Cerebral/Cortical Visual Impairment

“Focus” on Vision Impairment and Blindness Conference

Gena Heidary, MD, PhD
Director, Pediatric Neuro-ophthalmology Service
Pediatric and Adult Strabismus
Boston Children’s Hospital
Harvard Medical School
What is the “visual brain”?

- Eyes capture visual information and transmit it to the striate cortex
- This information is processed
- The interpretation of this information informs
  - Our recognition of elements of the scene
  - How we move our eyes towards items of interest and attend to these items
  - Visually guided movements of our body
- The interpretation needs to be continuously updated and processed

Lueck and Dutton, Vision and the Brain, 2015.
Cerebral or cortical visual impairment

- Visual impairment that cannot be attributed to pathology within the eye or the anterior visual pathways

- Retro-geniculate pathway injury which may include
  - Optic radiations
  - Occipital cortex
  - Higher order visual association centers

- Ocular injury and cortical visual impairment may coexist

- The diagnosis is a clinical one and requires a multidisciplinary approach
Epidemiology of CVI

- Leading cause of significant visual impairment in children in developed countries
  - Study of 3070 US children attending schools for the blind

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>1999 No</th>
<th>1999 % of total</th>
<th>2012 No</th>
<th>2012 % of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cortical visual impairment</td>
<td>515</td>
<td>20</td>
<td>556</td>
<td>18</td>
</tr>
<tr>
<td>Optic nerve hypoplasia</td>
<td>166</td>
<td>7</td>
<td>445</td>
<td>15</td>
</tr>
<tr>
<td>ROP</td>
<td>320</td>
<td>13</td>
<td>442</td>
<td>14</td>
</tr>
<tr>
<td>Optic Atrophy</td>
<td>124</td>
<td>5</td>
<td>211</td>
<td>7</td>
</tr>
<tr>
<td>Albinism</td>
<td>140</td>
<td>5</td>
<td>126</td>
<td>4</td>
</tr>
<tr>
<td>Coloboma</td>
<td>26</td>
<td>1</td>
<td>86</td>
<td>3</td>
</tr>
</tbody>
</table>

- UK population based study of children with profound vision loss: 48% CVI

Kong et al., JAAPPOS 2012; Merabet et al, Seminars in Pediatric Neurology, 2017.
Common Etiologies of CVI

- Perinatal hypoxia/ischemia
  - Term infant there is injury to the cortical watershed areas: parieto-occipital infarction

- Periventricular leukomalacia (hypoxic/ischemic)
  - Premature infant there is injury to the subcortical visual pathways: this affects the optic radiations

- Head injury/ trauma
- Hydrocephalus
- Infection (e.g. encephalitis, meningitis)
- CNS malformations
- Metabolic disorders
- Neurodegenerative disorders
Co morbidities in the Setting of CVI

- Cognitive deficits/delay
- Seizures
- Motor deficits/cerebral palsy
- Sensory deficits (hearing)
Normal Grating Acuity

Visual Development is Impaired in CVI

- Study of vision in CVI
  - 19 term babies
    - Hypoxic-ischemic encephalopathy
    - Seizures
    - MRI-confirmed injury
  - Results
    - PL improved 1 octave on average
    - VEP improved 1 octave on average

Visual Development is Impaired in CVI

- VEP and PLT results are discrepant in CVI
  - Normally VEP acuity may measure better than PLT by ~1 octave
  - In most CVI patients, VEP acuity abnormally exceeded PLT

Visual Fields may be Affected in CVI

- Homonymous visual field loss
- Bilateral inferior visual field loss in the setting of PVL

Efferent Dysfunction is Common

- Strabismus (range 22%-73%)
  - 70 patients with CVI and strabismus
  - 16% had spontaneous resolution

<table>
<thead>
<tr>
<th>Outcome category</th>
<th>ET</th>
<th>E(T)</th>
<th>XT</th>
<th>X(T)</th>
<th>All ET</th>
<th>All XT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spontaneous resolution</td>
<td>2(18%)</td>
<td>1(9%)</td>
<td>6(55%)</td>
<td>2(18%)</td>
<td>3(27%)</td>
<td>8(73%)</td>
</tr>
<tr>
<td>Unoperated</td>
<td>6(22%)</td>
<td>2(7%)</td>
<td>15(56%)</td>
<td>4(15%)</td>
<td>8(30%)</td>
<td>19(70%)</td>
</tr>
<tr>
<td>Operated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final ≤10 PD</td>
<td>6(33%)</td>
<td>2(11%)</td>
<td>7(39%)</td>
<td>3(17%)</td>
<td>8(44%)</td>
<td>10(56%)</td>
</tr>
<tr>
<td>Final &gt;10 PD</td>
<td>6(43%)</td>
<td>0(0%)</td>
<td>6(43%)</td>
<td>2(14%)</td>
<td>6(43%)</td>
<td>8(57%)</td>
</tr>
<tr>
<td>All</td>
<td>20(29%)</td>
<td>5(7%)</td>
<td>34(48%)</td>
<td>11(16%)</td>
<td>25(36%)</td>
<td>45(64%)</td>
</tr>
</tbody>
</table>

*ET, constant esotropia; E(T), intermittent esotropia; XT, exotropia; X(T), intermittent exotropia.

- Nystagmus
- Gaze palsy
- Difficulty with saccades

Huo et al, BJO, 1999; Dutton and Jacobsen, 2001; Binder, Kruglyakova, Borchert, JAAPOS, 2016.
Two Stream Hypothesis of Visual Processing

Frontal lobe

Parietal lobe

Dorsal visual stream; this portion determines “Where is it?”

Occipital lobe

Ventral visual stream; this portion determines “What is it?”

Temporal lobe
Impact of CVI on Visual Processing

Dorsal Stream Dysfunction
- Difficulty with visual complexity
- Inability to sustain visual attention
- Difficulties with visual-motor planning

Ventral Stream Dysfunction
- Difficulty with recognition of objects or faces
- Difficulty with visual memory

https://voer.edu.vn/file/57853
Behavioral Characteristics

- Light gazing
- Gaze avoidance
- Use of peripheral vision to locate an object
- Increased latency of visual response
- Difficulty with visual complexity
- Difficulty with visual novelty
- Proclivity for a color to see
- Use of movement to see
- Difficulty with distance vision
- Variability of visual attention
  - Exacerbated by concurrent auditory or tactile stimuli
Elements of the CVI Assessment

- Ophthalmology visit
- Functional vision assessment
- Low vision assessment
- Involvement of a teacher for visual impairment
- Additional services
  - OT, PT, Orientation and Mobility
- Input from multidisciplinary team

- Tools for assessment of CVI
  - Christine Roman-Lantzy CVI Range
  - Gordon Dutton or Els Ortibus CVI inventories

The Anatomy of CVI

- What is the neuro-anatomic basis of CVI?
Case 1

16 year old girl with difficulty in school characterized by tracking issues, visual inattentiveness, and hardship with complex images particularly interpreting those on a grid.

<table>
<thead>
<tr>
<th>Birth History</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Born at 32 weeks gestation</td>
<td>• Developed grade III intraventricular hemorrhage and subsequent</td>
</tr>
<tr>
<td></td>
<td>• Diagnosed with periventricular leukomalacia</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ocular History</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Strabismus surgery at 11 months for esotropia</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Medical History</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Spastic diplegia</td>
<td></td>
</tr>
</tbody>
</table>
## Examination

<table>
<thead>
<tr>
<th></th>
<th>Right Eye</th>
<th>Left Eye</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visual acuity</strong></td>
<td>20/50</td>
<td>20/40</td>
</tr>
<tr>
<td><strong>Cycloplegic refraction</strong></td>
<td>Mild hyperopic astigmatism</td>
<td></td>
</tr>
<tr>
<td><strong>Pupils</strong></td>
<td>Normal with no relative afferent pupillary defect</td>
<td></td>
</tr>
<tr>
<td><strong>Contrast sensitivity</strong></td>
<td>Reduced</td>
<td>Reduced</td>
</tr>
<tr>
<td><strong>Anterior segment</strong></td>
<td>Normal</td>
<td>Normal</td>
</tr>
</tbody>
</table>
Fundus Photos and OCT
Case 2

22 year old man with significant cognitive delay. Visual difficulty characterized by visual inattentiveness and inability to identify objects in a crowded scene.

| Birth History         | • Born at 28 weeks gestation  
|                       | • Developed perinatal brain hemorrhage  
|                       | • Diagnosed with periventricular leukomalacia  
| Ocular History        | • Strabismus surgery before age 3 for esotropia  
| Medical History       | • Marked developmental delay  
|                       | • Cerebral palsy  

# Examination

<table>
<thead>
<tr>
<th></th>
<th>Right Eye</th>
<th>Left Eye</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visual acuity</strong></td>
<td>20/100</td>
<td>20/100</td>
</tr>
<tr>
<td><strong>Cycloplegic Rx</strong></td>
<td>+1.50+1.25 x 15 OD</td>
<td>+1.50+1.25 x 175 OS</td>
</tr>
<tr>
<td><strong>Pupils</strong></td>
<td>Normal with no relative afferent pupillary defect</td>
<td></td>
</tr>
<tr>
<td><strong>Contrast sensitivity</strong></td>
<td>Reduced</td>
<td>Reduced</td>
</tr>
<tr>
<td><strong>Anterior segment</strong></td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td><strong>Sensorimotor</strong></td>
<td>Full motility</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Manifest fine amplitude nystagmus</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Consecutive exotropia</td>
<td></td>
</tr>
<tr>
<td><strong>Posterior segment</strong></td>
<td>Optic atrophy bilaterally</td>
<td></td>
</tr>
</tbody>
</table>
Goldmann Visual Fields
Hypothesis: CVI is a disease of abnormal neuronal connectivity

- Pilot study to map major white matter connections between visual cortex and higher order visual association centers using HARDI (high-angular-resolution diffusion imaging)
  - Patients 14-21 years of age
  - Corinna Bauer, PhD and Lotfi Merabet, OD, PhD

Superior longitudinal fasciculus (SLF)
  - occipital-parietal: visual complexity, visual attention

Inferior fronto-occipital fasciculus (IFOF)
  - occipital-ventral frontal: visual attention, eye movement control

Inferior longitudinal fasciculus (ILF)
  - occipital-temporal: object vision, color, faces
Axial T1 weighted MRI Images

Control

Case 1
Preterm 32 weeks
PVL

Case 2
Preterm 28 weeks
PVL

Bauer, Heidary, Merabet, JAAPOS 2014.
Paucity of white matter connections in CVI patients

Bauer, Heidary, Merabet, JAAPOS 2014.
The Anatomy of CVI

- CVI may be secondary to abnormal connectivity amongst vision association centers

- May we use this understanding to develop an individualized approach towards habilitation or an improved educational plan for our CVI patients?
Ophthalmologist’s Role in CVI

- Maximize vision function
  - Prescribe glasses when relevant
  - Manage strabismus when relevant
  - Specifically evaluate visual fields to determine whether there is visual field loss

- Recognize CVI and initiate appropriate referrals
  - Low vision assessment
  - Functional vision assessment
  - Ensure patient has a teacher for visual impairment
  - Register with State Services

MA Commission for the Blind

using an ETDRS chart, they would not be classified as legally blind because they were able to read one letter on the 20/100 line. If acuity testing is problematic due to a vision condition such as cortical visual impairment, please answer the optional question below.

Standard acuity testing is impossible or unreliable and, in my medical opinion, the functional vision is at the level of legal blindness as defined above? Yes No
Summary

- CVI is the leading cause of childhood blindness in developed countries
- The condition is likely underreported
- There are visual and behavioral findings which characterize CVI
- A multidisciplinary approach towards evaluation and treatment is essential
- Recognition of CVI will facilitate our children receiving the appropriate services to maximize visual function