OPTICAL COHERENCE TOMOGRAPHY AND VISUAL OUTCOMES IN PEDIATRIC ABUSIVE HEAD TRAUMA

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Purpose: Compare follow-up optical coherence tomography with visual function in children with abusive head trauma (shaken baby syndrome).

Methods: Retrospective follow-up studies of three children who were victims of abusive head trauma within the first year of life.

Results: Optical coherence tomography showed disrupted retinal layering, thick detached internal limiting membrane, focal posterior vitreous separation, and multilayered tractional retinoschisis. Significant vision loss occurred in three of four eyes with a history of traumatic retinoschisis. Normal visual acuity and low-normal visual-evoked potentials were measured in a child with foveal distortion, reduced global nerve fiber layer thickness, detached internal limiting membrane, and history of vitreous hemorrhage.

Conclusion: Significant abnormalities of retinal anatomy can be detected on optical coherence tomography years after abusive head trauma. Optical coherence tomographies and assessment of visual pathways help to elucidate causes of visual dysfunction in children with abusive head trauma.

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Abusive head trauma (AHT) including "shaken baby syndrome," describes a range of clinical findings due to nonaccidental cranial injuries in young children. At clinical presentation, common findings include loss/altered consciousness, intracranial hemorrhage, subdural hematomas, retinal hemorrhages, and abnormal diffusion-weighted imaging.[1–5] Numerous and extensive, multilayered retinal hemorrhages, extending to the ora serrata, often with traumatic retinoschisis (TR), are highly associated with AHT.[3] Previous studies have revealed a range of localized abnormalities on optical coherence tomography (OCT), such as vitreoretinal interface detachment, perimacular folds, optic nerve sheath hemorrhage, retinal fibrotic scars, multilayered retinoschisis or disruption of all retinal layers, foveal detachment, and macular pseudoholes.[6–9] A poorer neurological outcome is believed to occur in those who present with extensive retinal hemorrhages and TR.[1,3,5] The object of this case series was to compare visual outcomes with long-term OCT findings. The hypothesis was that residual OCT changes would help elucidate causes of visual dysfunction.

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Case 1

A boy presented to an outside hospital at 157 days of age with seizures and bilateral subdural hemorrhages (SDHs) in both anterior middle cranial fossae. He had bilateral intraretinal hemorrhages, posterior vitreous separation over the macular area in the right eye, and vitreous hemorrhage inferotemporal to the optic nerve in the left eye. At 18 months of age, visual-evoked potentials were low-normal in each eye. Optical coherence tomography (Spectralis, Heidelberg Engineering) at 5 years of age (Figure 1) revealed mild bilateral distortion of the fovea. In the right eye, a thick internal limiting membrane remained detached, and there was a small isolated outer retinal lesion superior temporal to the fovea. In the left eye, there was thinning of the inner retina temporally and a floating body in the vitreous (likely the detached internal limiting membrane) that cast a shadow on the infrared image. Global nerve fiber layer thickness was subnormal at 74 μm in the right eye and 65 μm in the left eye. The corresponding fundus examination revealed trace optic pallor, dim foveal reflex, and vitreous detachment bilaterally. Snellen acuity was 20/20 in the right eye and 20/30 in the left eye. Optical coherence tomography findings were unchanged after 2 years. The data indicate optic nerve loss and inner retina loss in the left eye with relatively preserved visual acuity.

Case 2

A boy presented to an outside hospital with seizures and SDHs at 229 days of age. Brain MRI showed normal gray/white differentiation. He had bilateral scattered intraretinal hemorrhages and bilateral TR cavities filled with blood. Visual-evoked potentials were subnormal under binocular viewing at 19 months of age. Optical coherence tomography at 11 years of age (Figure 2) revealed bilateral distortion of the fovea and circumferential retinal fold temporal to the macula in both eyes (right eye more prominent than the left eye on the infrared image). At the fold, there is a "notch" of abnormal retinal layering, particularly the outer nuclear layer. A thick internal limiting membrane remained detached in the left eye with evidence of localized retinal traction superior to the optic disc. Global nerve fiber layer thickness was normal at 116 μm in the right eye and 119 μm in the left eye. The corresponding dilated fundus examination revealed circumferential preretinal fibrosis temporal to the macula of the right eye and a complete ring of preretinal fibrosis encircling the macula of the left eye. The optic nerve appeared normal in both eyes. Snellen acuity was 20/400 in the right eye and 20/30 in the left eye. In summary, the OCT data indicate retinal damage and abnormal layering of the fovea associated with subnormal visual-evoked potentials. There is evidence of superimposed amblyopia of the right eye.

Case 3

A boy presented to our hospital at 133 days of age with seizures, SDHs, acute and subacute rib fractures, a radius fracture, and multiple bruises. He had bilateral diffuse intraretinal, preretinal, and subretinal hemorrhages; TR cavity; retinal edema; and swollen optic discs. His abuse was diagnosed by a child abuse pediatrician and confirmed by a multidisciplinary conference. A brain MRI 3 days after presentation showed diffuse hypodensity with loss of gray–white matter differentiation throughout the right cerebral hemisphere as well as in the left temporal and occipital lobes, concerning for ischemia versus

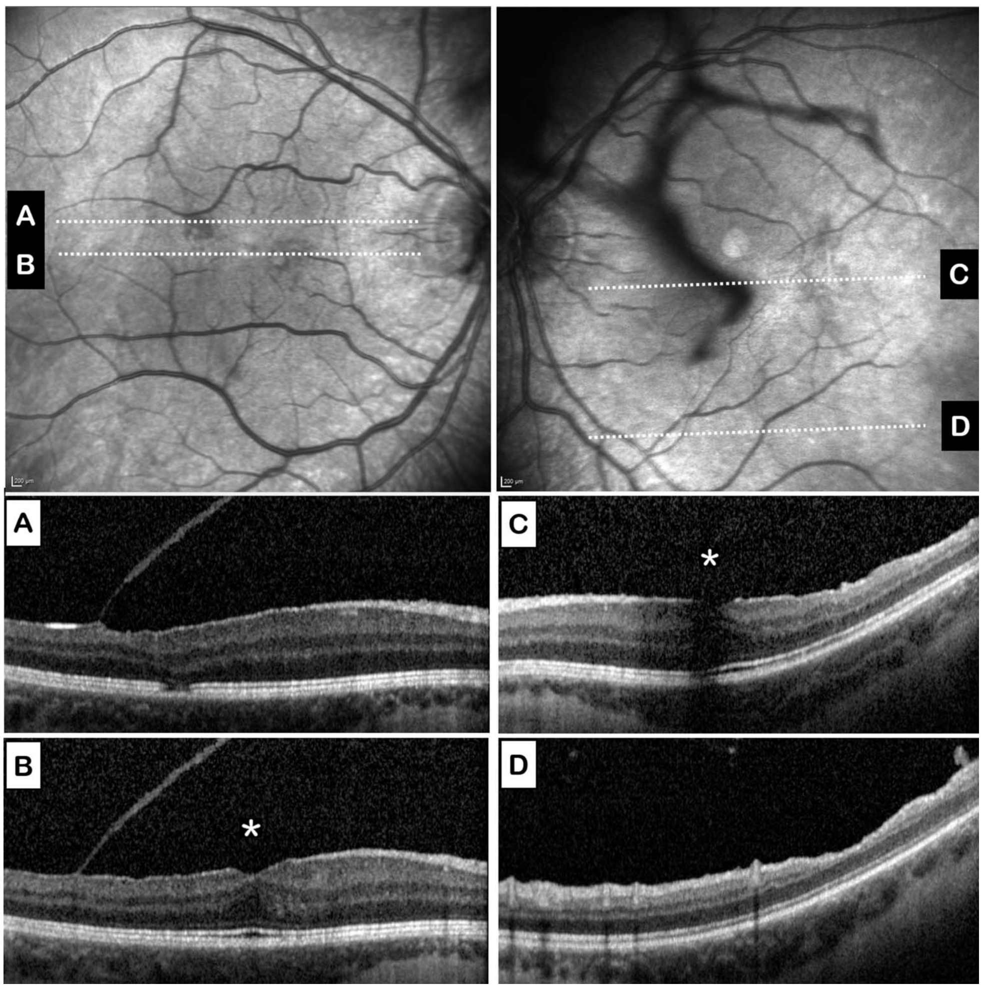

Fig. 1. Optical coherence tomography of Case 1 at 5 years of age. Confocal infrared image of the right eye (left column) shows two cross sections (**A** and **B**). The internal limiting membrane is detached, and there is a small isolated outer retinal lesion superior temporal to the fovea (**A**). The confocal infrared image of the left eye (right column) shows two cross sections (**C** and **D**). There is a large vitreous floater and loss of the inner retina temporally (**D**). The fovea in each eye shows mild distortion (asterisks).

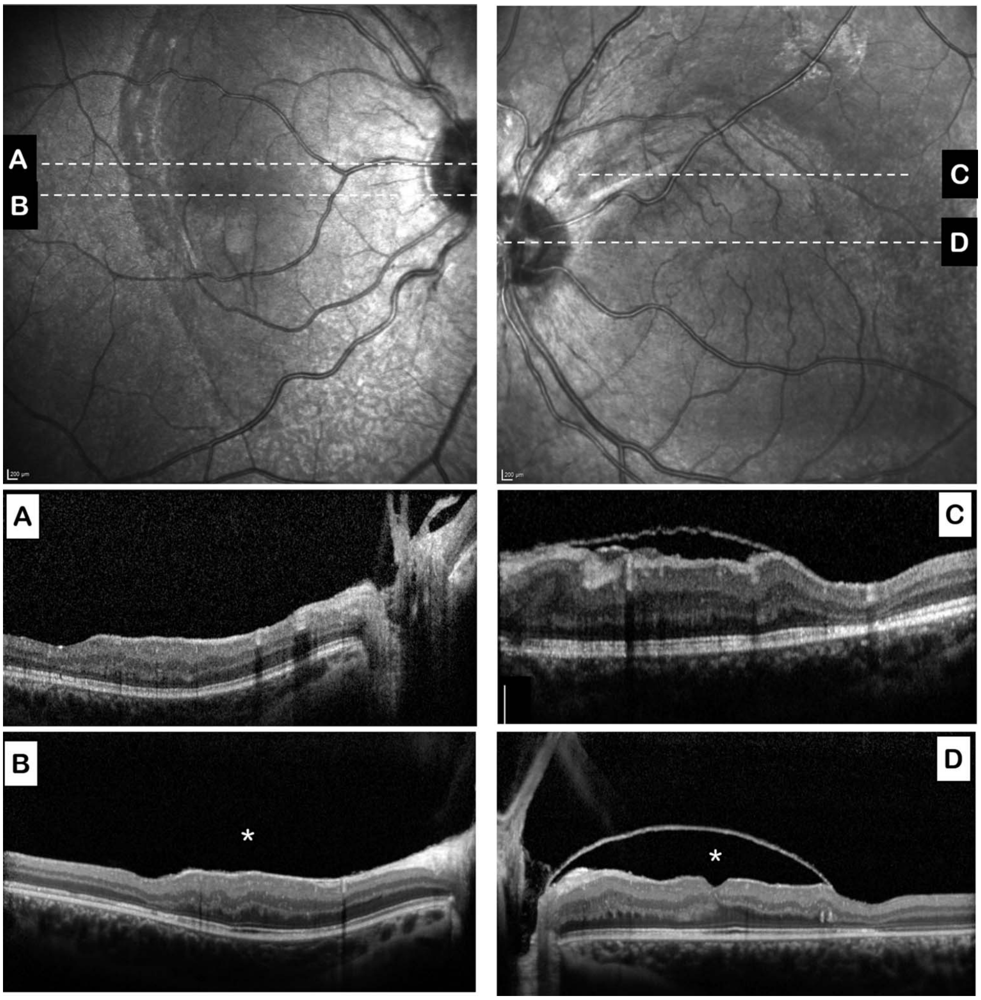

Fig. 2. Optical coherence tomography of Case 2 at 11 years of age. Confocal infrared image of the right eye (left column) shows two cross sections (**A** and **B**), and the left eye shows two cross sections (**C** and **D**) in the right column. The internal limiting membrane is detached and shows evidence of retinal traction. The fovea is distorted in each eye (asterisks).

post-traumatic diffuse axonal injury. Deterministic tractography (DSI Studio, http://dsi-studio.labsolver.org) using diffusion tensor imaging showed reduced volume of the optic radiations (right > left hemisphere) but intact white matter metrics by fractional anisotropy (Figure 3). Visual-evoked potentials were nearly extinguished bilaterally at 7 months of age. Optical coherence tomography at 9 years of age was limited to isolated line scans in the right eye but revealed distortion of the fovea and mild disruption of the outer retina. The nerve fiber layer was mildly thinned. A dilated fundus examination revealed bilateral pigmentary changes in the macula and bilateral optic pallor. The left eye had vitreous strands and a circumferential fold temporal to the TR cavity on the infrared imaging. Teller card acuity was subnormal at 20/130 in the right eye and 20/4,000 in the left eye. Tractography at 8 years of age showed reduced fractional anisotropy with progressive loss of optic radiations and ventriculomegaly in the right hemisphere.

Discussion

Optical coherence tomography imaging supports the hypothesis that shearing and/or tractional forces cause multilayered tractional retinoschisis associated with long-term disruption of the retinal microarchitecture and focal posterior vitreous separation. The OCT also highlights posterior vitreous separation associated with a thick detached internal limiting membrane. Prior autopsy studies in the acute phase show vitreous fibrils and Muller cell organelles attach to the inner portion of the internal limiting membrane.[10] It remains to be seen if the thick internal limiting membrane on long-term follow-up represents residuals of these findings in the acute phase. Our OCT data support the findings of hemorrhagic detachment of the internal limiting membrane and vitreoretinal traction underlying perimacular folds in AHT during the acute phase.[6,7,10]

Severity of brain injury leading to cortical visual impairment and traumatic optic neuropathy likely plays a significant role in the visual outcome in patients with AHT. Optical coherence tomography results from two of our cases helped to demonstrate the presence or absence of retinal damage, foveal damage, and optic nerve axon loss. In the other case, subnormal visual acuity and reduced visual-evoked

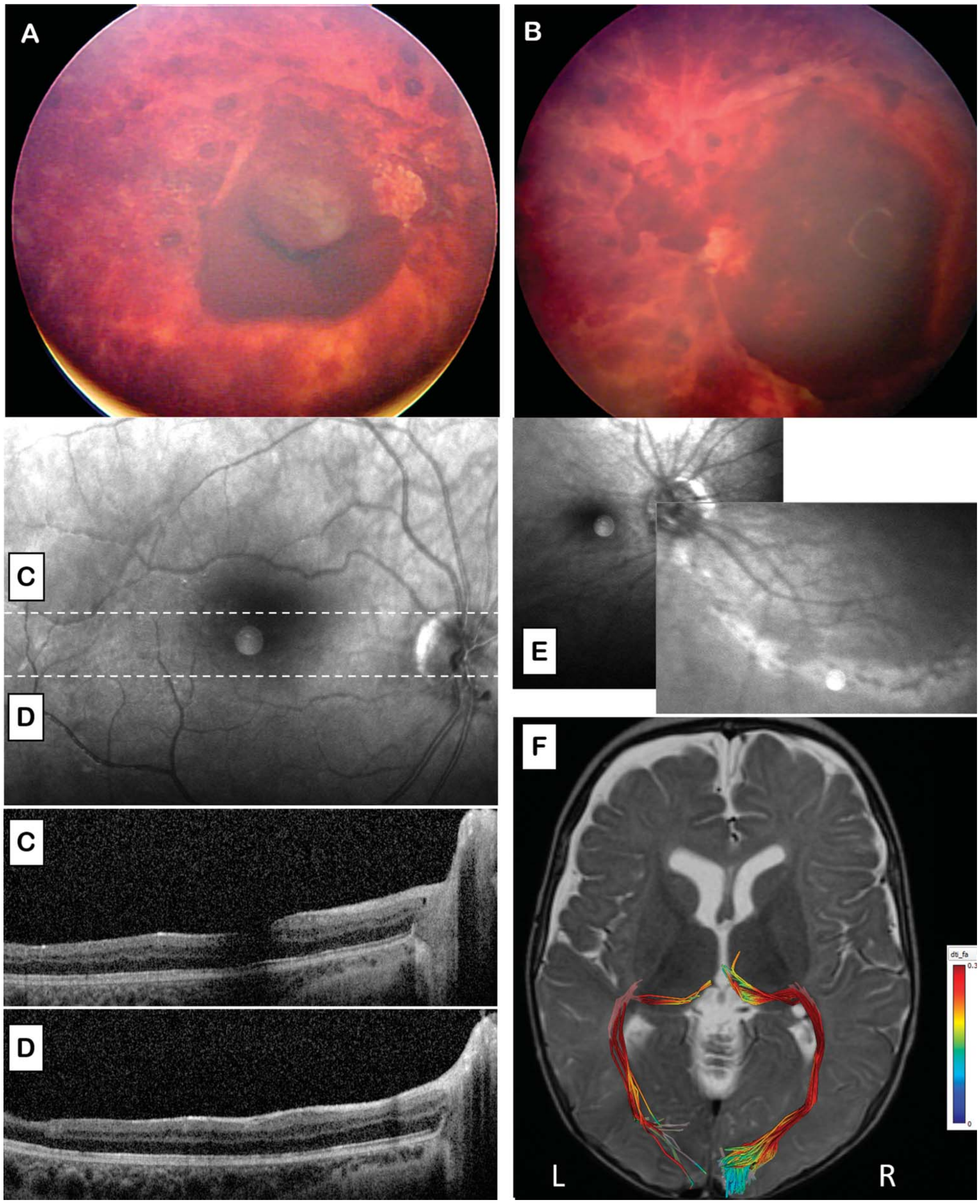

Fig. 3. Case 3, RetCam fundus images of the right (**A**) and left (**B**) eyes at presentation (133 days age). Optical coherence tomography at 9 years age was limited to isolated line scans in the right eye (confocal infrared image C and D, with respective locations). The left eye (**E**) showed a circumferential fold along the rim of the traumatic schisis cavity on the confocal scanning laser ophthalmoscope image. Tractography (**F**) of the optic radiations using diffusion tensor imaging superimposed on the axial T2-weighted image.

potentials occurred in the presence of posterior vitreous separation and mild anatomical changes in the retina. In this subject, diffusion tensor imaging indicated loss of axons in occipital cortex leading to cortical visual impairment. Our data are similar to prior case reports[6,8] showing significant vision loss in the presence of perimacular posterior vitreous separation and mild anatomical changes in the retina, also suggesting an element of cortical visual impairment. Furthermore, the OCT can show severe atrophy of the retinal in the macula that can be associated with severe vision loss.[6,8] A caveat of this study is a lack of ultrawidefield fluorescein angiography to better characterize the inner retinal ischemia seen on OCT.

Key words: abusive head trauma, nonaccidental trauma, optical coherence tomography, shaken baby syndrome, retinal hemorrhages, visual acuity.

References

1. Greenwald MJ, Weiss A, Oesterle CS, Friendly DS. Traumatic retinoschisis in battered babies. Ophthalmology 1986;93:618–625.
2. Feldman KW, Bethel R, Shugerman RP, et al. The cause of infant and toddler subdural hemorrhage: a prospective study. Pediatrics 2001;108:636–646.
3. Morad Y, Kim YM, Armstrong DC, et al. Correlation between retinal abnormalities and intracranial abnormalities in the shaken baby syndrome. Am J Ophthalmol 2002;134:354–359.

4. Bechtel K, Stoessel K, Leventhal JM, et al. Characteristics that distinguish accidental from abusive injury in hospitalized young children with head trauma. Pediatrics 2004;114:165–168.
5. Kelly JP, Feldman K, Wright J, et al. Retinal and visual function in infants with non-accidental trauma and retinal hemorrhages. Doc Ophthalmol 2020;141:111–126.
6. Scott AW, Farsiu S, Enyedi LB, et al. Imaging the infant retina with a hand-held spectral-domain optical coherence tomography device. Am J Ophthalmol 2009;147:364–373.
7. Muni RH, Kohly RP, Sohn EH, Lee TC. Hand-held spectral domain optical coherence tomography finding in shaken-baby syndrome. Retina 2010;30:S45–S50.
8. Nakayama Y, Yokoi T, Sachiko N, et al. Electroretinography combined with spectral domain optical coherence tomography to detect retinal damage in shaken baby syndrome. J AAPOS 2013;17:411–413.
9. Seider MI, Tran-Viet D,Toth CA. Macular pseudo-hole in shaken baby syndrome: underscoring the utility of optical coherence tomography under anesthesia. Retin Cases Brief Rep 2016;10:283–285.
10. Breazzano MP, Unkrich KH, Barker-Griffith AE. Clinicopathological findings in abusive head trauma: analysis of 110 infant autopsy eyes. Am J Ophthalmol 2014;158:1146–1154.