JOURNAL OF
CONTEMPORARY MEDICINE

DOI: 10.16899/gopctd.365158
J Contemp Med 2018;8(1):29-33

Original Article / Orjinal Araştırma

Can Hounsfield unit be used in the diagnosis of hydrocephalus?

Hounsfield ünitesi hidrosefali tanısında kullanılır mı?

Özgür Demir

Department of Neurosurgery, Gaziosmanpaşa University Faculty of Medicine, Tokat, Turkey

Abstract

Introduction: Diagnosis of hydrocephalus is still challenging. It is important to confirm the diagnosis before deciding surgical treatment. Defined criteria in the literature seems insufficient for the diagnosis of hydrocephalus in some cases. We aimed to analyze the effects of hydrocephalus to CSF/parenchymal density and give an understanding about the changes in CSF/parenchymal density in non-treated and treated hydrocephalus patients.

Methods: We used computed tomography (CT) with Hounsfield unit (HU) for density measurements. Two study groups were evaluated in this retrospective study. Twenty patients who had diagnosis of hydrocephalus and underwent ventriculoperitoneal shunt surgery, were included in the operation group. These patients were evaluated both preoperatively and postoperatively with CT. Therefore, this group also was divided into preoperative and postoperative study groups. Twenty patients who had brain CT with no detected cerebral pathology were included in the control study group. Cerebral density measurements were obtained from clinical CT with HU. HU values of the study groups were compared with each other by using statistical analysis.

Results: The HU values of the ventricules in the frontal and occipital horns consistently decreased after the operations. There were extremely significant differences between the preoperative HU values and the postoperative HU values of the all evaluated ventricles statistically. Additionally, there were very significant decreases after the operations in the HU values of white matter near grey mater.

Discussion and Conclusion: Density measurements with CT can easily make contribution in the diagnosis of hydrocephalus.

Keywords: Hounsfield unit; hydrocephalus.

Özet

Amaç: Hidrosefalinin tanısı hala ciddi bir sorundur. Cerrahi tedaviye karar vermeden önce tanıyı doğrulamak önemlidir. Literatürde tanımlanmış kriterler bazı vakalarda hidrosefali tanısı için yeterli gözükmemektedir. Biz hidrosefalinin BOS/parankim dansitesi üzerine etkilerini araştırdık ve tedavi edilmiş ve tedavi edilmemiş hidrosefali hastalarında bu dansitelerdeki değişiklikleri göstererek bir fikir vermeyi amaçladık.

Gereç ve Yöntem: Biz dansite ölçümleri için bilgisayarlı tomografi (BT) ile Hounsfield ünitesini (HU) kullandık. Bu retrospektif çalışmada iki çalışma grubunu inceledik. Hidrosefali tanısını almış ve ventriküloperitoneal şant cerrahisi tedavisi uygulanmış 20 hasta operasyon grubunu oluşturdu. Bu gruptaki hastalar operasyon öncesi ve sonrası BT ile ayrı ayrı değerlendirildi. Bu nedenle bu gruptaki hastalar aynı zamanda preoperatif ve postoperatif çalışma gruplarını oluşturdular. Serebral patoloji saptanmamış tomografiye sahip 20 hasta da kontrol grubunu oluşturdu. Serebral dansite ölçümlerini klinik BT kullanarak HU ile yaptık. Çalışma gruplarının HU değerleri birbirleri ile istatistiksel analiz kullanılarak karşılaştırıldı.

Bulgular: Ventriküllerin frontal ve oksipital hornlarından alınan HU değerleri operasyon sonrası uyumlu bir şekilde azaldı. İncelenen ventriküllerde, preoperatif HU değerleri ile postoperatif HU değerleri arasında istatistiksel olarak ileri derecede fark bulundu. Ayrıca gri cevher komşuluğundaki beyaz cevher HU değerlerinde operasyon sonrası istatistiksel olarak çok belirgin azalmalar tespit edildi.

Sonuç: BT ile dansite ölçümü hidrosefali tanısına kolaylıkla yardımcı olabilir.

Anahtar Sözcükler: Hounsfield ünitesi; hidrosefali.

It is still difficult to determine which patients with ventriculomegaly should undergo surgical treatment.[1,2] There are many methods and radiological studies described in the literature to diagnose hydrocephalus before invasive procedures. Besides well known radiological studies, some new radiologic studies for the diagnosis of hydrocephalus have been de-

Corresponding *(İletişim)*: Özgür Demir, Gaziosmanpaşa Üniversitesi Tıp Fakültesi, Nöroşirürji Anabilim Dalı, Tokat, Turkey
E-mail *(E-posta)*: cerendemir40@gmail.com
Received *(Geliş Tarihi)*: 13.12.2017 **Accepted *(Kabul Tarihi)*:** 30.01.2018

scribed in the literature. Most of these studies provide information about cerebrospinal fluid (CSF) volume and flow dynamics with magnetic resonance imaging (MRI) and CT.[3–5] Despite improved diagnostic methods, some cases with hydrocephalus may remain unrecognized and untreated.[6] Additionally, due to conditions of patients or hospitals further imaging studies can not be provided. So there is a need for different diagnostic techniques to support diagnosis of hydrocephalus.

For this purpose, we proffered a different technique to contribute the diagnosis of hydrocephalus in this presented study. We obtained cerebral density measurements with HU from the hydrocephalic patients before and after the shunt operations. Therefore, this technique can easily be applied without the need for additional studies. We reported the efficiency of a protocol for measuring cerebral tissue and ventricular density with HU.

Materials and Method

We retrospectively studied 20 patients with hydrcephalus that underwent surgical procedures of ventriculoperitoneal shunt between 2008 and 2014. We excluded the patients with hydrocephalus accompanying with cerebral pathologies like infections, hemorrhages, tumors, etc. We included the patients with hydrocephalus who had no detected pathology for the occurence hydrocephalus and who had non-contrast brain CT, one to three days before the surgery and one to three days after the surgery. The mean age of the patients was 40.68. Twentytwo patients were female and eighteen patients were male. All of the patients in the operation group were diagnosed as acute hydrocephalus with different clinical symptoms. Nine patients in this group had different radiological studies in addition to CT before the surgeries. Twelve patients had different radiological studies after the surgeries. All of the microbiological and biochemical cerebrospinal fluid (CSF) studies of the patients were in the normal ranges. Operation group was evaluated preoperatively and postoperatively. So we divided this group into preoperative and postoperative groups. We also retrospectively studied 20 patients with nonspecific complaints who had brain CT with no detected pathology. These patients formed control group. We evaluated the groups with cerebral density measurements. We aimed to present density measurement results in a simple manner. For this reason we did not add too many criteria to avoid confusion.

A helical eight-channel computed tomography scanner (LS; General Electric) was utilized for all measurements. Computed tomography parameters included a slice thickness of 1.25 mm with a 0.625-mm interval, a tube voltage of 120 kVp, a tube current of 300 mA (Smart mA/Auto mA range, 150 to 750), and a bone reconstruction algorithm (window width/window level, –3000/300). Dimensional reconstruction were obtained in the axial planes.

GE Universal Viewer was used to calculate an average HU value by placing an elliptical region of interest (ROI) that was confined to the white matter away from periventricular region and near gray mater, periventricular region near frontal horn, periventricular region near occipital horn, lateral ventricles in the frontal horn and lateral ventricles in the occipital horn preoperatively (Fig. 1a) and postoperatively (Fig. 1b). A mean HU value for each patient in the operation and control groups was recorded. We made elliptical ROI areas as big as possible within the limits of the interested area. Additionally we avoided image artefacts and anatomic variation in CT images. So we did not aim to perform ROI areas standart and equal.

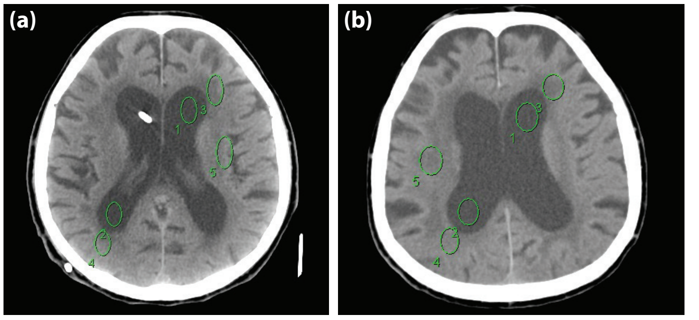

Figure 1. (a) Technique of obtaining HU values is demonstrated preoperatively. Elliptical region was placed into the different cerebral and ventricular areas. **(b)** Technique of obtaining HU values is demonstrated postoperatively.

Results were evaluated by statistical analysis. Data are expressed as mean±standard deviation. Independent sample t test or Hotelling T2 test were used to compare the continuous normal data between/among groups. Bonferroni confidence intervals were used to determine which variables are different after Hotelling T2 test. A p-value <0.05 was considered significant. Analyses were performed using SPSS 19 (IBM SPSS Statistics 19, SPSS inc., an IBM Co., Somers, NY). For time factor different superscripts (a, b) in the same column (Paired Samples t test) indicate a statistical significant difference. We used Prism scheme to classify the p values (Table 1). We numbered the regions of interest to facilitate reading (Table 2).

Results

We firstly compared the measurements of the preoperative and postoperative groups with the measurements of the control group in the same regions.

We compared ventricular the mean HU value of the preoperative group with the mean HU value of control group in frontal

Table 1. Prism scheme for classifying p values

P value	Wording	Summary
<0.0001	Extremely significant	****
0.0001 to 0.001	Extremely significant	***
0.001 to 0.01	Very significant	**
0.01 to 0.05	Significant	*
≥0.05	Not significant	NS

Table 2. Numbering of the regions of interest

Number	Region of interest (ROI)
1	Preoperative ventricular density frontal horn
2	Postoperative ventricular density frontal horn
3	Preoperative ventricular density occipital horn
4	Postoperative ventricular density occipital horn
5	Preoperative periventricular tissue frontal region
6	Postoperative periventricular tissue frontal region
7	Preoperative periventricular tissue occipital region
8	Postoperative periventricular tissue occipital region
9	Preoperative white mater region
10	Postoperative white mater region

and occipital horn regions. We found extremely significant difference (***) between these groups (p<0.001). The mean ventricular HU values in the frontal and occipital horns were higher than the mean values of the control group in the same regions (Table 2, 3) (Fig. 2).

We found non significant difference (ns) when we compared the mean ventricular HU value of the postoperative group in the frontal horn with the mean value of the control group (p=0.053). We found significant difference (*) when we compared the mean ventricular HU values of the postoperative group in the occipital horn with the mean value of the control group (p=0.025) in the same regions (Table 2, 3).

We compared the mean periventricular HU value of the preoperative group with the mean HU value of control group near the frontal horn region. We found significant difference (*) between these groups (p=0.011). Periventricular mean HU value near the frontal horn was higher than the mean value of the control group. We compared periventricular mean HU value of the preoperative group with the mean HU value of control group near the occipital horn region. We found very significant difference

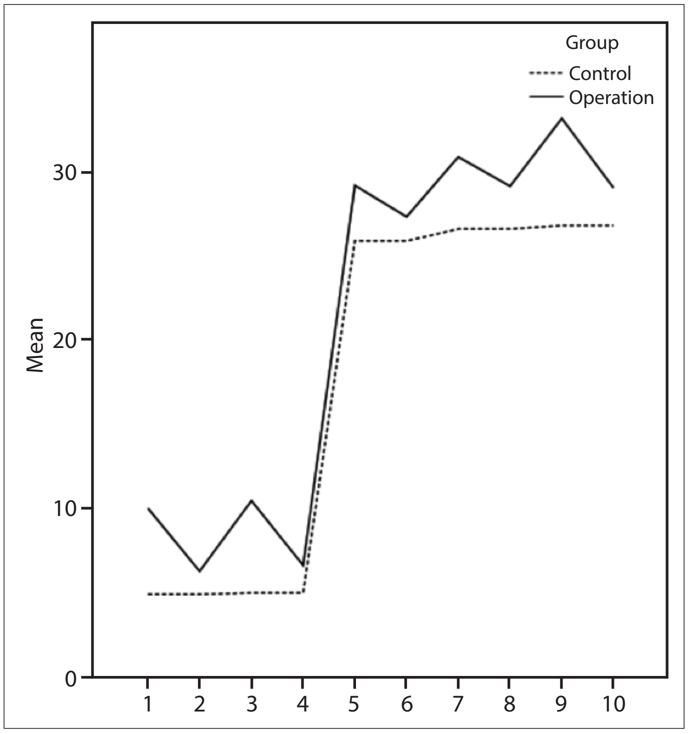

Figure 2. Profile plot for densities all regions means.

(**) between these groups (p=0.001). Periventricular mean HU value near the occipital horn was higher than the mean value of the control group in the same regions (Table 2, 3).

We found non significant difference (ns) when we compared the periventricular mean HU value of the postoperative group near the frontal horn with the values of the control group (p=0.304). We found significant difference (*) when we compared the periventricular the mean HU value of the postoperative group near the occipital horn with the mean value of the control group (p=0.046) in the same regions (Table 2, 3).

Table 3. Distributions of quantitative variables according to group

Variables	Control	Operation	p^1	p^2	p^3	Bonferroni 95% CI	
	Mean±SD	Mean±SD				Lower	Upper
Age	40.45±23.1	40.9±30.02		0.958	–	–	–
1	4.94±0.68	10.05±2.90[a]	<0.001	<0.001	<0.001	-6.67	-3.55
2	4.94±0.68	6.30±2.90[b]		0.053		-2.92	0.19
3	5.02±0.66	10.5±3.11[a]	<0.001	<0.001	<0.001	-7.13	-3.82
4	5.02±0.66	6.66±2.97[b]		0.025		-3.22	-0.05
5	25.92±1.41	29.22±5.15[a]	0.096	0.011	0.023	-6.08	-0.51
6	25.92±1.41	27.35±5.90[a]		0.304		-4.60	1.74
7	26.63±1.68	30.91±4.58[a]	0.117	0.001	0.002	-6.82	-1.73
8	26.63±1.68	29.17±5.12[a]		0.046		-5.35	0.27
9	26.83±1.88	33.20±3.83[a]	<0.001	<0.001	<0.001	-8.59	-4.13
10	26.83±1.88	29.07±4.07[b]		0.034		-4.57	0.10

SD: Standard deiviation; a, b: For time factor different superscripts in the same column (Paired Samples t test) indicate a statistical significant difference.

We compared the mean white mater near the gray mater HU values of the preoperative group with the mean HU values of control group. We found extremely significant difference (***) between these groups (p<0.001). The mean white mater HU value near the gray mater was higher than the mean value of the control group in the same region (Table 2, 3) (Fig. 2).

We found significant difference (*) when we compared the mean white mater near the gray mater HU values of the postoperative group with the values of the control group (p=0.034) in the same region (Table 2, 3).

We additionally compared the measurements of the preoperative group with the measurements of the postoperative group in the same regions.

When we compared the mean HU value of the preoperative group in all ventricular regions with the mean values of the postoperative group in the same regions we found extremely significant differences (***) (p<0.001) (Table 3) (Fig. 2).

We found extremely significant difference (***) when we compare the mean HU value of the preoperative group in the white mater near gray mater region with the mean value of the postoperative group in the same region (p<0.001) (Table 3) (Fig. 2).

When we compared the mean HU value of the preoperative group in all periventricular regions with the mean values of the postoperative group in the same regions we found non significant differences (ns) (p=0.096, p=0.117) (Table 2, 3).

Discussion

There are still difficulties in the diagnosis of hydrocephalus in some cases. There is a need for additional techniques to confirm the diagnosis of hydrocephalus.[1,2,7] Well-known radiological imaging studies are not always sufficient for an exact diagnosis. Therefore, there are many reports in the literature to develop a safe diagnostic tool for hydrocephalus. These reports include some CSF flow dynamic, volumetric, morphological and functional imaging studies with MRI, CT, ultrasound and some radionuclear studies.[3–5,8–10] These attempts to diagnose hydrocephalus noninvasively have lacked the ability to either quantitatively or qualitatively obtain data.[6]

CT is the radiological technique of choice in patients with acute neurologic symptoms because of the easy access and low cost world widely. Therefore, the use of CT technique to accelerate a diagnosis will be effective. HU with CT is widely used in the diagnosis of many disorders. Thrombus, plaque, bone, graft, etc. densities with HU are used as a diagnostic and predictive tool in the literature.[3,11] Brain density measurements are widely used in the case of cerebral edema after trauma, ischemia and radiation therapy.[12–15] There is no report in the literature about the use of HU in the case of hydrocephalus. Additionally, there is no report in the literature about the use of HU in the ventricular region. In the present study, computed tomography with HU was used to analyze the density within different localizations of the brain parenchyma and CSF. We analyzed the effects of hydrocephalus to the cerebral parenchymal and CSF densities by HU.

In our study, ventricular and white mater, near grey mater regions are the most eloquent regions to support diagnosis of hydrocephalus by our method. In these regions, we found extremely significant increase of the HU values in the patients with hydrocephalus when we compare the patients with no cerebral pathology. We also found extremely significant decrease of the HU values in these patients after the shunt operations. Differences of the HU values between the patients with hydrocephalus and the patients with no cerebral pathology significantly reduced after the operations.

In the patients with no cerebral pathology, the mean HU value of the ventricles is found to be approximately 5 (ventricles in the frontal horn 4.94±0.68, occipital horn 5.02±0.66). In the patients with hydrocephalus, the mean HU value of the ventricles is found to be approximately 10 (ventricles in the frontal horn 10.05±2.90, occipital horn 10.5±3.11). The HU value of the ventricles is approximately 2 times higher in the patients with hydrocephalus than the values in the patients with no cerebral pathology. We found that the mean HU value of the ventricles in the patients with hydrocephalus reduced after the shunt operations (ventricles in the frontal horn 6.30±2.90, occipital horn 6.66±2.97) and almost equalized with the mean value of the ventricles in the patients with no cerebral pathology. This condition may be due to CSF changes depending on the changes in the CSF biochemistry and biophysics. Changes in the CSF biochemistry and biophysics may change CSF density. Although we did not find any abnormality in CSF biochemistry further studies are needed. There are also some studies in the literature showing the relationship between hydrocephalus and some biochemical agents.[16–20] These studies are also insufficient for definitive judgments.

We obtained similar statistical results from the region of white mater near gray mater. The mean HU value of this region (33.20±3.83) in the hydrocephalic patients reduced after the shunt operations (29.07±4.07) and came closer to the mean value of the patients with no cerebral pathology (26.83±1.88). This condition may be due to brain edema caused by cerebrovascular congestion.

We did not obtain similar statistical results from the periventricular regions. The mean HU values of these regions (periventricular area near the frontal horn 29.22±5.15, near the occipital horn 27.35±5.90) in the patients with hydrocephalus didn't show statistically significant difference after the shunt operations (periventricular area near the frontal horn 30.91±4.58, near the occipital horn 29.17±5.12). This condition may be due to transependymal flow of CSF. This is usually seen in the setting of an acute hydrocephalus.[21] We included acute and chronic hydrocephalus into the present study. This condition may have led to statistical insignificance.

As a result of our study, density measurements from ventricles and white mater near grey mater can be useful in the diagnosis of hydrocephalus. The present study has some limitations.

We tried to evaluate the patients retrospectively. This situation caused to remain a limited number of patients with limited follow up. Although we reported the issue which is not previously reported in the literature, we can not present any data to support causations. A long-term follow-up of a cohort of patients with hydrocephalus and normal controls will be recommended to provide further evidence on causations.

Conflict of interest: There are no relevant conflicts of interest to disclose.

References

1. Pennell T, Yi JL, Kaufman BA, Krishnamurthy S. Noninvasive measurement of cerebrospinal fluid flow using an ultrasonic transit time flow sensor: a preliminary study. J Neurosurg Pediatr 2016;17:270–7.
2. Szczepek E, Czerwosz L, Nowiński K, Dmowska-Pycka A, Czernicki Z, Jurkiewicz J. The usefulness of the evaluation of volumetric and posturographic parameters in the differential diagnosis of hydrocephalus. Wiad Lek 2015;68:145–52.
3. Kosteljanetz M, Ingstrup HM. Normal pressure hydrocephalus: correlation between CT and measurements of cerebrospinal fluid dynamics. Acta Neurochir (Wien) 1985;77:8–13.
4. Tisell M, Tullberg M, Hellström P, Edsbagge M, Högfeldt M, Wikkelsö C. Shunt surgery in patients with hydrocephalus and white matter changes. J Neurosurg 2011;114:1432–8.
5. Virhammar J, Laurell K, Ahlgren A, Cesarini KG, Larsson EM. Idiopathic normal pressure hydrocephalus: cerebral perfusion measured with pCASL before and repeatedly after CSF removal. J Cereb Blood Flow Metab 2014;34:1771–8.
6. Marmarou A, Young HF, Aygok GA, Sawauchi S, Tsuji O, Yamamoto T, et al. Diagnosis and management of idiopathic normal-pressure hydrocephalus: a prospective study in 151 patients. J Neurosurg 2005;102:987–97.
7. Kiefer M, Unterberg A. The Differential Diagnosis and Treatment of Normal-Pressure Hydrocephalus. Dtsch Arztebl Int 2012;109:15–26.
8. Hartman R, Aglyamov S, Fox DJ Jr, Emelianov S. Quantitative contrast-enhanced ultrasound measurement of cerebrospinal fluid flow for the diagnosis of ventricular shunt malfunction. J Neurosurg 2015;123:1420–6.
9. Song Z, Chen X, Tang Y, Yu X, Li S, Chen X, Peng J, et al. Magnetic resonance three dimensional sampling perfection with application optimized contrasts using different flip angle evolution sequence for obstructive hydrocephalus: impact on diagnosis and surgical strategy modification. Zhonghua Wai Ke Za Zhi 2015;53:860–4.
10. Thompson EM, Wagner K, Kronfeld K, Selden NR. Using a 2-variable method in radionuclide shuntography to predict shunt patency. J Neurosurg 2014;121:1504–7.
11. Cala LA, Thickbroom GW, Black JL, Collins DW, Mastaglia FL. Brain density and cerebrospinal fluid space size: CT of normal volunteers. AJNR Am J Neuroradiol 1981;2:41–7.
12. Kozler P, Pokorny J. CT density decrease in water intoxication rat model of brain oedema. Neuro Endocrinol Lett 2014;35:608–12.
13. Mangel L, Vönöczky K, Hanzély Z, Kiss T, Agoston P, Somogyi A, et al. CT densitometry of the brain: a novel method for early detection and assessment of irradiation induced brain edema. Neoplasma 2002;49:237–42.
14. Rózsa L, Grote EH, Egan P. Traumatic brain swelling studied by computerized tomography and densitometry. Neurosurg Rev 1989;12:133–40.
15. Wu O, Batista LM, Lima FO, Vangel MG, Furie KL, Greer DM. Predicting clinical outcome in comatose cardiac arrest patients using early noncontrast computed tomography. Stroke 2011;42:985–92.
16. Calcagni ML, Taralli S, Mangiola A, Indovina L, Lavalle M, De Bonis P, et al. Regional cerebral metabolic rate of glucose evaluation and clinical assessment in patients with idiopathic normal-pressure hydrocephalus before and after ventricular shunt placement: a prospective analysis. Clin Nucl Med 2013;38:426–31.
17. Cerda M, Manterola A, Ponce S, Basauri L. Electrolyte levels in the CSF of children with nontumoral hydrocephalus Relation to clinical parameters. Child's Nervous System 1985;1:306–11.
18. Kang K, Ko PW, Jin M, Suk K, Lee HW. Idiopathic normal-pressure hydrocephalus, cerebrospinal fluid biomarkers, and the cerebrospinal fluid tap test. J Clin Neurosci 2014;21:1398–403.
19. Tedeschi E, Hasselbalch SG, Waldemar G, Juhler M, Høgh P, Holm S, et al. Heterogeneous cerebral glucose metabolism in normal pressure hydrocephalus. Neurol Neurosurg Psychiatry 1995;59:608–15.
20. Wikkelsø C, Blomstrand C. Cerebrospinal fluid proteins and cells in normal-pressure hydrocephalus. J Neurol 1982;228:171–80.
21. Segev Y, Metser U, Beni-Adani L, Elran C, Reider-Groswasser II, Constantini S. Morphometric study of the midsagittal MR imaging plane in cases of hydrocephalus and atrophy and in normal brains. AJNR Am J Neuroradiol 2001;22:1674–9.