Posterior callosal section in a non-epileptic patient

ANTONIO R DAMASIO, HELENA C CHUI, JAMES CORBETT, AND NEAL KASSEL

From the Department of Neurology (Division of Behavioral Neurology and Benton Laboratory of Neuropsychology), and Department of Surgery (Division of Neurosurgery), University of Iowa College of Medicine, Iowa City

SUMMARY The major studies of the effects of callosal section in humans have been conducted in severe epileptic patients in whom commissurotomy has been performed for management of intractable seizures. In spite of the evidence which has been amassed it is possible to criticise the results, on the grounds that all patients had seizures for many years prior to surgery and hence it is conceivable that some adaptive reorganisation of the epileptic brain might account for the different behaviour of the two hemispheres. Specifically, since the primary epileptic focus and its possible underlying focal damage are often asymmetric, one hemisphere might have had to adapt to the functional deficit of the other and thereby produce the basis for the unusually striking hemispheric differences. The answer to these reservations must come from the study of non-epileptic subjects who undergo some form of commissurotomy for reasons other than treatment of seizures, particularly if the intervention involves the posterior third of the corpus callosum, the sector considered responsible for the more remarkable "disconnection" signs. Only seven such cases have been reported. Here we report findings in a non-epileptic and previously normal 16-year-old boy who underwent section of the splenium for exploration of a pineal tumour. Our results indicate that surgical section of the splenium produced visual disconnection signs comparable to those seen in epileptic patients with complete commissurotomy.

CASE REPORT
The patient is a 16-year-old white boy, right handed, a high school junior. He presented to University Hospitals complaining of progressive headaches over a period of three months. He described the headaches as throbbing and located in the occiput or vertex, but occasionally generalised. They were associated with neck stiffness and were aggravated by cervical flexion. During the month preceding admission, the patient noted blurred vision and diplopia, and in the two weeks prior to his first visit the headaches became more frequent, more severe, and were accompanied by nausea and vomiting. Burning eye pain and dizziness, especially in the morning upon arising, also appeared.

On admission the patient was afebrile and alert. The general examination was remarkable only for bilateral submandibular lymphadenopathy. There was resistance to neck flexion. Pupils reacted poorly to light but well to accommodation. There was a mild skew deviation and vertical nystagmus on up-gaze. The patient reported diplopia. The optic disc margins were indistinct nasally, venous pulsations were absent, and a haemorrhage was present in the right disc. Visual acuity (20/40 OU), visual fields assessed by confrontation, and the function of the remaining cranial nerves were intact. Muscle tone, strength, and stretch reflexes were normal. Plantar responses were flexor. Sensory and cerebellar examination were unremarkable. Sphinctor function was intact.

Complete blood count, SMA 6/60 and 12/60 were normal. Lumbar puncture was performed and the opening pressure was 300 mm H2O. The cerebrospinal fluid was clear and contained 65 lymphocytes, 3 histiocytes, and 3 red blood cells per mm3. Protein was significantly elevated at 1-23 g/l. Glucose 3-27 mmol/l (59 mg%) and chloride (127 mg%) were normal, as was the cell count.

An amorphous calcification in the midline, 1 cm in diameter, was seen on skull radiographs. On computerised tomography, this proved to lie...
within a 4 by 4 cm mass in the region of the pineal gland, a mass that enhanced with contrast. In addition, there was moderate dilatation of the lateral and third ventricles (fig). Distortion of the middle and posterior portion of the internal cerebral vein was shown by arteriography.

Dexamethasone was immediately started and a right lateral ventricular shunt was placed. The headaches subsided. The following week, a right parieto-occipital craniotomy was performed. The right parietal lobe was retracted laterally, and the posterior portion of the splenium of the corpus callosum was sectioned longitudinally. The entire incision was approximately 1.5 cm in length. A light grey, gelatinous tumor was exposed, lying immediately below the splenium, spreading to the internal cerebral veins bilaterally, and extending into the third ventricle. A biopsy was obtained.

Histopathology showed cords and nests of moderately atypical large cells with vesicular nuclei and abundant amphophilic cytoplasm. Lymphocytes were distributed amongst narrow collagenous trabeculae. The suggested diagnosis was atypical teratoma (seminoma).

The postoperative course was unremarkable, except for a left parotitis which was treated with penicillin, and radiation therapy to a total dosage of 5500 rads to the primary tumor site and 3500 rads to the entire spinal axis was administered. The patient resumed normal school activities.

**Behavioural study**

1. **General Evaluation** The patient was studied in six different sessions, which took place at 14, 15, 16, 28, 35 and 70 days after operation. His return to full school activities precluded the continuation of testing sessions. He was oriented and cooperative at all times. He appeared appropriately concerned with his condition and with his future although not depressed. Except for some mild fatigue and a reduction in speed in reading ability, he had no complaint and thought nothing had changed in him, physically or mentally. Speech was well articulated, fluent, prosodic and without paraphasic errors. Verbal intelligence assessed by the Wechsler Adult Intelligence Scale was average (IQ=100).

   Naming of objects in the tactile modality (using the tactile naming test of the Neurosensory Center Comprehensive Examination of Aphasia) placed in either the right or left hand with the subject blindfolded was normal, suggesting that interhemispheric transfer of tactile information was intact.

   Pure tone audiometry was unremarkable. A relative extinction of the left ear in a verbal dichotic listening task was present at two weeks after surgery but no extinction could be demonstrated two months later. Praxic ability was normal.

2. **Study of Visual Function** Following surgery the patient's sole visual complaint was a subjective slowing in reading ability. Nevertheless he was able to read at a college graduate level as assessed by the Wide Range Achievement Test. Later he reported improvement of this defect.

   **Global visuoperceptive ability** was assessed by the tests of Facial Recognition and Judgment of Line Orientation. The patient scored in the normal range in both.

   **Neuro-ophthalmological evaluation** was carried out on two occasions. Specific testing included kinetic Goldmann perimetry using I24 and I10 isopters, which was normal, Farnsworth-Munsell 100 hue test, which revealed a mild deuteranomaly (as present in 7% of men), and testing for Pulfrich stereo-phenomenon which was also normal. Visual acuity was 10/15 in both eyes. Since intactness of the visual field would be a major factor in the performance of tachistoscopic tasks, and in spite of the normal fields reported on confrontation and on Goldmann perimetry, it
was decided to use static perimetry as well. This proved to be entirely normal, in the 0–180° axis.
In summary, except for a mild deuteranomaly (defect to green) no evidence of visual dysfunction could be detected with neuro-ophthalmologic examination
techniques.

Study of interhemispheric transfer of visual information was carried out in a Three Channel
Tachistoscope Model GB of the Scientific Prototype Manufacturing Company. This equipment
allows effective addressing of visual stimuli to either the left or right visual field, by limiting
the duration of stimulus exposure, and circumventing the problem of quick saccadic
refixation. The patient was adapted to darkness for several minutes. Visual fixation was directed
at a black point centrally located in one of the
channels. Stimuli were presented to either the left or right visual fields, or in both fields simultaneously. The field chosen for stimulus presentation
was altered in a random sequence. Identical
stimuli were exposed in each field randomly
during the course of a testing session. Stimulus
duration was 100 ms or less. The sizes and
peripheral loci of the stimuli varied. In general
they subtended 0-5-1.5 degrees vertically and
were situated 1–2.5 degrees lateral to fixation.
All responses to test stimuli were verbal. For
certain tasks the latency of response was measured from the onset of stimulus exposure
until the time the patient initiated a response.
Specific tasks included reading of verbal stimuli,
naming of simple and complex pictures of
objects or scenes, judgment of line orientation,
and judgment of emotional facial expressions.

Reading of single letters disclosed a minimal
and nonsignificant superiority of the right visual
field over the left field (98% versus 85%,
percentage of correct responses). Reading of
digit singles showed even less difference, near
perfect scores being obtained bilaterally.

In striking contrast there was a significant
superiority of the right visual field in the reading
of three letter words. The latter were of the
consonant-vowel-consonant form. This task was
administered on six occasions spanning a period
of two months. The average number of correct
responses to words seen in left visual field was
0.36 (standard deviation = 0.10). This contrasted
with an average of 0.99 (standard deviation
= 0.08) for stimuli presented to the right field.
The difference was statistically significant
(p < 0.01) (table).

A similar difference was reflected in the
latencies of response. Mean response times for
the left and right visual fields were, respectively,
3.5 sec (standard deviation = 1.2) and 1.2 sec
(standard deviation = 0.20). This difference also
was significant (p < 0.001) (table). Considering
the latencies of the correct responses only, thus
eliminating the possibility that delays might be
more prolonged for incorrect responses, the
differences remained constant and significant
(p < 0.001).

Object naming was evaluated using both simple
visual stimuli (simplified line drawings) and com-
plex visual stimuli (magazine coloured photos-
graphs). A superiority of the right visual field
was evident for both. In the first condition, 66%
of 36 figures were correctly named in the left
visual field versus 88% on the right side. In the
condition of complex stimuli, the number of test
samples (10) was too small for differences to be
treated statistically. However, qualitative analysis
of the performances showed remarkable differ-
ences. Whereas only a single stimulus (10%) was
interpreted correctly when presented on the left
visual field, six (60%) were described correctly
when appearing on the right. Also a stimulus
first presented in the right visual field and ap-
propriately interpreted, always would next
produce no response when given to the left.

<table>
<thead>
<tr>
<th>Task</th>
<th>Left visual field</th>
<th>Right visual field</th>
<th>Significance of difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raw score</td>
<td>Per cent correct</td>
<td>SD</td>
</tr>
<tr>
<td>Reading of digits</td>
<td>33/30</td>
<td>0.92</td>
<td>—</td>
</tr>
<tr>
<td>Reading of letters</td>
<td>46/54</td>
<td>0.85</td>
<td>—</td>
</tr>
<tr>
<td>Reading of words</td>
<td>40/108</td>
<td>0.36</td>
<td>(0.01)</td>
</tr>
<tr>
<td>Average response delay</td>
<td>24/36</td>
<td>3.52 s</td>
<td>(1.20)</td>
</tr>
<tr>
<td>Naming of simple drawings of objects</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naming of magazine photographs</td>
<td>1/10</td>
<td>0.10</td>
<td>—</td>
</tr>
<tr>
<td>Judgment of line orientation</td>
<td>24/35</td>
<td>0.69</td>
<td>—</td>
</tr>
<tr>
<td>Average response delay</td>
<td>9/10</td>
<td>0.9</td>
<td>—</td>
</tr>
<tr>
<td>Identification of “emotional” faces</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NS—non-significant; SD—standard deviation.
In the task of judgment of line orientation the subject was presented with one of eleven lines positioned on a display at 18° angles from one another. After a one second interval, a key displaying all eleven lines numbered consecutively, was flashed and the patient asked to select the line previously seen by calling out its number. The proportion of correct responses was identical for lines seen in the left visual space and for those seen in the right visual space. On the other hand, the mean latency of response was greater for the stimuli projected in the left field (5.7) as compared to 3.0 for those in the right field, a difference significant for p<.001.

Judgment of emotional facial expression: Polaroid photographs of persons simulating the facial expressions usually associated with joy, sadness, anger, fear, and pain were exposed for 100 ms in either visual field. Credit was given for responses that were in general concordance with either a “negative” or “positive” emotion. Although the number of stimuli (10) was insufficient for quantitative analysis, qualitative appreciation of performance suggested that reporting was better for faces seen in the left visual field. Cross errors occurred on presentations to the right visual field only (for example in three instances a “happy” face was interpreted as “sad” or vice-versa).

Discussion

The surgeon’s estimate of splenial section was approximate, given the restricted view of the area, but it appears likely that the whole splenial bulb was sectioned in order to reach the pineal mass. Even though the shape of the splenium varies considerably from subject to subject, it appears likely that a midline 1-5 cm longitudinal section would have destroyed all or most of the interhemispheric visual fibres. Indeed, it is even possible that some auditory fibres which cross in a position immediately anterior to the visual ones (as suggested by the studies of Pandya et al.) might also have been destroyed. For this reason a dichotic listening test was administered in order to find out whether or not the patient had a “paradoxical” left ear extinction known to be associated with callosal disconnection. Shortly after the operation the patient did show an inferiority of the left channel which possibly indicated dysfunction in interhemispheric auditory pathways, but when the test was repeated the pattern of dichotic listening was normal suggesting that the abnormality had been transient. We conclude that auditory fibres were disturbed but not destroyed, in the postoperative period, and recovered later on.

The interhemispheric somatosensory fibres, which cross more anteriorly in the callosum, should have been intact, so that no disturbance of praxis or naming in the left hand should have been present. In fact, that was the case and the patient exhibited normal tactile naming in either hand immediately after the operation. The restriction of behavioural defects to the visual realm is consistent with the assumption that visual fibres but not auditory or somatosensory ones, were destroyed by the operation.

The subject’s performance in visual tasks was comparable to that described in epileptic patients after a complete callosotomy. The striking sign of disconnection appeared in the tasks of object naming. Even after the subject had seen a given visual stimulus with his left hemisphere and had named it appropriately, he was unable to produce any verbal response when the stimulus was presented to the right hemisphere. The phenomenon indicated a lack of “cross-talk” between the hemispheres, and its magnitude cannot be explained by mere asymmetry of brain function. The generally lower quantity and quality of verbal responses given to stimuli directed at the right hemisphere, can be explained by the inability to transfer most visual information arriving in the right hemisphere to the verbally competent left half of the brain, combined with the right hemisphere’s limited verbal competence. Given the short duration of the disease these behavioural asymmetries cannot be explained by a special form of adaptive cerebral development as could be invoked in patients with seizures.

This boy’s performance also was similar to that in the comparable case reported by Gazzaniga and Freedman: in both, naming of objects seen in the right hemisphere was impaired. In this aspect, the cases appear different from that of Maspes and from some cases of pure alexia. But the discrepancy may be an artefact. On the one hand the techniques used in Maspes’ study were not comparable to the ones currently used and, on the other, although naming of three dimensional objects can be preserved in pure alexia, naming of the corresponding 2 dimensional pictures tends to be impaired. Our findings also were similar to those reported by Iwata and collaborators.

What is the interpretation of the impoverished but by no means nonexistent ability of the right hemisphere either to fully process, or at least originate, some verbal responses? The fact that
Posterior callosal section in a non-epileptic patient

verbal responses appeared at all suggests that either the right hemisphere was capable of some language comprehension and expression, or that the right hemisphere was capable of some linguistic processing but relied on residual transfer to the left, for the purpose of linguistic expression.

That the right hemisphere is capable of some linguistic processing which stops short of propositional expression has been demonstrated in split-brain patients and in a case of left hemispherectomy. In our case the verbal expression shown to stimuli directed at the right hemisphere was always required, limited the assessment of right hemisphere performance and it is possible that a more pronounced superiority might have been seen if different testing conditions had been possible. In addition, there had been a possibility of giving an appropriate number of presentations in the test of emotional facial recognition, we suspect an absolute superiority of the right hemisphere would have appeared.

References

7 Sreen O, Benton AL. Neurosensory Center Examination for Aphasia (NCCEA), Victoria, British Columbia: University of Victoria, 1969.
12 Milner B, Taylor L, Sperry RW. Laterised


