

The Value of MRA Versus MRI Brain DWI (ADC) in the Management of Ventriculomegaly in Pediatric Age Group

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Abstract

Background: Neurosurgeons may find difficulties in differentiation between progressive and compensated hydrocephalus since signs and symptoms of raised intracranial pressure can be subtle or completely absent in children with progressive hydrocephalus. The CBF and ADC values can help to differentiate between compensated and progressive hydrocephalus thus facilitating the decision to withhold CSF diversion in an infant with a compensated hydrocephalus.

Material and Methods: This prospective study included (40 participants) 10 control (5 males and 5 females) and 30 patients (18 males and 12 females). Patients were divided according to their clinical presentation into two groups, suspected to have Progressive Pressure Hydrocephalus (PPH) and Compensated Pressure hydrocephalus (CPH). All the patients underwent routine MRI brain, DWI (ADC) and MRA examinations.

Results: In our study, we found that each patient has his own CBF as base line for follow-up in hydrocephalic children with mean ADC value (1,018) as a cut off value below which compensated pressure hydrocephalus is diagnosed and above which progressive pressure hydrocephalus is diagnosed.

Conclusion: MRA is helpful as a complementary non invasive tool and each patient has his own CBF as base line for follow-up in hydrocephalic children due to great variations in the measured CBF with clear mean ADC cut off value for differentiation between compensated from progressive pressure and follow-up.

Key Words: Compensated Pressure Hydrocephalus (CPH) – Progressive Pressure Hydrocephalus (PPH) – MRI – MRA – CBF.

Introduction

IN infants with compensated hydrocephalus there is no need for CSF diversion, thus avoiding the complications that may accompany CSF diversion in 40 percent in the first year [1] and 5 percent in subsequent years [2].

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Compression of peripheral arterioles by raised ICP can influence CBF significantly. Distinction between compensated and progressive hydrocephalus can be difficult, especially in infants because clinical signs and symptoms can be either absent, nonspecific or unreliable [3] a significant decrease of CBF can be detected, CBF increases after CSF diversion. Moreover, post-operative CBF values are within the normal range [4].

Raised intracranial pressure in infants with progressive hydrocephalus may cause a 50% decrease in Cerebral Blood Flow (CBF) [5].

The presence of a normal CBF can help to differentiate between compensated and progressive hydrocephalus thus facilitating the decision to withhold CSF diversion in an infant with a compensated hydrocephalus [6].

The available data were inconsistent regarding to whether CBF values were dependent on age or not [7].

The absence of interstitial edema can help to differentiate between compensated and progressive hydrocephalus thus facilitating the decision to withhold CSF diversion in an infant with a compensated hydrocephalus [6].

The increased ADC values in infants with progressive hydrocephalus are probably caused by an increase of the extracellular water compartment. This phenomenon is explained by transependymal CSF absorption and stasis of extracellular fluid flow [8].

Diffusion imaging proved useful in the initial assessment and in the post-treatment monitoring of patients with hydrocephalus. Regardless of the

initial values, successful treatment resulted in nearly normalization of the ADC value [9].

Aim of the work:

To highlight both the strengths and weaknesses of MRA (CBF) and DWI (ADC) techniques to differentiate between compensated from progressive hydrocephalus and follow-up.

Patients and Methods

This study was performed on 40 participants at Kasr Al-Ainy Cairo University during period between December 2014 and January 2016; 10 controls (5 males and 5 females) and 30 patients (18 males and 12 females).

All patients were referred to the Diagnostic Radiology Department from Neurosurgery Outpatient Clinic.

Patients were divided according to their clinical presentation into two groups, suspected to have Progressive Pressure Hydrocephalus (PPH) and Compensated Pressure Hydrocephalus (CPH).

Inclusion criteria:

Patients had previous neuroimaging (U/S, CT and/or MRI) of ventriculomegaly. Either due to obstructive or communicating hydrocephalus.

Exclusion criteria:

- Patients with the combination of hydrocephalus and intra-parenchymal lesions, such as an intra cerebral tumour, were excluded.
- Patients with ex vacuo ventricular dilation by neuroimaging.
- Any contraindication for MRI: Anaesthesia or sedation complications (young children need complete sedation for performing MRI examinations).

Methods:

All cases (n=40/40) were subjected to routine MRI (axial T1 WI, T2 WI and T2 FLAIR, sagittal T2WI) and MRA to measure (CBF) and DWI (ADC).

Phase contrast MRA (Total Cerebral Blood Flow (TCBF):

Using 1.5-T (Philips-Intera) scanner (non-triggered; 30 phases, velocity 150-200cm/s). Scan time 4-5min. On the basis of 2 localizer MRA scans in the coronal and sagittal planes, a 2-Dimensional Phase-Contrast (2D-PC) slice was

positioned at the level of the skull base to measure the volume flow in the Internal Cerebral Arteries (ICAs) and the Basilar Artery (BA).

Post processing:

On an independent workstation, quantitative flow values were calculated from the phase contrast images. Circular to elliptical Regions of Interest (ROIs) were drawn manually around both ICAs and the BA on the phase-contrast images. These ROIs encompassed the entire lumen of the vessel. The value of mean signal intensity in each ROI reflected the flow velocity in the vessel (cm/sec). Flow (in ml/sec) was calculated by multiplying the average velocity with the cross-sectional area of the vessel.

To calculate total Cerebral Blood Flow (CBF) (in ml/min), flow rates for the ICA's and the BA were summed. This method is similar to flow measurement methods described by Chumas et al., [2] and Biagi et al., [4].

Interpretation:

The available data were inconsistent with regard to whether CBF values were dependent on age. Some authors have suggested that CBF decreases with increasing age whereas others did not find evidence of such a decline [7].

We considered each patient initial measured TCBF as his own base line for follow-up.

Diffusion technique:

1.5-T scanner (Philips-Intera) by using b values 0 & 1000sec/mm², repetition time (TR) > 1880m sec, echo time (TE)=70m sec, number of excitations (NEX)=3, matrix 256 X 256 with a field of view as small as possible, slice thickness 7-8mm, slice gap 1-2mm, scan time 3-4min.

Post processing:

Since no statically difference between left and right hemispheres, the mean ADC values were calculated in the following manually selected regions of interest (ROI's) (one hemisphere):

- 1- Occipital grey matter.
- 2- Peri ventricular white matter next to the occipital horn of the lateral ventricle.
- 3- Thalamus.
- 4- Peri ventricular white matter next to the frontal horn of the lateral ventricle.
- 5- Frontal grey matter, according to Leliefeld et al., [6] technique.

Interpretation:

In normal children:

The calculated mean ADC value of 1075mm²/s in the control subjects [10].

In our study we used mean ADC value 1075 mm²/sec (Forbes et al., [10]) as cut off value above which progressive pressure hydrocephalus was diagnosed.

Results

Table (1): An overview of the patients distribution by diagnosis and cause of ventriculomegaly.

Cause of ventriculomegaly	Aqueduct stenosis	Obstruction beyond foramen Magendie & Lushka	Intra-cranial cyst	Dandy Walker malformation
<i>Number of cases:</i>				
Frequency	23	5	1	1
<i>Percent:</i>				
(%)	59%	23%	10%	8%

Table (2): An overview of the calculated parameters (mean & SD) pre and post in study group.

Group	BF/pre	MA/pre	BF/post	MA/post
<i>Controls:</i>				
Mean	503.70	920.388		
Std. deviation	338.153	105.1297		
<i>Compensated HC:</i>				
Mean	699.67	916.138	764.00	875.7013
Std. deviation	244.568	58.6920	228.537	76.62554
<i>Progressive HC:</i>				
Mean	231.53	1,201.987	367.53	987.3020
Std. deviation	183.646	188.8273	254.164	49.13593
<i>Total:</i>				
Mean	475.13	1,024.394	565.77	931.5017
Std. deviation	319.983	189.7318	311.531	84.97701

Table (3): Showing TCBF values ml/min and their related sensitivity and specificity by percentage.

TCBF (ml/min)	Sensitivity	Specificity
348.00	80%	93%
434.00	86%	80%
687.00	100%	67%

The *p* (0.003) value found to be of statistical significance (less than 0.05).

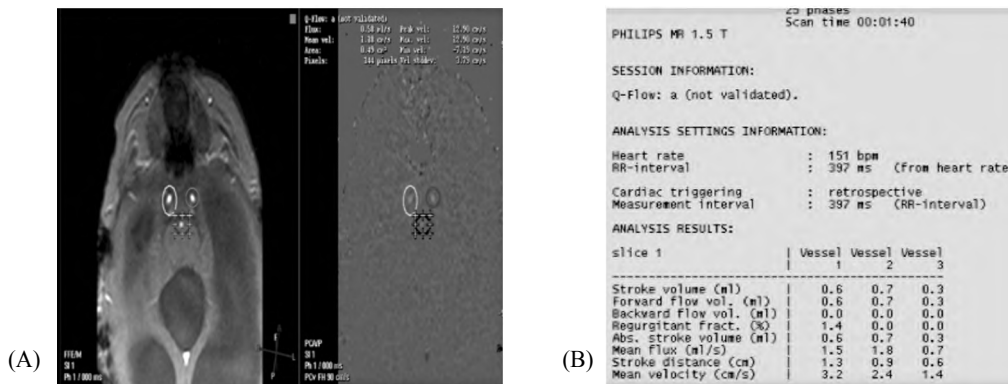


Fig. (1): (A) MRA image in a PPH 4 month old boy illustrating a 2D phase-contrast MRA axial section through the internal carotid arteries and basilar artery. (B) Quantitative flow values. (Vessel 1 indicates right sided ICA; 2 indicates left sided ICA; 3 indicates BA). TCBF 672ml/min.

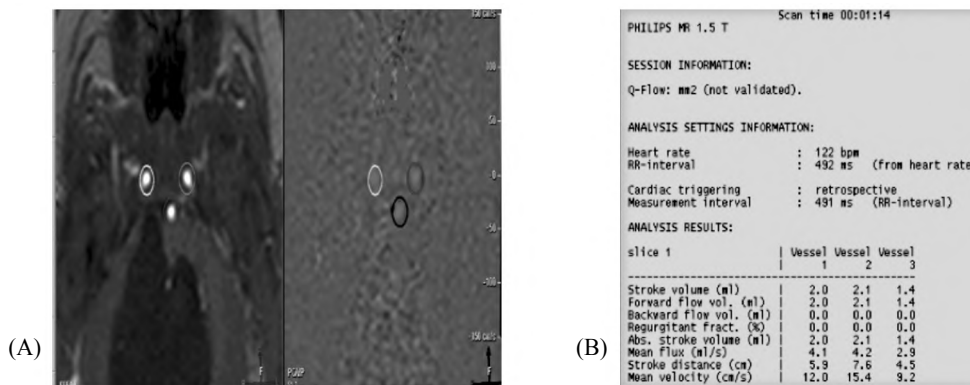


Fig. (2): (A) Post-operative MRA image of the same patient with increased TCBF 858ml/min compared to pre-operative 672ml/min.

Mean ADC value	Sensitivity	Specificity
1,018.630	100%	100%

The *p*-value (0.001) found to be of statistical significance (less than 0.05).

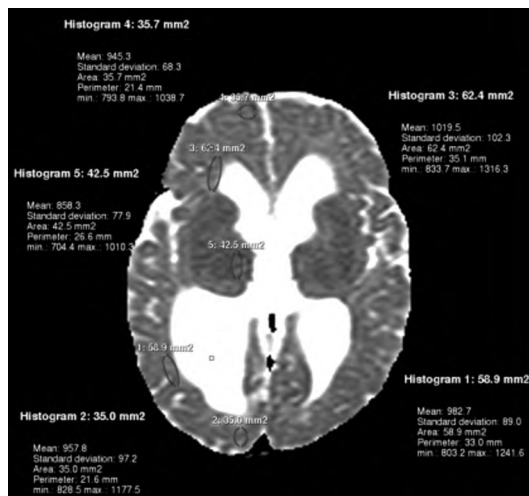


Fig. (3): 1 year old male presented with non-progressive large head circumference, delayed milestones and normal fundus examination. Normal mean ADC value $952.72 \text{ mm}^2/\text{s}$ and after 3 months follow-up showed mean ADC value $839.8 \text{ mm}^2/\text{s}$ (still normal), diagnosed as CPH.

Statistical analysis:

Data were statistically described in terms of mean \pm Standard Deviation (\pm SD), median and range, or frequencies (number of cases) and percentages when appropriate. Comparison of numerical variables between the study groups was done using Kruskal Wallis test with posthoc multiple 2-group comparisons. Within group comparison of numerical variables was done using Wilcoxon signed rank test for paired (matched) samples. For comparing categorical data, Chi square (χ^2) test was performed. Exact test was used instead when the expected frequency is less than 5. Accuracy was represented using the terms sensitivity, and specificity. Receiver Operator Characteristic (ROC) analysis was used to determine the optimum cut off value for the studied diagnostic markers. p -values less than 0.05 was considered statistically significant. All statistical calculations were done using computer program SPSS (Statistical Package for the Social Science; SPSS Inc., Chicago, IL, USA) release 15 for Microsoft Windows (2006).

Discussion

In our study we used similar technique as showed Leliefeld et al., [6] apart from we used different encoded velocity by several trials and we found that at encoded velocity 150-200cm/sec the least observed aliasing artifact while Leliefeld et al., [6] used encoded velocity 100cm/sec.

In our study we found that mean TCBF in control group (10 cases) is $503.70 \text{ ml/min} \pm 338.153$.

In our study we found that 14 patients from PPH group had TCBF values with mean TCBF pre value $231.53 \text{ ml/min} \pm 183.646$ which increased after shunt to be $367.53 \text{ ml/min} \pm 254.164$ except 1 patient which developed post shunt subdural hygroma and further decreased TCBF (42 ml/min) after shunt explained by external compression on the cerebral vessels by the effect of subdural hygroma history of shunt replacement was in this patient for follow-up. These results similar to the study confronted by Leliefeld et al., [6] (mean TCBF pre $187.8 \text{ ml/min} \pm 131.587$ and post mean TCBF value $432.66 \text{ ml/min} \pm 156.7002$).

In our study we found that all fifteen patients with CPH had TCBF values with mean pre value 699.67 ± 244.568 and post mean TCBF 764.00 ± 228.537 . These results similar to the study confronted by Leliefeld et al., [6] (mean TCBF $305 \text{ ml/min} \pm 206.572$).

Since there were a very wide range and variations in TCBF in the study group by Kirkness CJ, [7], we found the same results so we consider that every patient included in our study, had his own base line TCBF for further follow-ups.

Our data suggest for the diagnosis of compensated hydrocephalus it is very important to have follow-up using MRI with cerebral blood flow values which can be obtained during the same MRI enabling distinction between compensated and progressive hydrocephalus.

In our study we measured the ADC values at one cerebral hemispheres instead of both cerebral hemispheres as Leliefeld et al., [6] showed that ADC values in the left and right sided ROI's were compared using a paired Student's t -test and no significant difference between left and right sided ADC values was found, left and right sided ADC values were averaged for each of the examined areas.

Forcebs et al., [10] found the control subjects with calculated mean ADC value of $1075 \text{ mm}^2/\text{sec}$.

In our study we found that mean ADC in control group (10 cases) $920.388 \text{ mm}^2/\text{sec} \pm 105.1297$.

In our study we found that mean ADC in all 15 patients with PPH was high and normalized after shunt with mean ADC value pre $1201.987 \text{ mm}^2/\text{sec} \pm 188.8273$ and post 987.3020 ± 49.13593 . These results similar to the study confronted by Leliefeld et al., [6] (mean pre ADC value $1196 \text{ mm}^2/\text{sec} \pm 136$ and post 924 ± 73).

In our study we found that mean ADC in all 15 patients with CPH was normal with mean ADC value pre 916.138mm²/sec ±58.6920 and post 875.70 13mm²/sec ±76.62554. These results similar to the study confronted by Leliefeld et al., [6] (mean pre ADC value 890.0mm²/sec).

Ulug et al., [6] documented that ventricular dilatation and PVH are not reliable signs in assessing hydrocephalus treatment concluding that ADC value measurement and normalization of subarachnoid spaces are reliable signs for treatment assessment which matched with our study.

Despite the MRI is non invasive method the cost benefit should be considered. Taking in consideration the clinical background of the patient to narrow the spectrum use of the MRA among grey zone patients (with misleading or even absent symptoms and signs of ICP) in presence of ventriculomegaly for both differentiation between CPH and PPH, On the other hand follow-up after surgery in patients of PPH.

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دور الرنين المغناطيسي على شرايين المخ وقياس معامل الإنتشار الظاهري في تشخيص وعلاج حالات تضخم البطين المخي المستقر والمتزايد في الأطفال

قد تتشابه أعراض تضخم البطين المخي المتزايد الذي يحتاج إلى تدخل جراحي مع حالات تضخم البطين المخي المستقر الذي لا يحتاج إلى علاج وفي هذه الحالات (تضخم البطين المخي المستقر) وجد المخ مسار بديل وحدث توازن جديد لذلك لا تدخل جراحي ضروري لهذا النوع من إستسقاء المخ وذلك لتجنب حدوث المضاعفات المصاحبة للجراحة كإلتهابات حول الصمام. يمكن للأطفال المرضى أن يتأثر بأعراض وعلامات خفيفة لإرتفاع ضغط المخاوف وقد تكون غائبة لذلك فمن الضروري الإكتشاف المبكر للإستسقاء المخي والتمييز بين النوعين المستقر والمتزايد يعد أمراً حيوياً.

وجد في بعض الأطفال التي تم تشخيصها بإستسقاء مخي متزايد والتي إستمر عندهم بعض من أعراض إرتفاع الضغط المخي كتأخر علامات النمو بعد إجراء جراحة ناجحة لهم وذلك بعد تحسن كمية تدفق الدم وقيم معامل الإنتشار الظاهري مقارنة بنفس القيم قبل الجراحة وذلك يمكن تفسيره بسبب تلف بعض الخلايا العصبية في المخ.

يعتبر كلا من قياس تدفق الدم الدماغي يساعدنا على التفرقة ما بين نوعي إستسقاء المخي المستقر والمتزايد، حيث أننا وجدنا إنخفاض كمية تدفق الدم للمخ وقيم معامل الإنتشار الظاهري والتي تتحسن بعد الجراحة الناجحة مع الإختلاف في حالات تضخم البطين المخي المستقر وجد مع التحسن الذاتي لكمية الدم المتدفق للمخ وفي مثل هذا الحالات مزيد من المتابعات يوصى بها.