I. Vernadsky Crimean Federal University (Protocol No. 53 of 06.12.2018). All legal representatives of the patients signed an informed consent to participate in the study.

327 children were preterm (group 1) and 153 were full-term infants (group 2). 184 children in group 1 and 107 children in group 2 received standard treatment according to the "LVV protocol".

In case of ventricular occlusion with SAS block in 143 preterm infants (group 1) and 46 full-term infants (group 2), the standard treatment protocol at the initial stage included coronary – lambdoid subarachnoid ventriculostomy (CLSV) [15] and in case of PHH progression – ventricular drainage in the SAS using ventriculosubarachnoid stenting system (VSS) [16].

The inclusion criterion for the proposed treatment options was decompensated PHH. In case of restoration of CSF circulation with compensation of PHH, further stages of correction were excluded. Tables 1 and 2 describe the amount of care provided for premature and full-term infants with the inclusion of the CLSV and VSS options.

Table 1

The amount of neurosurgical care in premature infants (group 1)

PHH correction stages	*n* (%)
According to the "LVV protocol"	
LP and VP with 20–22G needles	184 (100)
VSGD	151 (82.1)
VPS	132 (71.7)
inclusion of the proposed options in case of decompensated PHH	
CLSV (using 14 G needles) in combination with LP	143 (100)
Ventricular drainage in SAS in combination with VSGD	94 (65.7)
VSS system integration in the peritoneal part of the shunt	35 (24.5)

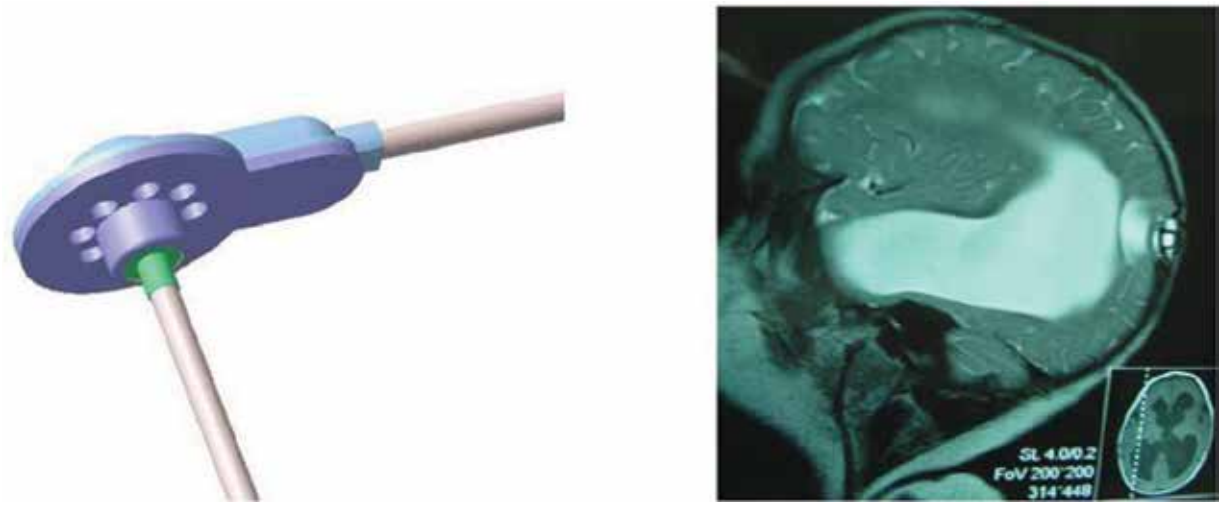
Table 2

The amount of neurosurgical care in full-term infants (group 2)

PHH correction stages	*n* (%)
According to the "LVV protocol"	
LP and VP with 20–22G needles	107 (100)
VSGD	90 (84.1)
VPS	85 (79.4)
inclusion of the proposed options in case of decompensated PHH	
CLSV (using 14 G needles) in combination with LP	46 (100)
Ventricular drainage in SAS in combination with VSGD	22 (47.8)
VSS system integration in the peritoneal part of the shunt	9 (19.6)

There were no complications and mortality associated with surgical trauma. CLSV was performed using a two-point puncture of the anterior and occipital horns of the lateral ventricles through coronary and lambdoid sutures using 14G needles, with evacuation of blood and CSF and SAS decompression. Irrigation of the ventricles was performed with normal saline with encephalolysis when the needles reached the SAS. Drainage canals were formed between the ventricles and SAS with collateral outflow of CSF and elimination of occlusion. We repeated the procedure 3 times with a 4-day interval, alternating it with irrigation of the craniospinal CSF pathways using LP, until CSF circulation was normalized.

The advantages of the method include ease of application (a child in a humidicrib), the effectiveness of evacuation of blood clots from the ventricles with minimization of brain injury during hemorrhagic tamponade, and reduction of irrigation time for the craniospinal CSF spaces. The VSS system developed by the authors provided CSF drainage in the SAS through a ventricular drain and a pump base perforation (Figure).



a *b*

Figure. VSS system: *a* – general view of the pump, *b* – magnetic resonance imaging (MRI) after surgery

For this purpose, after insertion of the ventricular drain into the ventricle with the control of CSF flow, the pump was installed in the burr hole with a diameter of up to 10 mm with the fixing cuff expanded in the SAS and fixed by sutures along the edges of the trepanned area. In addition, we exercised temporary CSF outflow from the pump through the distal drain into the subgaleal pocket (SP), which made it possible to alleviate intracranial pressure drops in the postoperative period with evacuation and irrigation of the CSF pathways. The dome of the pump was punctured and normal saline was injected with control of its outflow into the SAS and ventricles. Re-infusion of normal saline through the pump with vigorous irrigation of the SAS and ventricles and passive evacuation of CSF through SP in combination with LP was performed on days 3–5, 7, 10, 14, and at the end of week 3, 4, 5, and 6 after surgery. While maintaining the imbalance between the increasing age-related volume of CSF production and its absorption after 6 weeks, the VSS system was integrated through the connector of the distal drain with the peritoneal part of the shunt (Codman, Medtronic, USA), including a chamber with a medium-pressure valve, regulating the discharge of CSF into the abdominal cavity.

The data were processed using the Statistica 10.0 software (StatSoft Inc., USA). Fisher's exact test (FET) was applied to compare the efficiency rates of PHH compensation in premature and full-term infants under the standard LVV protocol and after the inclusion of the options for ventriculosubarachnoid drainage in the treatment regimen. The differences were considered statistically significant at $p < 0.05$.

RESULTS

Compensation of hydrocephalus at the initial stage of treatment according to the LVV protocol after LP was observed in 33 of 184 premature infants, which made it possible to avoid drainage in 17.9% of cases (Table 3).

Table 3

Comparative analysis of compensation of hydrocephalus in premature infants

Compensation of hydrocephalus	*n* (%)	*p**
After LP and VP (according to the LVV protocol)	33 (17.9)	0.046
After the inclusion of CLSV (in combination with LP)	49 (34.3)	
After VSGD (according to the LVV protocol)	19 (12.6)	< 0.001
After the inclusion of VSS (in combination with VSGD and and LP)	59 (62.8)	

*according to FET – here and in Table 4.

When the CLSV option was included in the hydrocephalus treatment protocol, PHH compensation was achieved in 49 out of 143 children, which allowed to exclude drainage in 34.3% of cases ($p = 0.046$). A decrease in drainage manipulations after the inclusion of CLSV resulted from effective evacuation of blood clots and CSF from the ventricles using 14G needles, irrigation of the ventricles and SAS with normal saline, elimination of the occlusion, and reduction of the irrigation time for the CSF pathways.

Compensation of hydrocephalus at the stage of surgical management after VSGD was observed in 19 of 151 children (12.6%), after inclusion of VSS, it was noted in 59 of 94 children, which made it possible to

exclude VPS in 62.8% cases ($p < 0.001$). The cumulative positive outcome with compensated hydrocephalus without VPS in preterm infants after the inclusion of the CLSV and VSS in the treatment regimen was achieved in 75.5% of cases vs. 28.3% with the standard protocol ($p < 0.001$).

Clinical case. Child K. was delivered by a nulliparous woman with an aggravated obstetric history at the Perinatal Center at 26 weeks of gestation, with an extremely low body weight of 650 g. The Apgar score was 1–2 points. Grade 2 cerebral ischemia was detected, and mechanical ventilation was performed. After birth, grade 4 periventricular and intraventricular hemorrhage with hemorrhagic tamponade of both lateral and third ventricles was diagnosed against the background of morphofunctional immaturity with respiratory and cardiovascular insufficiency. Treatment at the initial stage with CLSV in combination with LP made it possible to stabilize CSF circulation. After 30 weeks, PHH progression, compression and blockage of SAS were noted. Surgical treatment was performed with indirect ventricular drainage in the SAS using VSS system according to the described method, in combination with VSGD and LP. A decrease in the protein level in the CSF from 4.6 to 2.4 g / l on day 10, and to 0.8 g / l according to the last test, was revealed. By week 37, compensated PHH was noted according to the clinical data and CT-guided neurosonography findings at week 40. Follow-up during the first year of life did not show progression of intracranial hypertension; no seizures were noted.

The revealed differences were also noted in full-term infants (Table 4).

Table 4

Comparative analysis of hydrocephalus compensation in full-term infants

Compensation of hydrocephalus	*n* (%)	*p*
After LP and VP (according to the LVV protocol)	17 (15.9)	0.027
After the inclusion of CLSV (in combination with LP)	24 (52.2)	
After VSGD (according to the LVV protocol)	5 (5.6)	< 0.001
After the inclusion of VSS (in combination with VSGD and LP)	13 (59.1)	

According to the LVV protocol, compensation of PHH after LP was observed in 17 out of 107 full-term infants, which made it possible to exclude drainage in 15.9% of cases. When the CLSV was included in the treatment regimen, PHH compensation was achieved in 24 out of 46 children, which allowed to exclude drainage in 52.2% of cases ($p = 0.027$).

PHH compensation after VSGD was observed only in 5 out of 90 children (5.6%). After inclusion of VSS in the treatment regimen, compensated PHH was noted in 13 out of 22 full-term infants, which allowed to avoid VPS in 59.1% cases ($p < 0.001$). The cumulative positive outcome with compensated PHH in full-term infants after the inclusion of CLSV and VSS in the treatment regimen was achieved in 80.4% of cases vs. 20.6% under the standard protocol ($p < 0.001$).

In case of integration of the VSS system with the peritoneal part of the shunt, irrigation of the ventricles and SAS was performed with normal saline, which allowed to eliminate dysfunction of the ventricular segment and the pump. No signs of overdrainage were noted. To improve the efficiency of the VSS system, a hermetic self-expanding ventriculosubarachnoid stent was proposed [17] with an additional sealing cuff to place the stent into the burr hole without suturing and to eliminate the risk of liquorrhea.

DISCUSSION

Treatment of PHH in newborns involves LP at the initial stage. At the same time, this does not ensure the evacuation of blood clots from the ventricular system and requires long-term irrigation of the craniospinal CSF spaces; and a blood clot in the third ventricle and other types of occlusion are contraindications for LP [1–8].

Ventricular punctures using 20–22G needles do not provide effective evacuation of blood clots from the ventricles with a high risk of damage to the brain matter during vigorous aspiration. During long-term external drainage required for clot lysis, the risk of infection increases and occlusion of CSF pathways is not eliminated [1–8].

An increase in the effectiveness of treatment with the inclusion of CLSV results from the use of brain needles with a larger diameter and larger areas of access points with elimination of occlusion, formation of a ventriculosbarachnoid anastomosis, evacuation of blood clots from the ventricles, as well as evacuation of its degradation products from the craniospinal CSF spaces with a decrease in the irrigation time and the risk of adhesions.

VSGD provides long-term evacuation of blood from the ventricles with the elimination of occlusion of CSF pathways [1–8]. An increase in the effectiveness of treatment with VSS is achieved by restoring intracranial circulation and CSF absorption at the

stage of long-term irrigation of the craniospinal CSF spaces with normal saline in combination with VSGD and LP. The need for long-term irrigation with exclusion of blood release into the basal cisterns is a limiting factor for endoscopic ventriculostomy in the neonatal period [9].

VPS artificially drains CSF to the abdominal cavity. Shunt dependence and high rates of dysfunction and complications are noted [9–14]. Integration of the VSS into the peritoneal part of the shunt provided CSF drainage to the SAS and redirected excess CSF to the abdominal cavity with adaptation of the resorptive capacity to the increasing volume of CSF in the first year of life. Besides, it reduced the risk of system dysfunction without its replacement and reinstallation.

CONCLUSION

PHH compensation indicates the need for ventriculosubarachnoid drainage using CLSV and VSS to eliminate occlusion, ensure effective irrigation of the CSF spaces, and restore circulation and absorption of CSF. The inclusion of the CLSV and VSS options in the treatment algorithm led to an increase in the compensated PHH to 75.5% in preterm infants and to 80.4% in full-term infants vs. 28.3% and 20.6%, respectively, under the standard LVV protocol ($p < 0.001$). Integration of the VSS system with the peritoneal part of the shunt, while maintaining the imbalance between CSF production and absorption, allows to expand the potential scope of using shunt systems for the treatment of PHH in newborns.

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Authors contribution

Volkodav O.V. — conception and design; analysis and interpretation of data. Zinchenko S.A. — critical revision for important intellectual content. Khachatryan V.A. – final approval of the manuscript for publication.

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