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Brain CT Scan Indexes in the Normal Pressure Hydrocephalus: Predictive Value in the Outcome of Patients and Correlation to the Clinical Symptoms

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The aim of this study is to find out the correlation of the ventricular size of the brain, as it is estimated using brain computed tomography (CT) scan indexes in patients with normal pressure hydrocephalus (NPH), to: a) the clinical symptoms, and b) the results of cerebrospinal fluid (CSF) shunting procedures. We looked for any predictive value in the estimation of brain CT scan indexes, in patients as above, in whom a shunt is going to be placed. It is well known that it is very difficult to decide who is going to improve after shunting. We studied 40 cases of patients with the diagnosis «NPH» in whom the ventricular shunts were placed. Every symptom (disturbance of gait, of memory, incontinence) was separately evaluated preoperatively. The outcome of shunting was also evaluated and the patients were graded. The following CT scan indexes were estimated from the preoperative CT scans of the brain in every case: the ventricle-brain ratio (VBR), the bi-caudate and bi-frontal ratios, the third ventricle-Sylvian fissure (3V-SF) ratio, and the four largest cortical gyri. The method we have used for statistics is «one way analysis of variance», correlating the CT scan indexes to the symptoms of the patients preoperatively, and the outcome of them postoperatively.

The main conclusion is that the size of the lateral ventricles of the brain preoperatively is not correlated to the outcome after CSF shunting surgery, but it is correlated to the symptoms of NPH preoperatively.

Key words: hydrocephalus, normal pressure hydrocephalus, CSF shunting procedures, CSF shunting outcome, brain CT scan indexes

Introduction

NPH is a clinical syndrome of the elderly consisted of the presence of chronic hydrocephalus, without elevated pressure of the CSF, and a triad of symptoms: dementia, disturbance of gait and incontinence. It is a syndrome of great importance because it is possible to succeed an important improvement in cases with progressive dementia after a CSF shunt procedure. Since 1965, when Hakim and Adams first described this syndrome, it remains a big problem to predict those patients who are going to improve after surgery, because the initial enthusiasms were followed by disappointing results. The correct decision for shunting is very difficult, even in our days with the tremendous improvement of neuroimaging and interventional procedures (ICP measurements), and the international bibliography is unable to give a standard order for the patients selection for shunting.

In this retrograde study we examined the correlation of the brain CT scan indexes to the clinical picture of the patients with NPH (preoperatively), and to the clinical result after CSF shunting procedure (postoperatively). The aim of this is to test the hypothesis that these indexes may have a predictive value in patients with NPH and subjects for SCF shunt procedure.

Material and methods

Patient selection

This study is based on 40 patients who were admitted in the Departement of Neurosurgery of K.A.T. General Hospital in ten years with the diagnosis of "communicating hydrocephalus-NPH", and were subjected in surgical implantation of a ventriculo-peritoneal shunt. The search for the data used in this study included: the hospital charts, the department's operation logbook, and the outpatient follow up documents. The CT scan images were kept in the hospitalization files of the patient.

The diagnosis of NPH was established by both, clinical and, most importantly, CT scan criteria. The clinical criteria consist of the characteristic triad of gait disturbance-ataxia, memory disturbance-signs of dementia, urination disturbances-incontinence or urgent urination. The CT scan criteria refer to the evident of dilatation of the ventricular system and the lack of sulci and fissure enlargment (to avoid the false diagnosis of NPH in cases with ex-vacuo hydrocephalus, which is marginally improved by the drainage of CSF, as it is mentioned and reported in the literature)[4,46, 49,59]. The patients were subjected in a surgical procedure for the implantation of a ventriculo-peritoneal shunt via a medium pressure valve. The operations were not performed by the same surgeon in all cases, but the same general principles of pre-, intra-, and post-operative treatment, including 48 hour recumbence, were applied[59].

The postoperative assesment was performed by different surgeons in different time intervals, but in the present study the clinical state that the patient presented with after three months is concidered as the postoperative state[42]. This time coincides for most of them with a new postoperative brain CT scan. Of the 40 patients, 26 were men and 14 women. The youngest was 45 and the oldest 82, while the mean age was 65 years; the age in groups is shown in table 1.

In more of these patients history, a causative factor was not recorded to justify the presence of comunicating hydrocephalus, therefore it is characterised as NPH of unknown origin. The characteristic triad of symptoms (disturbances of gait, memory, urination) was present in 25 patients, while urinacy disturbances were absent in 15. In order to check the improvement and give the oportunity for statistical evaluation of these data, for every of the clinical symptoms the patients were divided in the following categories[4,59]. As far as the gait disturbances were concerned, the patients presented with:

(0) No gait disturbance

(1) Instability but able to walk

(2) Inability to walk without assistance.

(3) Inability to walk.

No patient belongs to category (0), 5 belonged in (1), 21 in (2) and 4 in (3).

As far as the symptoms of memory disturbance – signs of dementia are concerned, the patients presented with:

(0) No disturbance

(1) Mild loss of memory that can be revealed only after difficult questions and testing. (No special neurophychiatric evaluation tests were used.)

(2) Moderate memory disturbance with difficulty in recalling recent events.

(3) Severe disturbance with time-space disorientation.

No patient belongs to category (0); 7 in (1), 23 in (2) and 10 in (3).

According to the urination disturbances the patients were divided in the following categories:

(1) No disturbance

(2) Mild disturbance (as urgent urination)

(3) Moderate disturbance (only nocturnal incontinence)

(4) Severe disturbance (daytime incontinence too).

15 patients belonged to the first category, 8 in the second, 9 in the third and 8 in the fourth. In total, 40 patients presented gait disturbances, 40 memory disturbances (well enstablished in 33), while urination disturbances 25 of them. The time from symptoms on set was three months for 8 patients, between three and six months for 10, between six months and a year for 8 and more than one year for 14 patients. Many of the patients complained of headache (mild) and easy fatigability. For two of them episodes of spasms were reported. Co-morbid conditions (diabetes mellitus, hypertention) were also reported. The clinical examination revealed mild pyramidal signs in some patients (mostly brisk reflexes and the Babinsky sign), while extra pyramidal signs in three patients. The measurement of CSF pressure was performed either by lumbar puncture in the lateral recumbent position or during the implantation of the ventricular catheter in the operating theater. The value was marked in 26 patients, while it was found normal in the rest. For the marked values, two were up to 100 mm H2O and 24 were between 100 mm and 200 mm H2O. In the study of the brain CT scan preoperatively, no obstruction of the ventricular system was observed (to regard the hydrocephalus as obstructive in such case), and were not there noticeable areas of ischaemia. In this study the periventricular lucency was not taken into account, due to the possible unsuccessful estimation retrospectively [48].

The estimation of the postoperative result was based on the improvement of the preoperative symptoms triad, and for this study it was divided in three categories:

(1) Very good, which means the patients returned to their premonbid activities without neurological deficit.

(2) Good, this means return to activities but with neurological deficit.

(3) Poor, which means no improvement, i.e. the drainage was of no assistance for the patients.

Of the 40 patients, 15 (37%) had an excellent result, 17 (43%) good, and 8 (20%) had a poor result. The total percentage of successful outcome was high in the given series of patients, compared to others[4,59,48]. Of the 25 patients presenting with the complete triad of symptoms, a substantial improvement was observed in 18 (76%) while no improvement in 7 (28%). Of those without incontinence, 15 in total, improvement was observed in 14 (94%) while one had no improvement (6%).

As far as the result from the drainage is concerned in relation to the time of appearance of the symptoms, it is found the following: all those with symptoms for 3 months and all those with symptoms for 6 months were improved, of 8 patients with symptoms from 6 months to 1 year improved 7, while of those with symptoms for more than one year only 7 out of the 14 were improved (most of them had symptoms for more than 2 years). Postoperative subdural collections presented in 2 patients (it was found in brain CT scan); the one belonged in the group with good postoperative result, while the other in the group with the poor one. In these cases the drainage catheter was ligated for a future prospective of substituting the valve for another type. Finally, 4 patients died postoperatively from dif-

TABLE 1

Age in years	Number of patients
<50	3
50-60	12
60-70	13
70-80	11
80<	1

TABLE 2

No	3rd ventricle-Sylvian fissure index	Bi-frontal (FH) index	Bi-caudate index
	A	B	C
1	0.63	0.42	0.31
2	0.64	0.62	0.40
3	0.66	0.61	0.48
4	0.59	0.42	0.31
5	0.67	0.64	0.5
6	0.64	0.41	0.3
7	0.47	0.39	0.24
8	0.67	0.43	0.27
9	0.48	0.4	0.24
10	0.56	0.49	0.32
11	0.5	0.46	0.33
12	0.7	0.43	0.33
13	0.53	0.48	0.27
14	0.66	0.53	0.35
15	0.53	0.39	0.33
16	0.64	0.51	0.3
17	0.72	0.43	0.32
18	0.53	0.39	0.26
19	0.68	0.47	0.39
20	0.7	0.46	0.38
21	0.68	0.45	0.32
22	0.66	0.48	0.30
23	0.64	0.44	0.32
24	0.56	0.7	0.6
25	0.54	0.50	0.32
26	0.55	0.42	0.3
27	0.67	0.49	0.31
28	0.63	0.42	0.30
29	0.69	0.46	0.28
30	0.68	0.45	0.29
31	0.49	0.4	0.25
32	0.56	0.4	0.25
33	0.88	0.49	0.3
34	0.8	0.47	0.28
35	0.58	0.44	0.32
36	0.62	0.4	0.3
37	0.67	0.64	0.5
38	0.6	0.6	0.49
39	0.68	0.37	0.26
40	0.58	0.51	0.33

ferent complications (2 from pneumonia, 1 from severe meningitis due to infection of the drainage system, and 1 fell in coma immediately postoperatively). In all of these patients the immediate response to drainage was poor. These cases were not taken into account in the grouping of patients according to the clinical result of the drainage for the statistical elaboration. An important condition in the design of this study, in order to estimate the prognostic value of the CT scan indexes in the post drainage result, was the proven good function of the drainage mechanism; it means that any poor results could not been due to poor drainage function. This was possible with the study of postoperative CT scan, where the decrease of the size of the ventricular system was measured, which is a sign of good drainage function[4]. A postoperative CT scan there was in the files of 24 patients. There was improvement in 22 of them, while none in 2; this fact is in accordance with the opinion of some authors, that the improvement of the patients is not always accompanied by a decrease in the size of the ventricular system[46]. In two patients the function of the drainage mechanism was checked by the injection of metrizamide in the flushing device of the valve and the following radiological check. In the rest 14 patients good function of the valve was reported in the patient's follow up chart or in the readmision file; this diagnosis was based, by the examiner, on the clinical examinations (palpation of the flushing device of the valve, to feel the ease of pumping)[33].

Measurements of the brain CT scan indexes

We used linear measurements for the studied CT scan parameters, since they are totally reliable methods, as it is referred in the literature[10,24,47]. In order to be more precise, we used indexes that have been calculated in measurements for cases with cerebral atrophy[10,40] degenerative and post-traumatic encephalopathies and that were also used to check the correlation of the CT scan to continuous monitoring of the intracranial pressure[13,45]; finally for the calculation of Rout or Cout in infusion studies[35]. The use of divisional indexes reduces the restrictions of single linear measurements, due to the variety of the shape and the size of the skull[10].

In every one, of the above mentioned 40 cases, the following indexes were identified from the preoperative CT scans:

1. The third ventricle – Sylvius fissure distance index.

The measurements were made on a CT scan section at the level of the thalami, in their largest dimensions where the third ventricle and Sylvius fissure are well depicted. The distance between the lateral border of the third ventricle and the innermost border of the Sylvian fissure was measured in each side (right and left). The two values were added and divided by the value of the total intracranial distance at the same level. (Fig. 1A, 2A)

2. Frontal horns indexes.

The measurements took place on a CT section at the level of the heads of the caudate nuclei, and two indexes were calculated: the bi-frontal and the bi-caudate. The bi-frontal is defined as the product of the distance between the apexes of the frontal horns, divided by the total intracranial distance at the same level. The bi-caudate is defined as the product of the distance between the two caudate nuclei, divided by the total intracranial distance at the same level. (Fig. 1B, 2B)

3. Brain – ventricular system indexes.

The measurements took place on a CT section at a level above the caudate nuclei, where the ventricular system is widest. The following indexes were calculated: the bi-frontal and the bi-occipital. The bi-frontal index is defined as the product of the distance between the lateral borders of the frontal horns, divided by the total intracranial distance at the same level. The bi-occipital is defined as the product of the distance of the far lateral borders of the occipital horns, divided by the total intracranial distance at the same level. (Fig. 1C, 2C)

4. Cortical gyri index.

The measurements took place on a CT section at the level of the large cortical sulci, and the absolute size of the four biggest gyri of the cortex, in the better imaged hemisphere, was measured. (Fig. 1D, 2D)

All the above measurements were done 3 times and the mean value was used[10].The measurements were recorded after referral to a common scale. The results are given at the tables 2 and 3. As far as the reliability of these indexes is concerned, it must be said that possible errors are due to the width (a result of the partial volume) and the size of the CT scan sections[47], especially in the case of the cortical gyri index. The reliability of this index is further decreased because the CT scans were not performed by the same scanner. 27 exams were done at a Siemens Somaton (D), while the rest at two other types of scanners. Of course, as it is mentioned above, referral to a common measurement scale was performed.

Statistical analysis

For the statistical evaluation of the data, gathered from the patient group and the measurement of the CT scan indexes, the method of one way analysis of variance was used. With this method it is possible to compare the mean values of the studied groups of variables, and is the most preferable in the case where the possible influence between the quality characteristics of the group of patients is being evaluated. To make these quality characteristics amenable to statistical analysis, they were expressed in a grading way and by the numbers 1, 2, 3, 4, as in the table 4.

For the analysis of the variability in one direction, we calculate the quotient of the variability F which is compared to the relevant F in the statistical tables for (k-1) and (n-k) degrees of freedom (for the numerator and the denominator accordingly). In the case that the calculated value exceeds the relevant value in the statistical tables, for the relevant degrees of freedom, and for a given level of significance $P \sim 0.05$

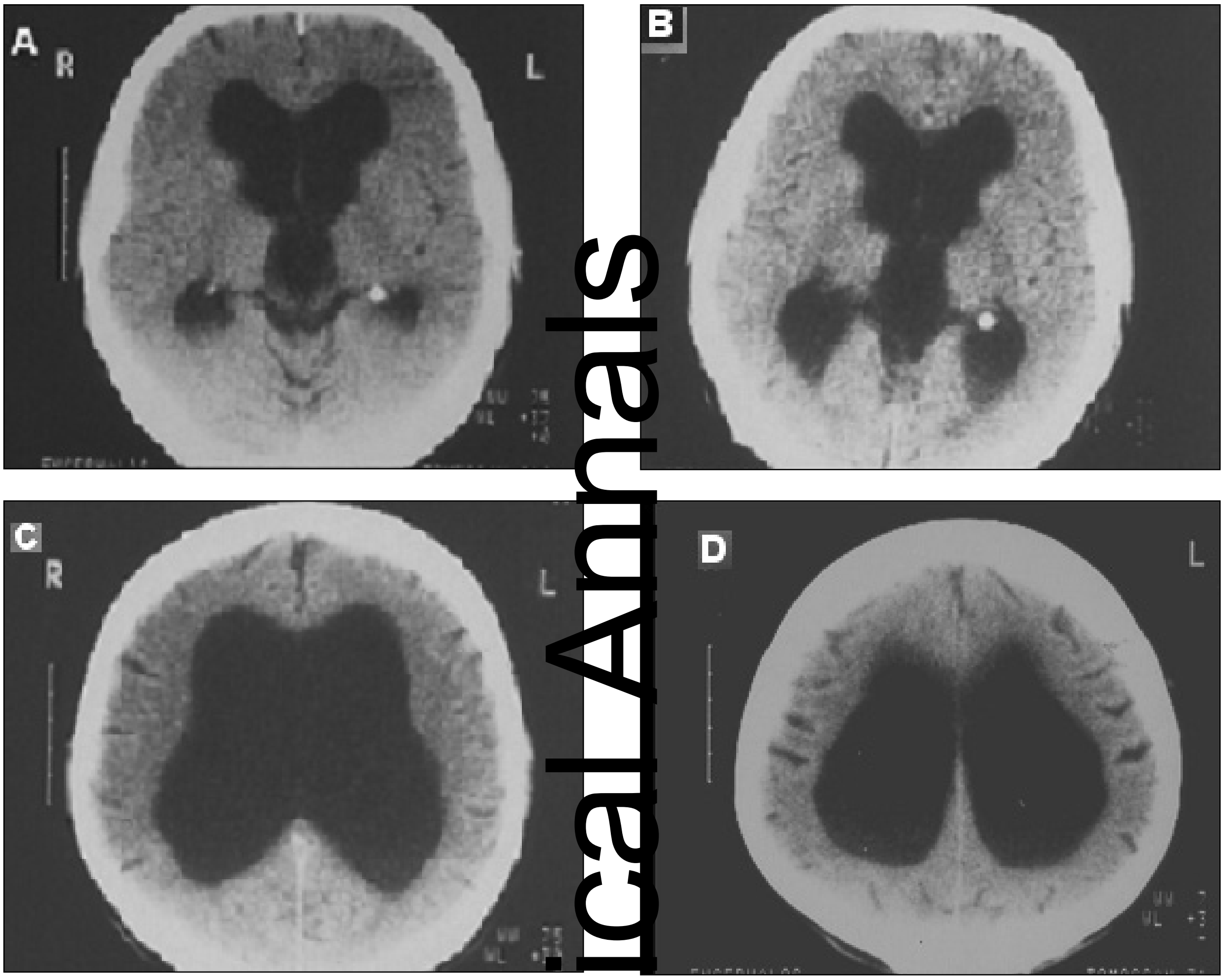

Fig. 1. (A) CT scan section at the level of the thalami where the measurements for the third ventricle-Sylvius fissure distance index were made. (B) CT section at the level of the heads of the caudate nuclei where the measurements for the frontal horns indexes were made. (C) CT section at a level above the caudate nuclei where the measurements for the brain-ventricular system indexes were made. (D) CT section at the level of the large cortical sulci, where the measurements for the cortical gyri index were made.

or P~0.01 (in this case we choose P~0.05), then the compared mean values differ between them in a statistically significant degree; as a result there are statistically important influences between the values of the studied groups. In the case that the calculated F is smaller than the corresponding F of the table, then the interactions between the studied groups are statistically insignificant. For the analysis of the variability in one direction, (the statistical packet SPSS was used), the validity of the following assumption was checked: the mean values of the studied groups do not differ between then.

Results

The value of F was bigger than the corresponding value of F at the statistical tables for a P~0.05, and therefore the assumption, that was made earlier, was proved to be invalid in the following cases:

1) In the correlation of the index of the third ventricle – Sylvian fissure distance to the symptom "gait disturbances". In this case for degrees of freedom n1=2 and n2=37, F=5.5758 (bigger than the relevant of the table), mean = 0.6278, SD=0.0921, SE=0.0146.

2) In the correlation of the cerebral substance-ventricular system, between the frontal horns, index to the symptom of "gait disturbances". In this case for n1=2, n2=36, F=7.5762 (bigger than the relevant of the table), mean= 0.5538, SD= 0.1094, SE=0.0175.

3) In the correlation of the cortical gyri index to the symptom "gait disturbances". In this case for n1=2, n2=37, F=12.2426 (bigger than the relevant of the table), mean= 4.465, SD= 0.7195, SE=0.1138.

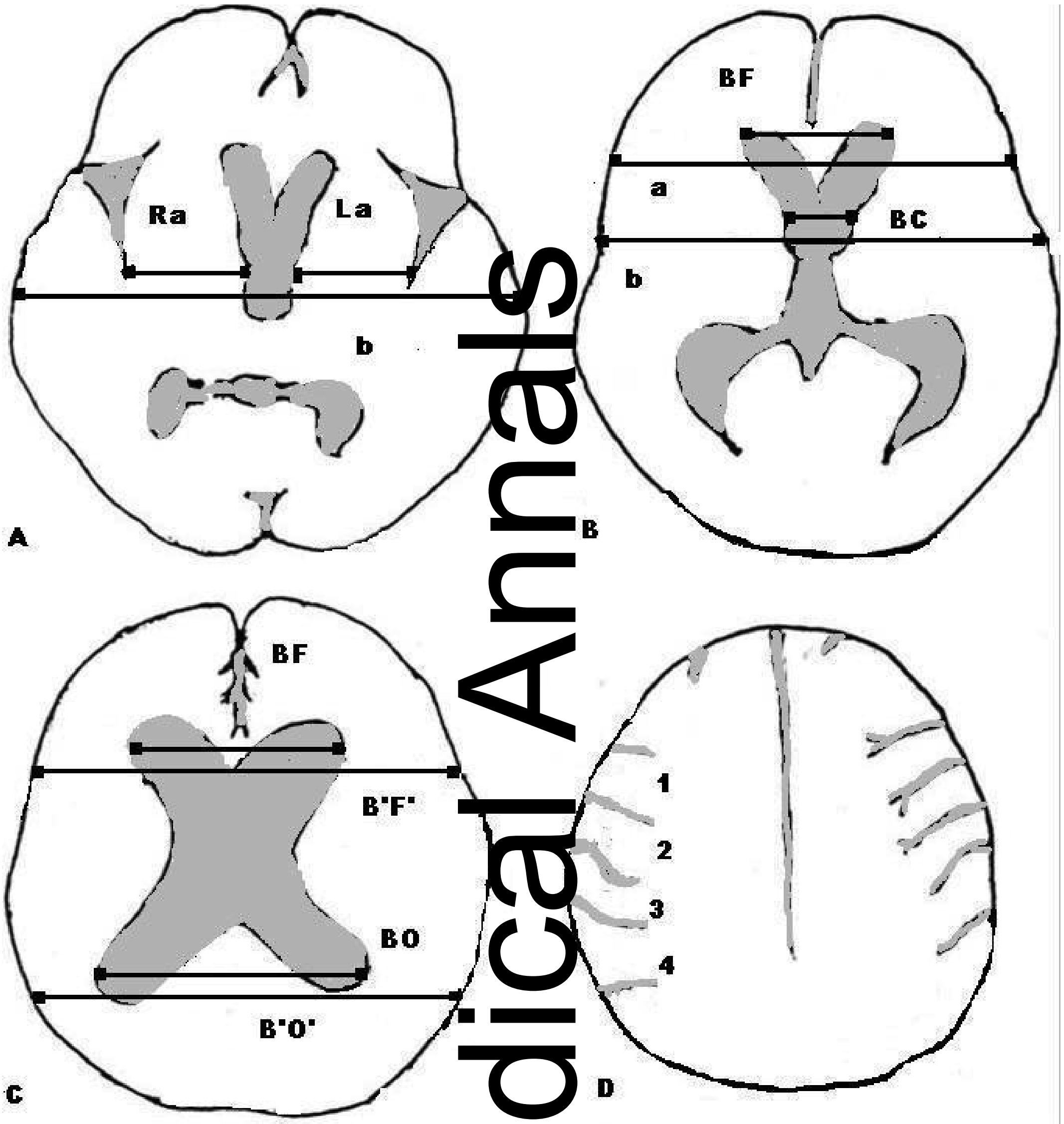

Fig. 2. (A) Third ventricle- Sylvius fissure distance index = (R a + L a) / b. (B) Frontal horns indexes; bi-frontal index = BF / a, bi-caudate index = BC / b. (C) Brain-ventricular system indexes; bi-frontal = (BF) / (B'F'), bi-occipital=(BO) / (B'O'). (D) Cortical gyri index = (1) + (2) + (3) + (4), (R) or (L).

4) In the correlation of the cerebral substance-ventricular system, between the occipital horns, index to the symptom "memory disturbances". In this case for n1=2, n2=37, F=4.3122 (bigger than the relevant of the table), mean=0.6035, SD=7.06, SE=0.0112.

5) In the correlation of the cortical gyri index to the outcome of the shunting procedure. In this case for n1=2, n2=34, F=7.7130 (bigger than the relevant of the table), mean=4.5486, SD=0.6462, SE=0.1062.

6) In the correlation of the cerebral substance-ventricular system, between the frontal horns, index to the symptom "memory disturbances". In this case for n1=2, n2=36, F=3.3703, (bigger than the relevant of the table), mean=0.5538, SD=0.1094, SE=0.0175.

7) In the correlation of the cortical gyri index to the symptom "urination disturbances". In this case for n1=3, n2=36, F=3.2402 (bigger than the relevant of the table), mean=4.4650, SD=0.7195, SE=0.1138.

In all of the above cases the mean values of the investigated groups differ markedly between them, and therefore, we considered that there is influence of the specific indexes on the specific qualitative characteristics.

In the cases where the value of the third ventricle-Sylvian fissure index was lower than 0.50, complete inability to walk was observed. We also observed that

TABLE 3

No	Bi-frontal (BV) index	Bi-occipital index	Cortical gyri index
	D	E	F
1	0.48	0.6	4.6
2	0.49	0.58	4.7
3	0.51	0.6	4.9
4	0.49	0.69	4.2
5	0.5	0.59	4.8
6	0.47	0.59	4.7
7	0.69	0.63	3
8	0.53	0.5	4.8
9	0.7	0.64	2.9
10	0.6	0.56	4
11	0.57	0.54	3.2
12	0.54	0.73	4.5
13	0.5	0.51	5
14	0.6	0.61	4.7
15	0.38	0.61	5
16	0.57	0.48	4.5
17	0.56	0.73	4.5
18	0.5	0.52	5.4
19	0.52	0.67	5
20	0.5	0.65	5
21	0.47	0.58	5.2
22	0.79	0.73	3.9
23	0.45	0.55	5.4
24	0.54	0.63	4.2
25	0.79	0.71	4
26	0.62	0.58	3.9
27	0.78	0.70	4.3
28	0.46	0.56	5.5
29	0.55	0.51	4.7
30	0.54	0.52	4.9
31	0.71	0.65	2.9
32	0.71	0.64	3
33	0.55	0.53	4.9
34	0.53	0.51	4.8
35	0.58	0.56	4
36	0.41	0.66	4.4
37	0.5	0.59	4.9
38	0.43	0.6	4.8
39	0.4	0.62	5.5
40	0.77	0.72	4.2

TABLE 4

No	Gait disturbances	Memory disturbances - signs of dementia	Urination disturbances	Postoperative result
	G	H	I	J
1	1	2	2	2
2	2	2	1	2
3	1	2	1	2
4	2	2	2	2
5	1	2	1	1
6	1	1	1	1
7	3	3	4	4
8	2	1	1	1
9	3	3	4	4
10	1	2	3	2
11	2	2	3	3
12	2	3	4	4
13	2	3	3	2
14	1	2	1	2
15	1	2	1	1
16	1	1	2	2
17	2	3	3	2
18	1	2	2	1
19	2	3	4	1
20	2	3	4	1
21	2	2	2	1
22	2	1	1	1
23	1	2	2	1
24	2	3	4	2
25	2	2	1	2
26	2	2	3	2
27	2	1	1	1
28	1	1	1	1
29	2	2	3	2
30	2	2	1	1
31	3	3	4	3
32	1	1	1	3
33	2	2	3	3
34	2	2	2	3
35	2	2	3	1
36	1	2	1	2
37	1	2	1	1
38	2	2	2	1
39	1	2	1	2
40	3	3	3	2

in 75% of the cases that presented with complete inability to walk, the value of the cerebral substance-ventricular system index was around 0.7 and the value of the cortical gyri index around 2.9. Finally, in 80% of the patients who benefited mostly from the shunting procedure had a cortical gyri index higher than 4.7, while 60% of the patients with poor outcome after CSF drainage had a cortical gyri index less than 3.2.

In no other cases (except the above seven) that were examined was proven any influence of the indexes on the qualitative characteristics (symptoms-results).

Discussion

One of the most commonly discussed clinical problems in neurological surgery is to point out and to accept a safe criterion for the selection of patients with NPH, who are going to improve after a CSF shunting procedure. Review of the literature, concerning results of this therapeutic method, show improvement in 50% of the cases treated, independently the criteria used for the patient selection [48]. The surgical mortality varies, in the different studied series, from 8% to 10%, and the morbidity from surgical complications, from 12% to 40%[6,27,28,43,49,55,58].

Since 1966, when Adams announced the case of a patient with symptomatic hydrocephalus and normal pressure in the CSF, many patients with radiological evidence of large ventricles and normal pressure CSF, but not presenting the clinical triad, have been mistakenly diagnosed and operated on with disappointing results[2,3,4,13,21,48,59]. It is a fact that the diagnosis of patients with NPH has mainly been based on radiological rather than clinical criteria, and this has made difficult the evaluation of credibility and usefulness of the predictive tests before surgery[27].

The role of cisternography seems to be mainly the diagnosis of communicated hydrocephalus[3,8,22,31,32,3[illegible],41]. Infusion tests have been considered by many authors a valuable preoperative test[5,15,29,42,44,55], but some others dispute credibility of them[53,55]. These tests seem to have theoretical rather than practical value for two reasons. First, according Ekstedt, because they have been used only in pathological situations and the normal values are unknown[17], and second, according Borgensen, because there are not convincing elements in the literature for the reproduction of the results of this method in the same patient[5].

As mentioned above, the diagnosis of NPH has been based mainly on the brain CT scan[34,39,50,57]. Large sizes of the ventricles, periventricular lucency, and the presence of a small degree or the absence of cortical atrophy are concidered characteristic evidence of communicating hydrocephalus[4,9,14,36,40,59]. Therefore, the CT scan is believed that images the pathological state of the reduced absorption of CSF, which is considered responsible, at least in part, for the creation of NPH by some authors[5]; others believe that the problem is the pathological circulation of CSF[4].

The MRI is a very promising method in the diagnosis, study, and generally the evaluation of hydrocephalus. This method gives the possibility to differentiate between flowing CSF from stagnant CSF. There is a specific sign, CSF-flow voiding sign (VS), which is very useful in the distinction of communicating hydrocephalus from non-communicating hydrocephalus and from hydrocephalus ex vacuo. The CSF-VS is a result of the speed of the CSF pulsating movement. It is more prominent in the communicating hydrocephalus and less evident, or absent, in the dysgenesis or stenosis of the aqueduct. However, this sign is not specific for the NPH, and presents no correlation to the degree of improvement after shunting[30,50]. In the MRI, the sign of periventricular lucency is not useful as in the CT, to verify that the hydrocephalus is active, while the MRI is a more sensitive method in the diagnosis of white matter damage than CT scan. Finally, various volumetric measurements are more precise with the MRI[3].

Regarding the CT scan as a fast and non invasive method, it could be considered the method of choise in the prognosis of patients selected for surgical drainage.

The advantages and disadvandages of CT as a diagnostic and prognostic method have been well documented. It also has been documented that experimental and clinical studies show an existing pressure gradient between the cerebral ventricles and the subarachnoid space, in the pathological physiology of NPH. Conner and others showed such gradient in cats after caolin injection[12]. Hoff and Barber showed similar results in patients studied intra-operatively[26]. The results of these studies may give an explanation for the presence of enlarged ventricles in spite the existence of normal pressure CSF. The pressure gradient between these two intracranial spaces applied through the cerebral parenchyma (the mantle) allows the expansion of the ventricular system. Based on these reports an assumption can be created, that the pressure gradient between the ventricles and the subarachnoid space causes the alteration in the width of the cerebral mantle, and as result there is a correlation of this gradient in pressure to the size of the cerebral mantle. Based on these assumptions, which rely on the pathophysiological mechanism of trans-mantle pressure as an explanation of NPH, there has been an effort in this study to test the hypothesis that:

There is an effect of the sizes of the ventricles and the cerebral mantle, measured in CT images, in the presentation of clinical symptoms and the outcome of the patients after drainage procedures, making possible in the last case, the evaluation of their prognostic value.

a. By using the indicator of the third ventricle–Sylvian fissure, the correlation of the width of the cerebral mantle to the result of CSF shunting procedure was studied. The study of this correlation was chosen to be applied at the level of the third ventricle because in pneumoencephalography[51] and CT scan studies[45], it has been found a stable correlation of the third ventricle size to the pathological pressure level, in recordings of the CSF pressure. No statistically important impact between those parameters was noticed. Therefore, this indicator has no prognostic value in the outcome of the shunting procedure. This finding is in accordance with the results of a study done by Stein and Langfitt; they correlated the width of the cerebral mantle to the outcome after the shunting, by means of pneumoencephalography[53].

b. By using the indicators of cerebral parenchyma–ventricular system, the correlation of the sizes of the lateral ventricles properatively to the outcome after the shunting was explored. The sizes of the lateral ventricles were evaluated taking into account separately the bi-frontal and bi-occipital indices. The bi-frontal indicator is the quotient of the maximum distance of the most lateral borders of the frontal horns, divided by the width of the internal of the skull at the same level. As it is mentioned in the international literature, it is a reliable index of the size of the ventricular system, because it is easier reproducible, than the indicator of the width of the ventricular bodies[40]. In addition, with the study of the bi-occipital indicator one more method of calculation of the size of the lateral ventricular system was applied.

No statistically important impact between the size of the ventricular system and the outcome of the shunting was noticed. Therefore these indicatores have no prognostic value for the outcome after the CSF drainage. This finding is in accordance with the results of Stein and Langfitt, who used pneumoencephalography to study the correlation of the sizes of the ventricles to the prognosis[53]. Crookard also found no correlation of the sizes of the ventricles to the recording of pathological pressures; this is a good prognostic factor comparing groups of patients with normal recordings of intracranial pressures, with other groups with pathological ones[13]. Finally, Kosteljanetz found no correlation of the size of the ventricular system to the resistance of CSF flow (Rout), which is also considered a good prognostic criterion by many authors[35]. In the cases of patients who did not improve postoperatively, it seems that they have sustained a non reducible injury of the neural circuity in the periventricular white matter[61].

c. By using the indicators of the frontal horns of the lateral ventricles, the correlation of the quality of the parenchyma to the outcome of the shunting was checked. Specifically, in the frontal white matter is measured by the bi-frontal indicator, at the tips of the frontal horns, and in the caudate area is measured by the bi-caudate indicator. Both those indicators are sensitive in the study of subcortical atrophy[10,52], which is not necessarily correlated to cortical atrophy. The subcortical atrophy is connected to varius pathological entities independent of age, in contrast to cortical atrophy which is age related. No statistically important correlation of the outcome to the above mentioned indicators was proven. This possibly means that there were no coexistent degenerative diseases, covering the good response after shunting, in patients with NPH, giving poor results[3,34,39,52]. Therefore these indicators have no prognostic value for the outcome.

d. By using the indicators of cortical gyri, the correlation of the width of cortical gyri to the outcome of shunting was checked. This indicator checks the cerebral cortical atrophy (quality of cortical parenchyma), but it may also check the flattening of the gyri due to existing trans-mantle pressure. In this case, a statistically important impact between the two variable groups was proven. This means that the lesser the degree of cortical atrophy, the better the outcome after drainage; this might also mean that the greater the degree of gyral flattening (which means greater trans-mantle pressure), the better the response to drainage. However, the poor credibility of this indicator, as it is mentioned earlier, limits its prognostic value. Many authors came to the same conclusion by calculating cortical atrophy, measuring the width of the four larger sulci of the cortex or even the Sylvius fissure using planimeter. Some others estimate the cortical atrophy empirically, as small, medium and large, characterizing the same time the pressure applied to the parenchyma, at the subarachnoid spaces of the convexity, when they are restricted[2,4,22,38,55,59]. As a result we can say that no single CT scan parameter, of those studied comprises a definite prognostic criterion. After the study of the correlation of the CT scan indexes to the clinical symptoms of the patients we can conclude the following:

a. The size of the ventricular system, calculated by the cerebrum-ventricular system (bi-frontal and bi-occipital) indexes, has a statistically significant influence in the severity of the symptom "memory disturbances". This is mainly due to vascular disturbances and vessel dilatation in the periventricular region; this results in a decrease in blood flow and consequently the malfunction of the areas and pathways regarding memory (perihippocampal region that lies in the vicinity of the temporal horn of the lateral ventricle), and of the cognitive areas causing dementia.[23,60].

b. The width of the cerebral gyri, calculated by the cortical gyri index, has a statistically significant influence in the severity of the symptom "urination disturbances". This is probably due to a malfunction of the cortical centres of micturition and defecation in the paracentral lobule, and its periventricular pathways, due to transmantle pressure applied to that cortical area especially when the subarachnoid spaces are obliterated[26].

However, there have been cases with severe disturbance of urination and small cortical gyri index. In these cases, probably it has been existed frontal syndrome due to cerebral atrophy[16] that was not properly diagnosed. The same is probably true in the case of the statistically significant influence of the cortical gyri index in the severity of the symptom of gait disturbances in patients with small cortical gyri index. For those cases it must be said that the cerebral gyri index is of low credibility.

c. The size of the ventricular system, calculated by the cerebrum-ventricular system (bi-frontal) index, has statistically significant influence in the symptom "gait disturbances". This is probably due to the fact that the dilatation of the lateral ventricles causes displacement and tenderness of the fibres that originate from the precentral motor cortex on their way to the internal capsule[18]. Additionally, alterations in the vascularity of the periventricular parenchyma structures have been implicated to explain the mobility dysfunction[62]. The correlation of the large ventricles to the gait disturbances is mentioned in many studies[18,19,54]. Sudarsky and Ronthal examined a series of 50 elder patients with gait disturbances and found that this group had an enlarged ventricular system, compared to a healthy group[54].

d. The depth of the cerebral mantle, calculated by the third ventricle – Sylvian fissure index, has a statistically significant correlation to the severity of the symptom "gait disturbances". This is probably related to the dilatation of the third ventricle, which has not been examined in this study and causes displacement and stretching of the fibres of the internal capsule; this also correlates to the pathologic pressure in studies with recording of intracranial pressure[45,51]).

Conclusion

The basic conclusions that can be drawn from the above are:

a) The size of the ventricular system of the brain, as it is calculated by the CT scan indexes, may correlate to the severity of the symptoms in NPH.

b) The size of the ventricular system of the brain does not comprise a definite prognostic criterion for the outcome of shunting procedures.

ΠΕΡΙΛΗΨΗ

Υδροκέφαλος φυσιολογικής πιέσεως και αξονοτομογραφικοί δείκτες εγκεφάλου. Η προγνωστική αξία τους για την έκβαση των παροχετευτικών επεμβάσεων και η σχέση τους με την κλινική συμπτωματολογία.

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Σκοπός της μελέτης αυτής ήταν να διαπιστωθεί αν υπάρχει σχέση του μεγέθους του κοιλιακού συστήματος του εγκεφάλου, όπως αυτό μετράται με δείκτες στην αξονική τομογραφία, με την κλινική εικόνα ασθενών με υδροκέφαλο φυσιολογικής πιέσεως και με την έκβαση μετά παροχετευτική επέμβαση του ΕΝΥ.

Αναζητήθηκε με αυτόν τον τρόπο η ύπαρξη προγνωστικής αξίας της μετρήσεως των αξονοτομογραφικών δεικτών σε ασθενείς με κλινική διάγνωση «υδροκέφαλος φυσιολογικής πιέσεως» και υποψηφίους να υποβληθούν σε κοιλιοπεριτοναϊκή παροχέτευση ΕΝΥ, γνωστών όντων των δυσκολιών στην επιλογή των ασθενών που θα βελτιωθούν μετά από μια τέτοια επέμβαση.

Μελετήθηκαν οι περιπτώσεις 40 τέτοιων ασθενών. Προεγχειρητικά εκτιμήθηκαν για κάθε ένα από τα χαρακτηριστικά συμπτώματα (διαταραχές μνήμης, βάδισης, ουρήσεως) ενώ μετεγχειρητικά για το αποτέλεσμα της παροχετεύσεως και κατατάχθηκαν σε κατηγορίες. Σε κάθε περίπτωση από τις ανωτέρω προσδιορίσθηκαν οι εξής δείκτες από τις αξονοτομογραφικές απεικονίσεις του εγκεφάλου: ο δείκτης αποστάσεως τρίτης κοιλίας-σχισμής του Sylvius, οι δείκτες των μετωπιαίων κεράτων των πλαγίων κοιλιών, οι δείκτες εγκεφάλου-κοιλιακού συστήματος και ο δείκτης ελίκων φλοιού. Στη συνέχεια χρησιμοποιήθηκε η ανάλυση μεταβλητότητας κατά μια διεύθυνση σαν στατιστική μέθοδος για την διερεύνηση της επιδράσεως των ανωτέρω δεικτών στα ποιοτικά χαρακτηριστικά της ομάδας των ασθενών (συμπτώματα πριν και έκβαση μετά την παροχέτευση).

Από την μελέτη των αποτελεσμάτων προέκυψε σαν κύριο συμπέρασμα ότι το μέγεθος του κοιλιακού συστήματος, όπως αυτό υπολογίζεται με τους ανωτέρω δείκτες στην αξονική τομογραφία, σχετίζεται με την συμπτωματολογία στον υδροκέφαλο φυσιολογικής πιέσεως αλλά δεν αποτελεί προγνωστικό κριτήριο για την έκβαση των παροχετευτικών επεμβάσεων.

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