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Article

Contrast Enhancement of the CSF System in Children With Hydrocephalus

Usmankhanov Odilkhon Ayubkhanovich[1]

1. Tashkent State Medical University Associate Professor, Department of Neurosurgery, Traumatology and Orthopedics, PhD in Medical Sciences
* Correspondence odilkhon@list.ru

Abstract: This study investigates the diagnostic and clinical significance of contrast-enhanced examination of the cerebrospinal fluid (CSF) system in children with hydrocephalus. The research is based on the analysis of 40 pediatric patients aged from 15 days to 15 years, examined using multislice computed tomography (MSCT), including ventriculography, cisternography, and cystography .

The methodology involved the use of contrast agents (Omnipaque 300/350 and Visipaque 270) with age-dependent dosages ranging from 2.5 ml to 7.5 ml, as well as advanced imaging modes such as tissue window, bone window, and 3D reconstruction. The study revealed that contrast-enhanced MSCT provides precise visualization of the morphofunctional structure of intracranial CSF spaces, allowing differentiation between isolated and communicating cavities, as well as accurate identification of intracranial cysts. The results demonstrated that in 17.7% of pediatric hydrocephalus cases, additional contrast studies were necessary to clarify the diagnosis and determine optimal surgical strategies. The obtained findings highlight the critical role of MSCT-based contrast diagnostics in improving preoperative planning, reducing diagnostic errors, and enhancing the effectiveness of neurosurgical interventions.

Keywords: Hydrocephalus, cerebrospinal fluid (CSF), intracranial cysts, MSCT, ventriculography, cisternography, cystography, pediatric neurosurgery, contrast imaging.

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1. Introduction

The aim of this study is to investigate the relationship between multiple intracranial cysts using multislice CT (MSCT), cisternography, ventriculography, and cystography. A study of cerebrospinal fluid spaces with Omnipaque 350 contrast (multispiral computed tomography — MSCT — ventriculography, cystography, and cisternography) was performed in 40 patients aged from 15 days to 15 years. MSCT scanning modes included "tissue," "bone window," and 3D reconstruction. MSCT — ventriculo-, cisterno-, and cystography — provided the clinician with objective information on the morphofunctional architecture of the craniocerebral cerebrospinal fluid system[1]. The results of contrast studies of the cerebrospinal fluid space of the brain in existing polycystic brain disease were the basis for conducting neurosurgical intervention and establishing indications for surgical intervention. Detailed characterization of the pathological intracranial cerebrospinal fluid system allowed for the selection of the surgical approach for neurosurgical treatment. It was found that MSCT (cystography and cisternoventriculo-computer imaging) are essential diagnostic methods for hydrocephalus, complementing MRI, and can be used in 34.7% of pediatric patients with hydrocephalus[2].

Modern invasive and non-invasive examination methods, such as computed tomography (CT) and magnetic resonance imaging (MRI), have significantly simplified and

facilitated the diagnosis of hydrocephalus in children . The problem of treating children with hydrocephalus, especially when complicated by intracranial cysts, remains relevant at present. Thus, hydrocephalus accounts for 10.6% of all mortality in planned pediatric neurosurgery . In a number of cases, CT and even MRI cannot exclude the use of invasive techniques[3]. Although, for example, in the case of an intraventricular cerebrospinal fluid cyst of the third ventricle, characteristic indirect signs (the "Mickey Mouse" symptom) have been described. In the case of cysts of the lateral ventricles, characteristic CT and MRI manifestations have not been described. The increased methodological level (MRI in myelography mode, phase-contrast MRI with cardiac synchronization, etc.) makes it possible to characterize, within a certain framework, some features of cerebrospinal fluid dynamics. However, invasive techniques (primarily cerebrospinal fluid analysis) have not lost their diagnostic value[4]. Presumptive conclusions about the isolated nature of the ventricles and (or) intracranial cerebrospinal fluid cysts are usually made on the basis of generalization of a number of factors: dissociation of the composition of cerebrospinal fluid (CSF) and cerebrospinal fluid pressure in various cavities; the presence of asymmetry, displacement and dislocation according to CT and MRI data; the state of adjacent subarachnoid and cisternal spaces; bulging and other deformations of the skull, etc. An objective judgment can be based on the data of research methods with contrast[5]. Contrast enhancement of cerebrospinal fluid cavities is usually combined with standard cerebrospinal fluid examination (ventricular and lumbar punctures, punctures of intracranial cysts with measurement of cerebrospinal fluid pressure, examination of cerebrospinal fluid composition and bacteriological culture). It is also appropriate to add that cerebrospinal fluid examination has not lost its significance and remains indicated and in demand to this day, especially in infants. In addition, for various forms of hydrocephalus, individual research methods have varying information content, which sometimes requires their combined use. When planning a surgical intervention, the clinician is faced with the question of the extent of the intervention[6]. In this regard, preoperative detailing of the level of possible occlusion or cystic brain lesion is quite important. The wide range of surgical interventions available (direct operations, cerebrospinal fluid shunt operations, neuroendoscopy and combined interventions) indicates objective difficulties and debatability in choosing an adequate treatment method. Possible complications of surgical treatment of intracranial cysts (postoperative cerebrospinal fluid leakage, meningitis, ventriculitis, shunt dysfunction, cyst recurrence, etc.) and unsatisfactory treatment results require a comprehensive study of the nature of the cyst in each specific case[7].

The aim of the study was to evaluate the capabilities of multislice CT (MSCT) ventriculography, cisternography, and cystography in assessing the relationships of intracranial cerebrospinal fluid cavities (hydrocephalus, Dandy-Walker cyst, arachnoid cysts, polycystic disease, etc.).

2. Material and Methods

A total of 181 children with a diagnosis of hydrocephalus were treated at the neurosurgical clinic of the Republican Center for Neurosurgery and the Tashkent Pediatric Medical Institute from 2005 to 2009 inclusive. Examination of the cerebrospinal fluid spaces with contrast (MSCT — ventriculography, cystography, and cisternography) was performed in 32 patients, accounting for 17.7%. The patients ranged in age from 36 days to 15 years, of whom 16 (50%) were infants. A total of 33 studies with contrast were performed: ventriculography was performed in 17 patients, cisternography in 9, and cystography in 7 (in one observation, a patient underwent ventriculography and cystography sequentially). Isolated forms of hydrocephalus were observed in 6 patients out of 32 examined; the remaining patients had a combination of cerebral hydrocephalus with other pathological processes (intracranial cysts, brain and spinal cord anomalies).

3. Results and Discussion

Intracranial cysts were predominantly represented by arachnoid cysts (lateral sulcus, posterior cranial fossa, corpora quadrigemina, transtentorial, and multiple), as well as porencephalic cysts, parenchymal cysts, intraventricular cysts, septum pellucidum cysts, and

polycystic cysts. The etiologic factors of hydrocephalus were congenital dysembryogenesis in 18 cases, intrauterine infection in 11, and traumatic brain injury in 3. Contrast manipulations during MSCT—ventriculography, cisternography, and cystography—were performed under anesthesia (intramuscular or intravenous sedation)[8]. According to well-known standards, cerebrospinal fluid (CSF) punctures were performed first, with CSF pressure and composition assessed. Then, a non-ionic water-soluble radiocontrast agent, Omnipaque 300 or Visipaque 270 (Nycomed), was injected into the cerebrospinal fluid space through a needle in a volume dependent on the age and body weight of the children: usually, 2.5–3.5 ml of contrast agent was injected into children under 6 months, no more than 5 ml into children under 1 year, and up to 7.5 ml into children over 1 year[9]. The volume of injected contrast agent was also selected individually, taking into account the expected volume of the cerebrospinal fluid cavities. However, the total amount of iodine in the injected agent should not exceed 3 g. All other things being equal, preference was given to injecting the contrast agent directly into the cerebrospinal fluid cavity of the "pathogenetic focus," for example, into a cyst or into an asymmetrically wider lateral ventricle. Posterior cranial fossa cysts were relatively accessible for puncture when the lambdoid suture was stretched and there was a gap for intersutural passage of the puncture needle[10]. To ensure adequate and safe needle insertion and placement during puncture of cerebrospinal fluid-containing cavities, neurosonographic (NSG) navigation was performed in 20 patients. During NSG navigation, the needle insertion point was marked, the distance to the cerebrospinal fluid-containing cavity was calculated, and the trajectory of access to it from various positions on the cranial vault was determined. An initial MSCT was performed 2-4 hours after contrast agent administration. If necessary, a delayed MSCT was performed 6-24 hours later[11]. MSCT was performed on a Philips Brilliance 64 multislice tomograph. Scanning modes included tissue, bone window, and 3D reconstruction. Results and discussion. Asymmetry of the lateral ventricles was a natural concern, as was the detection of lateral ventricular asymmetry on native CT and MRI. Contrast-enhanced examination of the ventricular system in these conditions allowed differentiation between occlusion at the level of the interventricular foramen and hemispheric hemiatrophy and porencephaly (Fig. 1). The ventriculograms demonstrate that ventricular asymmetry with right ventricular dilation is not due to ventricular separation as a result of occlusion, but is a consequence of structural damage to the right hemisphere[12]. Questionable interpretation of intraventricular cysts, based on native CT and MRI data, is potentially dangerous in terms of possible diagnostic and surgical errors.

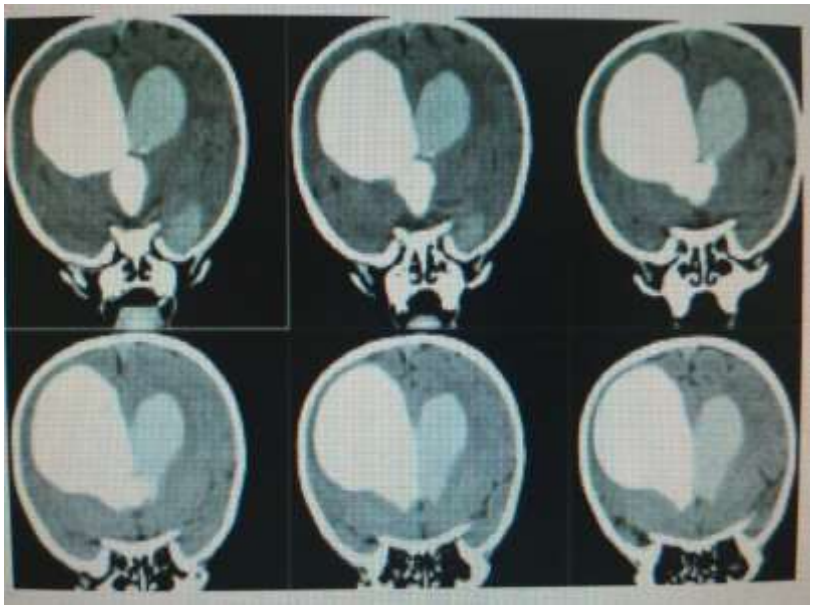

Figure 1. MSCT ventriculography in frontal reconstructions. Asymmetric hydrocephalus. Contrast agent spreads into all cerebral ventricles. Enlargement of all sections of the right lateral ventricle is noted, especially the posterior horn of the left ventricle.

In this situation, contrast-enhanced imaging techniques made it possible to isolate the morphological architecture of the pathological substrate from the overall mass of CSF density and CSF signal. It should be acknowledged that intraventricular cysts detected by MSCT ventriculography (Fig. 2) pose significant challenges not only from a diagnostic standpoint but also from a treatment perspective. In the context of the pathological conditions of the CSF

system under study, the combination of hydrocephalus and paraventricular cysts is of greatest practical interest[13]. Thus, differentiating between true and false porencephaly is a labor-intensive but crucial process. Published data and our own experience convince us that the prognosis is extremely unfavorable in so-called polycystic encephalopathy (encephalomalacia), especially in cases of localization (fragmentation) of the cerebral ventricles. MSCT ventriculography confirms the isolation of the ventricle from other CSF cavities and the need for additional, step-by-step contrast enhancement of the isolated CSF compartments. Subtentorial cysts stand out, with their transtentorial extension variants of considerable interest (Fig. 3)[14].

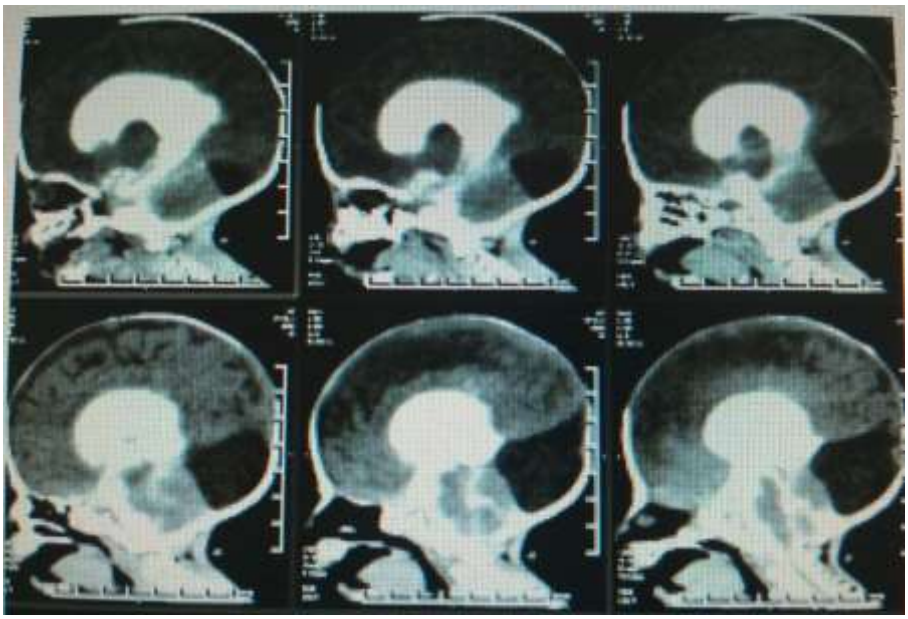

Figure 2. MSCT ventriculography in sagittal reconstructions. Contrast filling of all cerebral ventricles, including the fourth ventricle, is visualized. A CSF density formation is seen under the high tentorium, located midline with some lateralization to the left. Hydrocephalus is associated with a superior retrocerebellar cyst.

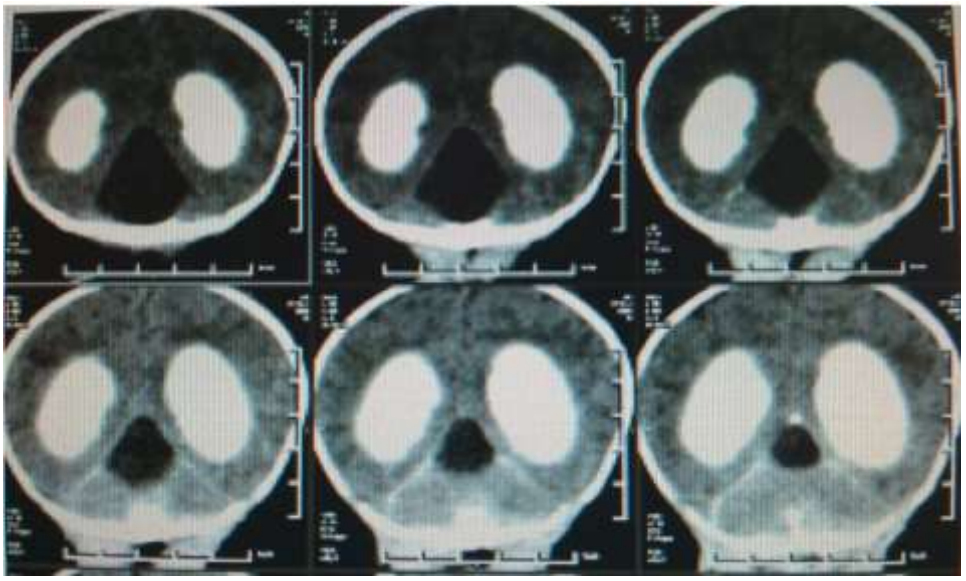

Figure 3. MSCT ventriculography in frontal reconstructions. Contrast filling of all cerebral ventricles, including the fourth ventricle, is visualized. Midline cerebrospinal fluid density is detected.

The particular delicacy of handling such cysts is primarily due to their gigantic size and hourglass-shaped parastem location. Frequently, in multicavity intracranial lesions, CSF cysts and isolated CSF cavities (due to the insufficient resolution of native MRI) are not delineated or identified. If surgical intervention is limited to a standard ventriculo-shunt procedure, this can result in a highly unusual, and sometimes life-threatening, condition. As is well known, when one isolated CSF cavities is shunted, the other cavities tend to enlarge[15]. Against this background, a change in the intracranial pressure gradient can lead to morphofunctional

ion of the brain due to its dislocation. The data presented in Figure 3 suggest the challenging task of balancing intracranial CSF dynamics for neurosurgeons. Complications following MSCT (ventriculography, cisternography, and cystography), according to our clinical observations, were few and easily manageable (subfebrile body temperature, rare vomiting, mild restlessness in children). We consider contraindications to ventriculography, cisternography, and cystography to be anatomical inaccessibility of cerebrospinal fluid (CSF) receptacles or physiological inadmissibility, which arose due to brain dislocation or the absence of a bony "window" for needle puncture. In our observations, contraindications to ventriculography, cisternography, and cystography were formulated in 2 patients. One of the undoubted advantages of contrast-enhanced CSF examination methods is the ability to assess CSF pressure and analyze CSF composition[16]. Disadvantages and side effects of this type of examination include invasiveness and, naturally, the need for sedation in children. Surgical correction of intracranial cerebrospinal fluid dynamics was performed in 23 children. The parents of 5 children abstained from surgical treatment, and in 4 children, surgical treatment was not attempted due to concomitant ongoing cytomegalovirus infection. Typical cerebrospinal fluid shunting (CSF) surgeries were performed in 14 patients. Atypical CSF shunting surgeries, according to the results of contrast studies, were performed in 9 patients. Thus, we can assume that MSCT—ventriculo-, cisterno-, and cystography in the axial plane, with frontal and sagittal reconstructions, as well as supplemented by multipositional 3D reconstruction—provides the clinician with objective information on the morphofunctional architecture of the craniocerebral CSF system[17]. The presented material demonstrates that a comprehensive examination of patients with multi-cavity brain lesions, including invasive techniques, allows for differentiation of the suspected nature of the intracranial pathological system. Consequently, contrasting of intracranial cerebrospinal fluid cavities creates the prerequisites for formulating indications for neurosurgical treatment and selecting the most appropriate surgical method. The obtained data justify the inclusion of MSCT techniques—ventriculography, cisternography, and cystography—in the diagnostic system for hydrocephalus. These techniques can significantly complement other methods, including MRI[18].

4. Conclusions

In children with various forms of hydrocephalus, the need for intracranial cerebrospinal fluid (CSF) cavities contrast arises in 17.7% of cases. These patients primarily have hydrocephalus combined with CSF cysts.

MSCT (ventriculography, cisternography, and cystography) allows us to identify various morphofunctional characteristics of the cerebral anomaly (disconnectivity or connectivity of various CSF cavities, true cyst size, multi-chambered cavities), which, in turn, enables surgical planning.

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