INTRA-OPERATIVE AWAKENING TO MONITOR SPINAL CORD FUNCTION DURING SCOLIOSIS SURGERY

DESCRIPTION OF THE TECHNIQUE AND REPORT OF FOUR CASES

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We used a modification of the wake-up test to monitor spinal cord function in 102 consecutive scoliotic patients undergoing Harrington instrumentation. Four patients were found to have a neural deficit when they were woken up during the operation. Three recovered immediately after partial release of the distracting force; one required immediate removal of the rod and was left with a slight neural deficit.

Using our method, we have encountered no problem in performing the wake-up test, although attention is drawn to the difficulty in repeating the test if the patient is re-anaesthetised with diazepam. There were no false negative results in this series.

Damage to the spinal cord is a recognised complication of corrective surgery for scoliosis. It may be produced by occlusion or spasm of the artery of Adamkiewicz (Keim 1970), or by excessive stretching of the spinal cord when the Harrington rods are extended. Recovery may occur if the distracting force is removed without delay.

There are, at present, two main methods for detecting damage to the spinal cord during scoliosis surgery: spinal cord monitoring, as described by Engler et al. (1978) and by Jones et al. (1983); and the wake-up test, as described by Vauzelle, Stagnara and Jouvinroux (1973) and by Hall, Levine and Sudhir (1978). The wake-up test must be performed by a skilled anaesthetist, but it does not require the use of any special apparatus.

PATIENTS AND METHOD

We studied 102 consecutive patients who had corrective surgery for scoliosis at the Royal Liverpool Children’s Hospital between June 1976 and November 1982. There were 33 males and 69 females. At operation 14 patients were aged between 5 and 9 years, 74 between 10 and 15 years, 12 between 16 and 20 years, and 2 were over 20. The cause of the scoliosis is shown in Table 1.

Table 1. Cause of the scoliosis

<table>
<thead>
<tr>
<th>Cause</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idiopathic</td>
<td>25</td>
</tr>
<tr>
<td>Infantile</td>
<td>8</td>
</tr>
<tr>
<td>Juvenile</td>
<td>46</td>
</tr>
<tr>
<td>Adolescent</td>
<td>14</td>
</tr>
<tr>
<td>Congenital</td>
<td>6</td>
</tr>
<tr>
<td>Neurofibromatosis</td>
<td>1</td>
</tr>
<tr>
<td>Marfan’s syndrome</td>
<td>1</td>
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<tr>
<td>Neurogenic</td>
<td>1</td>
</tr>
<tr>
<td>Cerebral palsy</td>
<td>1</td>
</tr>
<tr>
<td>Dystrophia myotonica</td>
<td>1</td>
</tr>
</tbody>
</table>

All the patients except one had preliminary halofemoral traction before Harrington rod instrumentation and posterior spinal fusion; the one exception was a six-year-old girl with infantile idiopathic scoliosis who was treated by Harrington instrumentation alone.

All 102 patients were anaesthetised using a technique which enabled intra-operative awakening to be carried out safely (Abbott and Bentley 1980).

During the pre-operative assessment the patients were told that after the operation they would be asked to move their hands and feet at frequent intervals to make sure that they were recovering properly. If, however, they
learnt that they would be "awakened" during the operation, they were reassured that they would feel no pain and that they would quickly go to sleep again.

Premarked consisted of tramperazine tartrate (0.5 mg/kg) given orally four hours before operation, and morphine (0.2 mg/kg) and atropine (0.01 mg/kg) given intramuscularly one hour before operation. Anaesthesia was induced with thiopentone (5 mg/kg) followed by tubocurarine (1.0 mg/kg); tracheal intubation and controlled ventilation with nitrous oxide and oxygen (in a ratio of 2:1) were used to achieve a PaCO₂ of 30 to 40 mmHg. Morphine (0.1 mg/kg) was given after induction of anaesthesia. Because of the relatively high initial dose of muscle relaxant, incremental doses were not usually required, since profound muscle relaxation is not necessary for this type of operation. During the wake-up test the patients were only partially paralysed and were able to make limited but effective movements of the hands and feet, but did not have the power to extube themselves or to dislodge the rod.

The sequence of anaesthesia described usually ensured a sufficient degree of co-operation without the need to give specific relaxant and narcotic antagonists. Volatile agents were not used since they would have prolonged recovery during the test. Awakening was accomplished by withdrawing nitrous oxide and ventilating the patients manually with oxygen and 5% carbon dioxide. Carbon dioxide was only used to alert the brain and 100% oxygen was used when the patients were awake.

Ventilation was controlled throughout the wake-up test since spontaneous ventilation, if deep, could have led to asphyxiation or open venous sinuses. In addition, the wound was sealed with wet packs and firm but gentle pressure was applied to the spine until the test had been completed and the patients re-anaesthetised.

The patients were addressed by their first names, and were asked to move their hands and fingers; only after a positive response were they asked to move both feet. They usually responded to spoken requests within about five minutes. Throughout the test they were continuously reassured, and the operation was recommenced only when they no longer moved their hands on request.

In the cases in which there was satisfactory movement of the fingers but not of the feet, the nitrous oxide was turned on again and after about five minutes the packs were removed from the wound, the rod was released, and the wake-up test was repeated. If nitrous oxide was insufficient to control muscular activity at this stage, halothane 0.5% was added; after the nitrous oxide and halothane had been turned off, the wake-up test was repeated. When the wake-up test showed no neurological damage the patients were more rapidly re-anaesthetised by giving diazepam (0.15 mg/kg) intravenously, together with nitrous oxide.

The use of muscle relaxants, thiopentone, or diaze-
radiograph taken immediately after the operation showed correction of the curve to 36°. She did not develop any neurological problems after operation. She did, however, develop a bilateral femoral vein thrombosis which was treated with heparin and then warfarin. She made a satisfactory recovery and has been left with no long-term disability.

Case 2. This 12-year-old girl with adolescent idiopathic scoliosis had been born with a ventricular septal defect and patent ductus arteriosus (which had been ligated when she was three years old). She had a right thoracic scoliosis that had first been noticed at the age of 10 years. The pre-operative curve measured 60° with the apex at T8. Halofemoral traction was applied, but whilst on traction she developed a mild "cast syndrome" which required nasogastric suction and intravenous fluids. The traction was reduced and a check radiograph showed that the curve had corrected to 38°. She was a Jehovah's Witness and her parents refused to allow blood transfusion. Because of this no bone grafts were taken from the iliac crest. In addition to excision of all the facet joints between T3 and L3, the spinous processes were excised and these were used as bone grafts. Hooks were inserted under the laminae of T3 and L3 and the rods distracted from 21 cm to 22.5 cm. When the patient was woken up it was found that she could not move her left foot. She was re-anaesthetised and the distraction force on the rod released by one notch. The wake-up test was then repeated and she could move both feet fully. The total blood loss was 275 ml. There were no long-term neurological problems.

Case 3. This nine-year-old boy with neurofibromatosis had a left-sided thoracic curve that had first been noticed when he was eight years old. His pre-operative curve measured 50°; a myelogram showed no evidence of intraspinal abnormality. The curve corrected to 34° on halofemoral traction. At operation hooks were placed on T3 and L2 and a Moe type of fusion performed. On being woken he was unable to move his right foot. He was re-anaesthetised and the rod released by one notch. He was then woken again, and this time he could move both feet fully. The curve measured 36° after operation. He made an uneventful recovery and has no evidence of any neurological impairment.

Case 4. This 10-year-old girl had congenital scoliosis which had been noticed since she was one year old. She had a left thoracic curve which measured 72° before operation. She had a hairy patch in the lumbar region. A radiograph showed her to have spina bifida, and a myelogram showed a wide spinal canal but no evidence of intradural abnormality. In the past she had been operated on for severe congenital talipes equinovarus of the right foot, but apart from an inequality in calf size due to this deformity, she had no abnormal neurological signs in the lower limbs.

On halofemoral traction her curve corrected to 66°. At operation she was found to have a small spina bifida at L2–L3. Hooks were placed on T2 and L5, and a Moe type of fusion performed. When woken up, she was unable to move her left leg. She was re-anaesthetised and the rod slackened by two notches, but when the test was repeated she still had poor movement in the left leg. It was thought that this was partly due to incomplete reversal and, as there was little tension on the rod, the wound was closed. In the recovery room she was again found to be unable to move her left foot, so she was immediately returned to the operating theatre and the rod removed.

After operation she had patchy sensory disturbance in the left leg and weakness of all muscle groups. She was nursed in a plaster bed and then placed in a localiser cast. At six weeks from operation she was mobilised. Initially she required a caliper because of weakness in the left leg, but over the next three months her neurological deficit recovered. Her only disability one year after operation was very slight weakness of the hip adductors on the left side. She no longer uses a caliper.

DISCUSSION

One of the most serious complications of corrective surgery for scoliosis is the development of a neurological deficit. The American Scoliosis Research Society, in its morbidity reports for 1975 and 1976, found an incidence of neurological problems in 1.17% of patients; partial or complete paraplegia occurred in 0.56%. More recently Winter (1984), quoting the American Scoliosis Research Society report for 1971–79, stated that neurological problems occurred in 332 of 33,250 patients, an incidence of 1%; half the lesions were spinal cord lesions and of these 25% were complete and 75% incomplete.

Early removal of the distracting force is known to result in a high rate of recovery of spinal cord function (Hall et al. 1978). It is obviously important therefore to detect any damage to the cord as early as possible. Recent advances in spinal cord monitoring techniques may provide an answer but they require expensive equipment and, in most cases, specially trained technicians to use it. The wake-up test requires no extra equipment and is relatively easy to perform in most patients.

In our series of 102 patients there were no false negative results, and in three of the four patients who were found to have neurological impairment at the wake-up test full recovery of function occurred following prompt action. The fourth patient was still unable to move her left foot fully when the wake-up test was repeated. Because of previous operations on her right foot (for talipes equinovarus) its movements were grossly restricted; comparison was therefore impossible and it was difficult to be certain if her inability to move the left foot was due to spinal cord problems or to incomplete reversal of the anaesthetic.

Engler et al. (1978) criticised the wake-up test because of a number of possible hazards involved in
arousing an anaesthetised intubated patient who was lying prone. They pointed out three main hazards.

1. Extubation due to raising the head.
2. Air embolism due to aspiration of air into the open vessels in the wound.
3. Dislodgement of the rod or fracture of a lamina due to sudden movement.

We feel that by using our modifications of the wake-up test we have eliminated these hazards completely. There were no complications from the test in any of our 102 cases.

Conclusion. The wake-up test is a safe, reliable method of detecting neurological problems during scoliosis surgery. Since modifying the test we have had no complications from it. The choice of agent for re-anaesthetising the patient if the test is to be repeated is important; diazepam causes great delay in the time taken to re-awaken the patient. In our series of 102 cases there were no serious long-term neurological problems.

REFERENCES