Visuospatial deficits in children 3 - 7 years old with shunted hydrocephalus

Serena V Frank, Theophilus Lazarus, Narendra Nathoo

Objective. To define non-verbal intelligence deficits in children 3 - 7 years of age following shunted hydrocephalus (HCP).

Design. Prospective randomised single-blinded study. Thirty shunted HCP (study) and 30 cardiac (control) patients between the ages of 3 and 7 years were compared on eight non-verbal subtests of the Junior South African Individual Scales (JSAIS).

Setting. Department of Neurosurgery at Wentworth Hospital, Durban, South Africa.

Results. Significant differences between the HCP and cardiac groups were recorded on all eight subtests of the JSAIS. The HCP group experienced problems with spatial orientation, perceptual planning and organisation, emotive deficits, abstract thinking and visual concepts.

Conclusion. All patients with shunted HCP had specific deficiencies in defined cognitive areas of non-verbal intelligence when compared with the controls. Further studies are warranted to determine the effects of ventriculoperitoneal shunting on non-verbal intelligence so that the special educational needs of HCP children may be met.


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The Form Board Test measures the cognitive processes of perceiving forms, together with the recognition of shapes and colour. It assesses visual-motor co-ordination, visual-motor speed and perception of spatial relations. The analysis in this study was based on groups and not individuals.

The Block Design Test measures convergent production or reasoning through the use of figural material (hence visual-spatial reasoning). It evaluates the ability to reproduce a visually presented design correctly. The specific skills involved include hand-eye co-ordination, perceptual ability and visual-motor organisation.

The Copying Test measures the ability to reproduce a visually presented design correctly. The specific skills involved include hand-eye co-ordination, perceptual ability and visual-motor organisational ability.

The Absurdities A Test measures the ability to notice absurdities in visual material. It is intended to measure the evaluation of figural systems and figural implications, in contrast to the evaluation of figural information as in Absurdities A.

The Absurdities B Test measures the ability to reproduce a visually presented design correctly. The specific skills involved include hand-eye co-ordination, perceptual ability and visual-motor organisational ability.

The Form Discrimination Test measures the ability to distinguish differences and similarities between complex units of figural information. Form discrimination is a complex task requiring visual reasoning ability together with perception of form, spatial orientation, perceptual constancy and perceptual organisation.

The Gestalt Test measures the ability to perceive apparently disorganised or unrelated parts as a meaningful whole within a time limit. Essential elements of the test performance include visual alertness, visual memory and artistic aptitude.

The Picture Puzzle Test measures visual concept formation. It is presumed that form perception, spatial orientation and visual-perceptual co-ordination are essential elements of test performance.

The Copying Test measures the ability to reproduce a visually presented design correctly. The specific skills involved include hand-eye co-ordination, perceptual ability and visual-motor organisational ability.

**Statistical analysis**

T-test statistical analysis was performed between the means in the study and control groups, on the 8 non-verbal subtests of the JSAIS. Differences were considered significant at \( p < 0.05 \). Comparison with norms was not performed in this study as norms reflected in the JSAIS manual involved the conversion of raw scores into age groups. The analysis in this study was based on groups and not individuals.

**Results**

Twenty-one of 30 patients (70%) had congenital HCP: 4 patients had aqueduct stenosis; 9 had communicating HCP; 5 had Dandy-Walker malformation (DWM); 1 had Chiari malformation, and 2 had arachnoid cysts. The remaining 9 patients had acquired HCP: tuberculous HCP (4), post-traumatic HCP (2), and post-meningitic HCP (3).

All patients with tuberculous meningitis and HCP were classified as grade 1 (patient with a normal sensorium and no neurological deficit). No evidence of vascular insults was detected on neuroimaging.

The following motor deficits were recorded on study entry. In the congenital group, 5 children could not walk (aqueductal stenosis 3, DWM 1, congenital communicating HCP 1), while 3 children could not stand (aqueductal stenosis 1, DWM 1, and congenital HCP 1). A single patient with acquired HCP following a focal traumatic brain injury had a right-sided monoparesis. However, owing to small numbers of patients in each subgroup, no meaningful analysis of aetiology was performed.

Statistical significance was found between the mean scores for the study and control groups for all 8 subtests of the JSAIS. T-test analysis showed significant differences on the Form Board Test, Block Design Test, Absurdities A Test, Absurdities B Test, Gestalt Test and Copying Test. T-test analysis showed significant differences for the Form Discrimination Test and Picture Puzzles Test. The standard deviations for most of the subtests were found to be very high, indicating a high variability in scores.

Similar mean scores for the 2 HCP groups across the 8 subtests of the JSAIS were recorded. It was not possible to determine whether there was any significance between these mean scores as there was a large variance in the number of subjects in the groups. Similar mean scores were obtained on 4 subtests of the JSAIS for shunt insertion on the left and right side of the brain. However, there were too few subjects (10%).

**Table I. Summary of demographic and medical information for the study and control groups**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Study group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age in months</td>
<td>57.6</td>
<td>62.4</td>
</tr>
<tr>
<td>Sex distribution (M : F)</td>
<td>16 : 14</td>
<td>13 : 17</td>
</tr>
<tr>
<td>Family income (N)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; R100</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>R100 - 1000</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>&gt; R1000</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Patients receiving medication (N)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patients not receiving medication (N)</td>
<td>22</td>
<td>12</td>
</tr>
</tbody>
</table>

with shunts inserted on the left side to ascertain any conclusive findings. Table I illustrates the demographic distribution, family income level and medication record of the study and control cohorts. Chi-squared analysis did not reveal a significant relationship between the two groups, except for current medication ($\chi^2 = 6.787$, df =1, $p < 0.05$). Table II illustrates that the study group’s performance on each of the 8 subtests of the JSAIS was considerably worse than that of the cardiac group ($p < 0.001$).

**Discussion**

The neuropsychological sequelae of HCP and the possible benefits of shunt insertion for later cognitive and emotional development of the child have been inadequately studied. The present study reports on the neuropsychological test performances of children between 3 and 7 years of age who were shunted for HCP in the first 6 months of life.

The presence of different types of HCP with varying levels of CSF obstruction may have influenced the poorer performance of the HCP group. However, Riva et al. reported on patients with different types of HCP, including subjects with aqueductal stenosis shunted early, aqueductal stenosis shunted late, HCP secondary to major supratentorial malformations, and Chiari malformations. Correlative analysis revealed that variables such as post-surgical haematomas or hygromas and the number of shunt revisions did not correlate with impaired IQ scores, nor did ‘site of obstruction’ of the HCP which would ultimately determine the type of HCP. These authors also noted that only lesions located in the hemispheres changed neuropsychological functions, while malformations in the posterior fossa did not interfere with visual-perceptual intelligence.

Dennis et al. also studied HCP children with different aetiologies and found no significant difference between the different types of HCP on any IQ measurement. The latter study included HCP secondary to Chiari malformations, encephalocele, aqueduct stenosis, DWM, intraventricular haemorrhage, haematoma, infections, subdural hygroma and arachnoid cysts. They concluded that the type of HCP does not affect the level or the pattern of intelligence. However, IQ scores may be misleading and cognitive tests need to be analysed independently. The broad spectrum of HCP subjects studied in the literature makes it difficult to draw conclusive findings on diagnosis and non-verbal measures.

Non-verbal intelligence as measured by the JSAIS comprises various cognitive components including visuo-perception, visual-construction, form discrimination, visual memory, visual object and shape recognition, visual motor-organisational ability and visual closure. The lower mean scores of the HCP group compared with the cardiac group on all 8 subtests of the JSAIS suggest specific deficiencies in defined cognitive areas of non-verbal intelligence in this group.

The right hemisphere is reported to be superior to the left in fitting designs into larger matrices, in sorting shapes into categories, in perceiving wholes from a collection of parts and in the intuitive perception of geometric principles. Perceptual organisational difficulties in the HCP group may have contributed to their lower mean scores on the Block Design Test. Block Design scores tend to be lower with other forms of brain insult too. Furthermore, Block Design deficits associated with lateralised lesions are usually most common and most pronounced when the lesions involve the posterior, particularly parietal areas on the right side. It is therefore possible that the hydrocephalic group’s poorer performance on the Form Board Test may be due to a possible lesion in the right cerebral hemisphere, consistent with the side of shunt.

Table II. Summary of results for the study (HCP, $N = 30$) and control (cardiac, $N = 30$) groups on the eight subtests of the JSAIS

<table>
<thead>
<tr>
<th>Sub-tests of the JSAIS</th>
<th>Mean study score</th>
<th>SD</th>
<th>Mean control score</th>
<th>SD</th>
<th>T-test</th>
<th>$p$-Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Form Board</td>
<td>3.866</td>
<td>3.674</td>
<td>8.500</td>
<td>4.141</td>
<td>-4.584</td>
<td>0.001</td>
</tr>
<tr>
<td>Block Design</td>
<td>8.566</td>
<td>8.435</td>
<td>19.566</td>
<td>12.378</td>
<td>-4.022</td>
<td>0.001</td>
</tr>
<tr>
<td>Absurdities A</td>
<td>3.833</td>
<td>4.518</td>
<td>7.933</td>
<td>4.645</td>
<td>-3.465</td>
<td>0.001</td>
</tr>
<tr>
<td>Absurdities B</td>
<td>.366</td>
<td>.889</td>
<td>3.566</td>
<td>2.750</td>
<td>-6.063</td>
<td>0.001</td>
</tr>
<tr>
<td>Picture Puzzles</td>
<td>2.566</td>
<td>2.885</td>
<td>5.033</td>
<td>3.056</td>
<td>-3.214</td>
<td>0.002</td>
</tr>
<tr>
<td>Gestalt</td>
<td>1.566</td>
<td>1.381</td>
<td>5.333</td>
<td>5.491</td>
<td>-3.643</td>
<td>0.001</td>
</tr>
<tr>
<td>Copying</td>
<td>1.100</td>
<td>1.748</td>
<td>5.533</td>
<td>6.317</td>
<td>-3.704</td>
<td>0.001</td>
</tr>
<tr>
<td>Form Discrimination</td>
<td>4.833</td>
<td>4.800</td>
<td>8.866</td>
<td>6.781</td>
<td>-2.659</td>
<td>0.01</td>
</tr>
</tbody>
</table>

* $t$-test
insertion in 24 of 30 patients (80%). However, the mean scores of patients with shunt insertion to the left and right hemispheres are not possible due to inadequate sample sizes.

However, Lezak et al. reported that constructional disorders reflected the involvement of both hemispheres in processing spatial information. Left-sided lesions are apt to disrupt the programming or ordering of movements necessary for constructional activity, while diagonality in design or construction reflects right hemisphere lesions. Visuo-spatial defects are therefore described as being associated with impaired understanding of spatial relationships or defective spatial imagery. In the present study, the HCP group were able to use their hands to rotate and manipulate the blocks, but were not able to organize the blocks according to the pattern within the given timeframe. Extending the time limits of testing may yield more conclusive data.

To perform the task of identifying missing details in pictures, subjects have to rely on long-term (semantic) memory, together with the use of visual organisation and reasoning abilities. The prefrontal lobes play a critical role in long-term memory, especially when learning materials are complex and require semantic processing during the encoding stage. It is further speculated that HCP has damaging sequelae on the development of the prefrontal lobes that are particularly concerned with executive functions, mental flexibility and conceptual planning abilities.

Difficulties in identifying what is humorous (as in the Absurdities B Test) could be related to socioemotive deficits, specifically in HCP children. In support of this assumption, Hilgard et al. specifically in HCP children. In support of this assumption, Absurdities B Test) could be related to socioemotive deficits, the present study, the HCP group could manoeuvre their pencils, but had great ability and the perception of detail. In the present study, the HCP group could manoeuvre their pencils, but had great difficulty in integrating or organising parts of the pattern into a whole. Difficulty in drawing the patterns correctly suggests deficits in visual and motor integration and the processing of information perceived. This discrepancy in non-verbal processing in HCP children may therefore be attributed to an impaired understanding of spatial relationships rather than constructional difficulties. The poor performance scores of HCP children in the present study on the Form Discrimination Test may be due to both the complexity of the task and to an information-processing deficit. It is possible that HCP patients experienced difficulty integrating and processing complex information as they were unable to respond correctly to drawings that were displaced, rotated or distorted. There is further need to study these specific perceptual difficulties.

**Conclusion**

The present study attempted to define the visuospatial deficits in children aged 3 - 7 years with shunted HCP, by exploring specific measures of non-verbal skills. The insertion of the shunt catheter in the right parieto-occipital region may have influenced the visuospatial deficits present in the study group. We recommend that future studies should take into account the side and site of shunt insertion.

We would like to thank the nursing staff of the departments of Neurosurgery and Cardiology, Wentworth Hospital, Durban, for assistance with this study. This study was supported by a grant from the National Research Foundation, South Africa.

**References**


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