Lessons Learned from 23 Years of Experience in Testing Visual Field of Neurologically Impaired Children

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Abstract

Background: Despite general difficulty to measure visual field (VF) in Neurologically Impaired (NI) children, the timely finding of a VF impairment may contribute to finding the right diagnosis and treatment as well as to explaining their visual behaviour to parents and caregivers. We describe the Standard Conventional Perimetry (SCP) and a potential gain in time to diagnosis of a visual field defect (VFD) when using a behavioural visual field (BVF) test.

Methods: NI children who underwent SCP at the University Medical Center Utrecht were retrospectively analysed and scored with the examiner-based assessment of reliability (EBAR) scoring system. The difference in time to diagnosis between the BVF and SCP tests was calculated.

Results: In this cohort of 115 NI children (69 boys and 46 girls), the majority suffered from neoplasms (36%) and stroke/haemorrhage (34%). The mean age at which they were able to complete an SCP test was 8.3 years (range 4.5 - 17.4). 44% were tested with the Full Field Peritest (FFP), 23% with the Goldmann VF test, 29% with the Central Peritest (CP) and 4% with the Humphrey Field Analyzer. Among the FFP 44% had “good” reliability versus 22% in Goldmann tests and 17% in CP (p < 0.001). The mean age of NI children performing SCP was 8.3 years versus 4.6 years with BV F (p < 0.001).

Conclusion: The Full Field Peritest is the most reliable VF test in this cohort of NI children. Use of the BVF test significantly reduces (average 3.7 years) the time to diagnosis of a peripheral VFD.

Keywords

Cerebral visual impairment (CVI), Neurological impairment (NI), Standard conventional perimetry (SCP), Behavioural visual field (BEFIE) test

Introduction

Children suffering from neurological impairment (NI) may show various visual impairments, such as a decreased visual acuity, visual field defects, disorders of eye movement and disorders of higher visual processing which may be diagnosed as Cerebral Visual Impairment (CVI) [1-3].

CVI, defined by Sakki, et al. as “a verifiable visual dysfunction which cannot be attributed to disorders of the anterior visual pathways or any potentially co-occurring ocular impairment” [4], is the main cause of childhood visual disability in developed countries. It may have a pre-, peri- or postnatal origin with a prevalence between 10 and 22 cases per 10,000 births [2,5].

Although the need for the development and refinement of approaches which allow early detection of gross VFD has recently been stressed by Patel, et al. [6], retrospective studies of the visual field (VF) in a large cohort of NI children with or without CVI are lacking in the current literature.

Several techniques can be used to measure VF in children, such as Standard Conventional Perimetry (SCP), confrontational behavioural visual field (BVF) methods (such as the BEFIE test, the use of Styczar balls or double-arc perimetry [7,8]) or eye-tracker and multifocal Visual Evoked Potential techniques.

However, despite these various options, it can still be difficult to measure VF in NI children [9-12] due to a lack of concentration, short attention span, psycho-mo-
tor impairment or retardation and intolerance to the restrictions of head movement required to perform most of these tests [12-14].

Detection of a VFD in NI children is important because it may represent one of the first symptomatic signs [15] or contribute to find the right diagnosis in pathologies such as paediatric stroke, cerebral palsy and periventricular leukomalacia [16-20]. It could also aid parents and caregivers to understand the child’s visual behaviour, resulting in better acceptance, improved quality of life and more adequate rehabilitation strategies [21,22].

To the best of our knowledge a comparison of SCP with a confrontational BVF method for testing VF in NI children searching for a potential gain in time to diagnosis of a VFD has never been performed. The aim of this study is to describe the SCP in a cohort of NI children. Additionally, to confirm a potential gain in time to diagnosis of a VFD when using a BVF test.

Materials and Methods

Patient selection

This study retrospectively followed all NI children that underwent a confrontational BVF test before the age of twelve and that also underwent SCP at the Utrecht University Hospital from January 1995 till June 2018. The study was approved by the institutional ethical committee of the University Medical Center Utrecht which also deemed the collection of written informed consent not necessary.

Data collection

The patient files were retrospectively analysed. The collected demographic and clinical characteristics included sex, age at examination and type of pathology.

Data of the earliest SCP tests with best representation of VF were gathered. If multiple SCP tests were used in an individual child, our preference went initially to the Goldmann VF test. When this was lacking, data of the first performed Full Field Peritest (FFP) or the first performed Humphrey Field Analyzer (HFA) including peripheral stimuli were recorded. As last resort, data on the first performed Central Peritest (CP) were gathered. If scores differed per eye, the score of the best eye was included. If the scores were the same, those of the right eye were included.

SCP

The SCP tests used in our center were manual kinetic testing on the Goldmann perimeter, semiautomatic-static testing on the Peritest (Rodenstock, Germany) [23] and automatic-static testing on the Humphrey Field Analyzer. These SCP tests could have either tested only central VF or the central and peripheral VF (Full Field). As soon as SCP was possible for a child, they were tested with CP or an SCP test with periphery, if it were possible. The treating ophthalmologist chose between Goldmann, FFP and HFA.

Confrontational behavioural measurement

The confrontational BVF method used in our center was The Behavioural Visual Field (BEFIE) Screening Test (see Figure 1), a simple kinetic BVF test, designed in our institution with the aim to test children of preverbal ages or NI children [7].

The BEFIE test, which requires an examiner and an observer, is easy to apply in clinical practice and creates a high intrinsic motivation for the child to co-operate due to the game-like interaction between examiner, observer and patient. With this test, peripheral VFDs such as hemianopic, quadrantanopic or concentric VFDs can be detected in children as young as four months of age [24].

SCP test reliability in NI children

To gain insight in the reliability of SCP tests in children with NI, the Examiner Based Assessment of Reliability (EBAR) scoring system [25] was used. To score

![Figure 1: The Behavioral Visual Field Screening Test [25]. A: Equipment includes a graded semicircular black metal arc with a stimulus at the end (1), a fixation target on a stick (2), and a stick with a level attached to it used for positioning (3). B: A typical example of the test in a clinical setting.](image-url)
tests more objectively, cooperation and fixation were dichotomized using the test results with comments made by the examiner. The scores were made by matching the descriptions of the EBAR scoring system with our retrospectively gathered results and comments. SCP tests were rated “good” when cooperation and fixation both had a score of “+” and an SCP test was scored as “fair” when cooperation and fixation were intermediate. Patients were excluded when no comment was given on the test result.

Average age

The children’s age during the earliest SCP test with best representation was compared to their age during the earliest reliable monocular BEFIE test. This analysis was performed in order to find the average age at which NI children are able to perform perimetry tests and to examine the potential gain in time to diagnosis of a VFD should the BEFIE test be routinely incorporated in an ophthalmologic department.

After their admission and full ophthalmological and orthoptic investigation including the first BEFIE test, these NI children obtained a regular follow-up using the BEFIE tests until SCP was possible. All BEFIE tests were performed by the same examiner (GP).

Reasons for exclusion for this analysis were: no monocular, but only binocular BEFIE tests, BEFIE and SCP tests performed on same day (for example before epilepsy surgery in accordance with local protocol) or age above 12 during the first BEFIE test.

Statistical analysis

Reliability was calculated using the chi-square test. Due to the large sample size and the normality in said sample in the BEFIE test age group, the analysis for average age difference between SCP and BEFIE was calculated using the paired sample t-test. All statistical tests were performed using IBM SPSS Statistics for Macintosh, version 25.

Results

In total 138 children were eligible for this study of which 115 NI children (69 boys) were included after implementation of the exclusion criteria. The mean age in which the NI children could perform an SCP test was 8.3 (range 4.5-17.4 SD 2.5) years.

Pathologies were divided by neoplasm (31%), stroke/haemorrhage (30%), high intracranial pressure (11%), cysts (7%), asphyxia (7%), lesions (5%), epilepsy (4%), unknown (3%), trauma (2%).

Of the types of SCP tests used, 43% were FFP, 23% were Goldmann VF tests, 30% were CP and 4% were HFA tests. For more details on pathology, sex and tests, see the baseline Table 1.

Table 1: Baseline table with NI children divided by pathology group and type of Standard Conventional Perimetry (SCP) with frequencies of different EBAR scores per SCP type. Gender percentages calculated horizontally of total in subgroup. Percentages of Total calculated vertically.
104 out of the total 115 children were included. For this subgroup, the mean age at which SCP was possible for children with NI was 8.2 (range 4.5-17.4 SD 2.5) years. The mean age in which the first monocular BEFIE test was possible for children with NI was 4.5 (range 0.7-11.8 SD 2.4) years. The mean total difference between the first BEFIE test and the first SCP test was 3.7 years (95% CI 3.15-4.21; \(P < 0.001\)).

Discussion

With data gathered over a period of 23 years, this is the longest and as far as we know, only retrospective study of the VF in such a large cohort of NI children with or without CVI.

This is probably due to the commonly underestimated importance of measuring VF in this group and the well-known methodological difficulties [9-12], such as a lack of concentration, short attention span, psycho-motor impairment or retardation and the intolerance to the restrictions of head movement required to perform most SCP tests [12-14].

Furthermore, there is little evidence regarding the

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Figure 2: Results of the EBAR scoring system per SCP test; FFP: Full Field Peritest, CP: Central Peritest, Goldmann, HFA: Humphrey Field analyzer. Good = green, Fair = yellow, Poor = red.

Reliability of SCP tests in NI children

All 115 children were included to measure the reliability of SCP tests, but due to the small number of children tested with central and full field HFA tests (1 and 3 respectively), results obtained using these two methods were excluded for the statistical analysis.

In total 37 were rated “good”, 38 as “fair”, 40 as “poor”. The ratings for the different SCP tests are shown in Figure 2.

Among the FFP, 46% (23) had “good” reliability, 42% (21) were rated as “fair” and 12% (6) as “poor”.

Of the Goldmann tests 22% (6) had a “good” reliability, 15% (4) were rated as “fair” and 63% (17) as “poor”.

Among the CP 18% (6) had a “good” reliability, 35% (12) were rated as “fair” and 47% (16) as “poor”.

The difference between SCP tests was significant with a \(P < 0.001\).

Average age

For the comparison between the average age during the first SCP test and during the first BEFIE test,
reliability of SCP in children with NI, a group of children that is at higher risk of developing a VFD [6].

Also, there is little consensus on how to approach these measurements, both in healthy as in NI children. In a recent study, Goldmann and Humphrey field tests, the two most common perimetric tests used in children, have shown to be reliable in healthy children using the EBAR scoring system [25]. Patel, et al. measured the reliability of the discontinued Goldmann and the Octopus perimeters in children with NI, while other authors limited their measurements to confrontation methods or the Amsler test [6,26,27].

Pathologies

Out of all NI children who were able to perform both a BEFIE test and a SCP test, the majority suffered from neoplasm (30.9%) or stroke/haemorrhage (26.6%). This could suggest that when these are the causes of NI, children may have a higher chance to be able to perform an SCP test, due to plasticity of the brain [28]. On the contrary, these data could be biased from a higher prevalence of these pathologies in our center. Therefore, more research is needed to support these data and hypotheses.

Although this study did focus on the various brain pathologies, it did not include their localizations. Therefore, no assumptions can be made about which SCP test is more reliable for each localization.

An assumption on which SCP test tends to be more reliable for each pathology group cannot be made, due to the small number of children in each group.

Perimetry tests used

Only 24.6% of NI children managed to complete a Goldmann VF test and only 26.6% completed a CP, whereas the majority of all participants (44.9%) managed to complete an FFP. Therefore, a Peritest could be suggested when the commonly used Goldmann test [9] is likely to fail. Unfortunately, internationally the Peritest is nowadays not routinely used, even though it was reported to perform well in the few studies that described it [23,29,30] and the same will probably happen to the discontinued Goldmann test.

Currently the most commonly used perimetry test in children is the HFA, although recent studies opt for the Octopus perimetry as a replacement for the Goldmann test [6,26,31]. In a recent study comparing both Goldmann VF test and Octopus perimetry, broad agreement was found, and these tests were recommended for children > 8 years with neuro-ophthalmic disease [6]. We believe that eye tracking applications might prove as a sound technique for testing VF in children in the future [32-34]. Furthermore, predicting VFDs using OCT seems to be possible in children with a developmental age of 3-6 years [35].

In our center the Octopus perimeter is not available, and the HFA is sparsely used in children due to the extensive and positive experience of staff in testing children with or without NI using the Peritest [36,37]. Hence, a comparison of Octopus perimeter and HFA was not possible in our retrospective study. Therefore, we suggest prospective studies using the two above-mentioned, more widely used, VF tests for a conclusive comparison.

Reliability of SCP tests in NI children

Due to the retrospective nature of this study, the results of the EBAR analysis might be not perfectly representative. Although a prospective study could incorporate the score definitions more accurately, in our opinion the data obtained give a fairly accurate representation of SCP reliability in children with NI. Although both kinetic and static perimetry should be considered in the NI child, the FFP, a static VF test, has a significantly higher reliability score for the first measurement of VF in NI children.

On the opposite, the Goldmann test, a kinetic VF test and one of the more commonly used SCP tests in clinical practice for testing children [6,9,14] and shown to be highly reliable in healthy ones [26], showed only a 22% “good” reliability in NI children in our cohort, probably due to a prolonged learning curve in comparison with the Peritest.

Pathology, localization and severity can predict which SCP method could be more suited or might have a higher chance of a successful measure of VF. For instance, in damage to the periventricular matter or to the parieto-occipital region, the sensitivity of movement perception might be reduced, consequently rendering the kinetic perimetry less applicable [27].

The CP had high numbers of “poor” ratings. This is probably due to more severe pathology, as this sample of NI children were only able to perform this shorter test of the central field and no more difficult tests.

Average age

An important finding in this study is that the mean age at which a NI child can perform an SCP test is 8.3 years. Furthermore, this study shows that a monocular BEFIE test for testing the peripheral VF can be successfully performed on average 3.7 years earlier than an SCP test.

This is due to the adaptations at the psycho-motor impairment of the NI child and the game-like interaction between the child and the examiner and observer [24]. These characteristics make it very suitable for healthy children of preverbal ages as well.

This finding highlights the importance of a wider clinical application of this behavioural test, especially when
considering that Koenraads, et al. already showed its specificity of 98% and sensitivity of 60%, which raises to 80% when only absolute PVF defects at SCP are taken into account [24].

Considering that VFDs may represent as one of the first symptomatic signs of CVI in children [15], such a considerable time gain of 3.7 years in the diagnosis of a VFD using the BEFIE test could help to drastically lower the doctor delay in diagnosing CVI in children.

Furthermore, it could help parents and caregivers to understand the child’s behaviour, resulting in better acceptance, improved quality of life and more adequate treatment or rehabilitation strategies [21-22].

In addition, as 29% of all NI children tested were able to have only their central visual field tested with SCP, while in all of them it was possible to test the peripheral VF using the BEFIE test, the BEFIE test could be a useful complementary test in addition to SCP.

Summarizing, we emphasize the importance of an early diagnosis of minimally a peripheral VFD by means of any available BVF test in the clinical practice as it leads to better care for NI children.

Limitations

This study is prone to several limitations, first of all those associated with a retrospective study. Moreover, it only reports on the reliability of the first BEFIE and SCP tests done by the NI children.

Although Koenraads, et al. [24] already reported a reliability of 69% on first BEFIE tests, it is still impossible to objectively determine reliability of BEFIE tests. Based on the results of this study, no assumptions can be made on the reliability of future VF tests.

In addition, this study reports the experience of a single center cohort, in which only one examiner, ophthalmologist GP, performed all the BEFIE tests, helped by different observers, which were all orthoptists. No inter-user data of the BEFIE test was hence gathered, while the SCP tests were performed by different technicians.

The BEFIE test requires a trained observer and examiner and it has the limitation of only testing the peripheral VF. Therefore, we strongly suggest the development of a reliability scoring system for the BEFIE test prior to widespread implementation in specialized ophthalmologic departments. Alternatively, we recommend the development of a better BVF test or ultimately an objective measurement of VF in children, less influenced by a lack of co-operation, attention or psychomotor impairment.

Our center has extensive experience using the Peritest for testing children, resulting in a larger cohort of NI children that performed the Peritest than HFA, which is nowadays considered the state-of-the-art when testingVF in children [38].

A prospective study, without the above-mentioned limitations, could further clarify which SCP test is best suited for NI children.

In conclusion, this retrospective study from 23 years of experience in testing visual field of NI children shows that the FFP was the most reliable VF screening test. A BVF test, such as the BEFIE test leads to a significant gain in time to diagnosis of a peripheral VFD of 3.7 years.

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Role of the Funder/Sponsor

The funders had no role in the design and conduct of the study; collection, management, analysis and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

References


