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Can Apparent Diffusion Coefficient Predict the Clinical Outcome in Drowned Children?

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Abstract

Introduction: Pediatric cerebral hypoxic-ischemic injury frequently results in severe neurological outcome. Imaging with diffusion-weighted magnetic resonance imaging (DWi) demonstrates that the acute cerebral injury and apparent diffusion coefficient (ADC) allow the assessment of the severity of brain damage. The main objective was to examine if spatial distribution of reductions in ADC values is associated with clinical outcome in drowned children.
Methods: This is a retrospective study of 7 children (7 examinations) suffering from a hypoxic-ischemic event who underwent DWi. Seven subjects with normal DWi served as controls. The mean patient age was 4.88 ± 2.93 years and the male-to-female ratio was 5:2. The neurological outcome was divided into 2 categories: 4 children with Apallic syndrome and 3 deaths. We analysed the differences between the drowned children and the control group regarding clinical data, DWi abnormalities, and ADC values.
Results: The ADC values in the occipital and parietal grey matter were significantly different between the drowned children (765.14 ± 65.47 vs 920.95 ± 69.62; $P = .003$) and the control group (670.82 ± 233.99 vs 900.66 ± 92.72; $P = .005$). The ADC showed low values in the precentral area also ($P = .044$).
Conclusion: The ADC reduction may be useful to predict the poor outcome in drowned children and can be a valuable tool for clinical assessment.

Résumé

Introduction : Les lésions hypoxiques ischémiques entraînent souvent des séquelles neurologiques graves chez les enfants. L'IRM de diffusion démontre qu'une lésion cérébrale aiguë et que le coefficient de diffusion peuvent servir à évaluer la gravité des atteintes au cerveau. L'étude avait pour principal objectif de déterminer si la répartition spatiale associée à une réduction du coefficient de diffusion apparent pouvait être corrélée au résultat clinique observé chez des enfants à la suite d'une noyade.
Méthodes : Cette étude rétrospective portait sur 7 enfants (7 examens) ayant subi une IRM de diffusion à la suite d'un événement hypoxique ischémique. Sept patients ayant obtenu des résultats normaux à l'IRM de diffusion ont servi de groupe témoin. L'âge moyen des patients était de 4,88 ± 2,93 ans et la proportion des sexes était de 5 garçons pour 2 filles. Les séquelles neurologiques ont été réparties en deux catégories: syndrome apallique (4 enfants) et décès (3 enfants). Les différences entre les enfants ayant subi une noyade et les enfants du groupe témoin ont été analysées sur le plan des données cliniques, des anomalies décelées à l'IRM de diffusion et des valeurs du coefficient de diffusion apparent.
Résultats : Les valeurs du coefficient de diffusion apparent dans la substance grise des régions occipitales et pariétales des enfants ayant subi une noyade (765,14 ± 65,47 contre 920,95 ± 69,62; $P = 0{,}003$) étaient significativement différentes de celles observées chez les enfants du groupe témoin (670,82 ± 233,99 contre 900,66 ± 92,72; $P = 0{,}005$). Le coefficient de diffusion apparent affichait également des valeurs faibles dans l'aire précentrale ($P = 0{,}044$).

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Conclusions : Une réduction du coefficient de diffusion apparent peut servir à prédire un résultat défavorable chez les enfants ayant subi une noyade et s'avérer un outil précieux dans le cadre de l'évaluation clinique.

Key Words: Apparent diffusion coefficient; Diffusion-weighted imaging; Drowning; Cerebral

Magnetic resonance imaging (MRI) represents a radiation-free, noninvasive imaging modality that allows for the obtaining of cross-sectional images from the human body in any direction with excellent soft tissue resolution. Because children have less developed compensatory mechanisms and suffer from a greater radiation sensitivity than adults, MRI is better suited for imaging in children, as Tkacz et al [1] suggested. MRI is used for diagnosis and grading of cerebral damage. Difussion-weighted imaging (DWi) depends on the water diffusion properties in tissues and represents a widely accepted technique for imaging of ischaemia in neuroradiology. The apparent diffusion coefficient (ADC) is part of DWi and is displayed as a parametric map. In addition to the visual assessment on DWi images, Koh and Collins [2] also mentioned the possibility of quantitative analysis by ADC region of interest (ROI) measurement. Lesions with restricted diffusion appear hypointense on ADC map and usually have lower ADC values compared with less cellular areas. In drowned children, cerebral hypoxic-ischemic injury (HI) frequently results in severe neurological disability and mortality as Vermeulen et al [3] stated. Savvas and Van Toorn [4] and Taouli and Koh [5] describe factors such as age that reflect brain maturity, duration, and severity of the injury that can give different ADC values on imaging studies.

The aim of this study was to assess the values of DWi, including ADC measurement and their prospective value for clinical outcome in drowned children compared to a control group.

Materials and Methods

Patients

Seven children were examined (mean age 4.88 ± 2.83 years; male:female ratio 5:2) suffering from a HI caused by drowning. The patients were evaluated in terms of age, gender, and neurological outcome. All patients underwent a standard head MRI including fluid-attenuated inversion recovery, T2 imaging, sagittal T1-weighted imaging, DWi, and T2-weighted imaging. The neurological outcome of the patients was divided into 2 groups: Apallic syndrome (4 patients) and deceased (3 patients). Apallic syndrome was defined after von Wild et al [6] and describes the behavioral feature of a patient who was awake but unresponsive secondary to severe brain damage. For all drowned patients were recorded: the time interval between the drowning event and the MRI study, the approximate duration of submersion, and core body temperature at hospital admission. The control group consisted of 7 children, age and gender matched (mean age 4.92 ± 3.05 years, male:female ratio 5:2) with the study patients, who were admitted to MRI for other reasons (mainly headache) and with normal MRI findings. They were free of neurological disorders or trauma.

MRI

In total 7 examinations and 7 controls were assessed using a 1.5T MRI scanner. Only the DWi and ADC were analysed in this study, whereas T2-weighted imaging was used for the anatomic cross-reference as suggested by Barett et al [7]. The DWi and ADC maps were evaluated by 2 investigators separately. According to Choi et al [8], in reanimated patients 15 ROIs were placed in areas of the cerebrum and cerebellum (Figure 1) of each hemisphere, except the pons where only an ROI was placed. The means and standard deviations of ADC values within these ROIs were computed and saved. Thus, a total of 29 ROIs were evaluated. In drowned patients ROIs were adopted to pathological areas within predefined anatomical regions, whereas in the control group they were placed in a standardized manner. The measurement of each ROI was made in agreement for each area. Because the hypoxic events are expected to affect both hemispheres symmetrically, corresponding ROIs of both hemispheres were averaged. Both investigators were blinded to patient outcome.

Statistical Analyses

Results are expressed as means ± SD. Box-and-whisker plots were constructed to summarize the percentage distributions of ADC values. A P value of $<.05$ was considered significant. The prognostic performance of ADC values was assessed using sensitivity, specificity, likelihood ratios, and receiver-operating characteristic curves. The most commonly used index of accuracy is the area under the receiver-operating characteristic curve, with values close to 1.0 indicating higher prognostic accuracy. Statistical analysis was performed using the SPSS 21.0 for Windows (IBM, Armonk, NY). For image display and ADC measurements a variant of ImageJ 1.48a (http://rsbweb.nih.gov/ij/; National Institutes of Health, Bethesda, MD) was used.

The study was performed according to the Good Clinical Practice guidelines and the Declaration of Helsinki. The study protocol was approved by the Ethics Committees of all the study centres involved. Informed consent was obtained from all participants or tutors prior to their inclusion in the study.