THE USE OF INDUCED HYPOTENSION TO CONTROL BLEEDING DURING POSTERIOR FUSION FOR SCOLIOSIS

NIGEL A. MALCOLM-SMITH, MICHAEL J. McMASTER

From the Princess Margaret Rose Orthopaedic Hospital, Edinburgh

The operative and anaesthetic technique for 44 patients undergoing posterior spinal fusion with Harrington rod instrumentation for idiopathic scoliosis is described. There were two groups of 21 and 23 patients, matched for diagnosis and status before operation. The management of both groups was similar but in one group anaesthesia with induced hypotension was employed, using a mixture of sodium nitroprusside and trimetaphan. The mean blood loss at operation and after operation in this group was significantly lower than in the other group, with a consequent reduction in the transfusion requirement. No adverse sequelae were observed. All patients showed a drop in haemoglobin concentration after operation, despite clinically adequate blood transfusion.

Procedures for surgical correction and posterior spinal fusion of patients with scoliosis are associated with considerable haemorrhage during and after operation. Induced hypotension has been established as a means of reducing bleeding during such operations (McNeill et al. 1974; Bennett and Abbott 1977; Grundy, Nash and Brown 1979; Abbott and Bentley 1980) although some authors have questioned its safety (Relton 1977). However, previous reports comparing groups of patients undergoing normotensive and hypotensive anaesthesia have failed to match the two groups: the aetiology of the scoliosis has varied, the operations have been carried out by a number of surgeons and the technique of operation has not always been the same.

The purpose of this paper is to compare the blood loss during and after operation in two groups of patients who were operated on by the same surgeon and accurately matched for age and size and for the aetiology of their scoliosis. The only difference was that in one group the patients were studied prospectively and had their blood pressure deliberately lowered below that occurring as a normal consequence of the anaesthetic technique. Hypotension was induced by a modification of the method employed by MacRae, Wildsmith and Dale (1981), using a mixture of sodium nitroprusside and trimetaphan. In their study the technique combined the advantage of ease of control of blood pressure with a low dose of the potentially toxic sodium nitroprusside.

MATERIAL AND METHODS

A study was made of two groups of male and female patients with idiopathic scoliosis who underwent posterior spinal fusion with Harrington rod correction at the Princess Margaret Rose Orthopaedic Hospital. The patients were aged between 10 and 18 years with an average age of 14.4 years, and all weighed over 45 kilograms. The anaesthetic technique was similar in all patients except that induced hypotension was employed in 23 patients (Group II) while 21 patients (Group I) were kept normotensive. The general health of all of the patients was good, with no significant difference in the mean systolic blood pressure or haemoglobin concentration between the two groups. All of the operations were performed by one of us (MJMcM) using an identical technique. An average of 10.8 vertebrae were fused in Group I and 10.1 in Group II (no significant difference at the five per cent level). The operations in Group I took place between 1977 and 1979 and in Group II between 1980 and 1982.

Anaesthetic technique. Induction of anaesthesia was by an intravenous dose of thiopentone, methohexitone or Althesin to produce sleep, followed by a non-depolarising muscle relaxant (alcuronium 0.2 milligrams per kilogram of body weight, pancuronium 0.1 milligrams per kilogram of body weight or d-tubocurarine 0.4 milligrams per kilogram of body weight), and an opiate analgesic (phenoperidine 0.5 to 1.5 milligrams or fentanyl 0.05 to 0.15 milligrams). The patient was intubated and intermittent positive-pressure ventilation established with a Cape Waine ventilator set to a minute volume of 120 millilitres per kilogram of body weight. Anaesthesia was continued with nitrous oxide and one per cent halothane, using an inspired oxygen concentration of at least 30 per cent rising to 50 per cent during the period of induced hypotension. Incremental doses of analgesic were given...
if indicated by the development of tachycardia, and muscle relaxant was given if venous bleeding became obvious. Blood pressure was measured in Group I with an oscillotonometer or with a sphygmomanometer and peripheral-pulse meter. In Group II direct intra-arterial measurement with a Bentley Transtec transducer and Roche 224–1 monitor was used. Throughout the operation there was continuous electrocardiographic monitoring.

**Fusion technique.** The position of the patient on the operating table, the surgical approach, the method of correcting the scoliosis and the fusion technique were identical in both groups of patients.

The patient was positioned prone on a specially designed foam mattress in which a hole had been cut allowing the entire abdomen to hang free of the table and mattress. The table was tilted so that the patient's head was approximately 10 degrees head down, and broken to allow the patient's hips to be flexed. By this method the intra-abdominal pressure was minimised and venous bleeding decreased.

A straight midline incision was made over the spine after infiltrating the intradermal and subcutaneous tissues with up to 40 millilitres of adrenaline solution (1:500 000) to reduce capillary bleeding. The soft tissues were stripped subperiosteally, starting over the tips of the spinous processes and extending laterally out to the tips of the transverse processes. Using this technique the whole of the scoliosis was exposed and the bleeding points controlled with diathermy.

Correction of the scoliosis was obtained by means of Harrington instrumentation using a single distraction rod (Harrington 1962). Corticocancellous bone grafts were taken from the outer cortex of the right iliac crest. In patients with thoracolumbar or lumbar curves, the grafts were taken through the same incision but in patients with thoracic curves a second incision over the iliac crest was necessary. The gluteal muscles were stripped subperiosteally and after the grafts had been taken an area of bleeding cancellous bone approximately six centimetres by six centimetres was exposed. Bone wax was applied to the area to control bleeding and a closed suction drain inserted into the dead space beneath the muscles.

The spine was fused by excising the interfacet joints and packing them with corticocancellous iliac bone grafts (Moe 1958). This was followed by a deep and thorough decortication of all the posterior bony structures from the midline out to the tips of the transverse processes. This exposed a large area of bleeding cancellous bone over which generous iliac onlay grafts were placed throughout the fusion area. Two closed suction drains were inserted and the wound closed in layers.

**Technique of inducing hypotension.** Hypotension in Group II patients was induced by an infusion of 25 milligrams of sodium nitroprusside and 125 milligrams trimetaphan in 500 millilitres of a five per cent solution of dextrose. The infusion rate was started at 60 millilitres per hour but adjusted, according to the response of the individual patient, to reduce the systolic blood pressure to between 60 and 70 millimetres of mercury; this was equivalent in all cases to a mean arterial pressure of 50 millimetres of mercury or greater. The infusion rate usually lay between 30 and 60 millilitres per hour, though in one case 150 millilitres per hour was required. The infusion was discontinued as the wound was being closed. The blood pressure rose within five minutes of discontinuing the infusion and in no case did hypotension persist, even in those in whom the manufacturer's recommended dosage of sodium nitroprusside (1.5 micrograms per kilogram of body weight per minute) had been exceeded. The operative time was approximately three hours in all cases; the duration of induced hypotension, where it was used, was over two hours.

**Fluid replacement and measurement of blood loss.** An infusion of saline or Hartmann's solution was started initially and replaced by blood when the loss had reached 500 millilitres or 10 per cent of the blood volume. Thereafter blood was given in amounts equivalent to the blood loss which was assessed by the measurement of blood in the suction bottle and by weighing of swabs.

**After-care.** Muscular relaxation was reversed by atropine 0.02 milligrams per kilogram of body weight and neostigmine 0.04 milligrams per kilogram of body weight. After operation the patients were observed in a recovery area for six hours before being returned to the ordinary ward. The tissue drains were opened at four-hourly intervals and the blood loss recorded. Requirement for blood replacement was assessed both by the drainage loss and by the state of the circulation. On the second day after operation the drains and the intravenous infusion were removed. In all cases the circulation was stable at this time and there was no further blood loss. Blood was taken for haemoglobin estimation.

**RESULTS**

The systolic blood pressures for both groups before, during and after operation are shown in Table I.

The blood losses for both groups with their standard deviations are shown in Table II. The mean loss during operation in Group II was 525 millilitres compared with 1530 millilitres in Group I. The mean total loss in Group II was 1058 millilitres compared with 2544 millilitres in Group I. The mean loss after operation in Group I (1014 millilitres) was also significantly greater than that in Group II (533 millilitres). These findings are reflected in the transfusion requirements (Table III). The mean total number of units of blood required in Group I was 4.9 compared with 2.2 in Group II.

A comparable drop in haemoglobin concentration was observed in both groups after operation despite clinically adequate blood replacement (Table IV).

There were no neurological complications relating to either the brain or spinal cord in either group. All the
Table I. Systolic blood pressures before, during and after operation

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of patients</th>
<th>Before operation</th>
<th>During operation</th>
<th>After completion of operation (still under anaesthesia)</th>
<th>One hour after operation</th>
<th>Four hours after operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>21</td>
<td>121</td>
<td>87</td>
<td>98</td>
<td>122</td>
<td>121</td>
</tr>
<tr>
<td>II</td>
<td>23</td>
<td>117</td>
<td>65*</td>
<td>109†</td>
<td>117</td>
<td>114</td>
</tr>
</tbody>
</table>

*Pressures significantly lower in Group II (P < 0.01)
†Pressures significantly higher in Group II than in Group I (0.05 > P > 0.02)

Table II. Blood losses during and after operation (mean ± standard deviation)

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of patients</th>
<th>Loss during operation (millilitres)</th>
<th>Loss after operation (millilitres)</th>
<th>Total loss (millilitres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>21</td>
<td>1530 ± 941</td>
<td>1014 ± 558</td>
<td>2544 ± 1260</td>
</tr>
<tr>
<td>II</td>
<td>23</td>
<td>525 ± 226*</td>
<td>533 ± 267*</td>
<td>1058 ± 339*</td>
</tr>
</tbody>
</table>

*Blood loss significantly less in Group II than in Group I (P < 0.001)

Table III. Blood transfusion requirements (mean ± standard deviation)

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of patients</th>
<th>Average number of units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>During operation</td>
</tr>
<tr>
<td>I</td>
<td>21</td>
<td>3.3 ± 1.6</td>
</tr>
<tr>
<td>II</td>
<td>23</td>
<td>1.3 ± 0.8*</td>
</tr>
</tbody>
</table>

*Amount of blood transfused was significantly less in Group II than in Group I (P < 0.001)

Table IV. Changes in haemoglobin levels after operation (mean ± standard deviation)

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of patients</th>
<th>Haemoglobin level (grams per decilitre)</th>
<th>Drop in haemoglobin level (grams per decilitre)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Before operation</td>
<td>After operation</td>
</tr>
<tr>
<td>I</td>
<td>21</td>
<td>13.6 ± 0.9</td>
<td>10.6 ± 2.0</td>
</tr>
<tr>
<td>II</td>
<td>23</td>
<td>13.5 ± 1.1</td>
<td>11.2 ± 1.3</td>
</tr>
</tbody>
</table>

No significant difference between the two groups

wounds healed satisfactorily and there were no infections.

The results were analysed using Student's t test for unpaired samples.

DISCUSSION

This study confirms that bleeding associated with posterior spinal fusion for scoliosis can be safely controlled by induced hypotension. Our patients were carefully matched for age, size, diagnosis, operation and anaesthesia. The only difference between the two groups was the induced hypotension during the operation, indicating that it was this rather than any other variable which reduced the bleeding. The reduction in mean total blood loss between the two groups was 58 per cent.

The common criticism that induced hypotension leads to increased bleeding after operation was not supported by our findings. In fact the group of patients who had undergone hypotensive anaesthesia lost less blood after operation than those who had been normotensive throughout. The reason for this is uncertain. Two factors that influence bleeding are the blood pressure and the integrity of the coagulation mechanism. In our patients the systolic blood pressures after operation in both groups were similar and no patient had clinical evidence of a coagulopathy. Jacobs, Asher and Gilbert (1980) found in their patients with spinal fusion that a coagulopathy was present following haemorrhage and transfusion, although their comparable patients required larger volumes of donor blood (average 65 millilitres per kilogram). Therefore it appears that either a higher blood loss is associated with the blood transfusion itself, or the circulatory change leading to reduction in bleeding persists after hypotensive anaesthesia by the technique we have described.

A fall in haemoglobin after operation was found in both groups despite the apparent complete replacement of blood loss during and after operation. This change could be explained by insufficient blood replacement, by haemodilutional anaemia, or by partial haemolysis of stored blood. In no patient was the haemoglobin after operation so low that late transfusion was needed.

It has been suggested that hypotension during operations for scoliosis may lead to neurological damage due to decreased blood supply to the brain and spinal cord (Hardy et al. 1973). This risk is theoretically increased by the use of Harrington instrumentation to correct the scoliosis; during this procedure the vascular supply to the spinal cord might be stretched. There were, however, no neurological abnormalities after operation in any of our
patients, all of whom had Harrington instrumentation. All of our patients have been seen regularly after leaving hospital and there have been no deteriorations in academic performances to suggest ischaemic damage to cerebral function. Fahmy, Mossad and Milad (1979) found that, in dogs, the effect of reduced blood pressure on the blood flow to the spinal cord and cerebrum was similar. Autoregulation of the cerebral blood flow in man occurs down to a mean arterial pressure of 40 millimetres of mercury (Conway 1978). It has been reported that sodium nitroprusside acts as a cerebral vasodilator and that in animals cerebral blood flow is well maintained at low levels of mean arterial pressure with this drug (Michenfelder 1980). Larsen et al. (1982), using sodium nitroprusside in anaesthesia during operations for cerebral aneurysm, found no change in cerebral blood flow down to a mean arterial pressure of 50 millimetres of mercury. A safe lower limit for mean arterial pressure in healthy patients under hypotensive anaesthesia has not been universally agreed, but Cottrell (1982) suggests 50 millimetres of mercury and Khambatta et al. (1978) using a hypotensive technique similar to ours have reduced the mean arterial pressure to 42 millimetres of mercury without adverse effects. We feel that during operations for scoliosis the blood pressure must be accurately monitored and the mean arterial pressure kept above 50 millimetres of mercury.

In conclusion we can state that induced hypotension during posterior spinal fusion for idiopathic scoliosis is an effective technique for reducing blood loss during and after operation. Using this technique, a 55 per cent reduction in the blood requirement was achieved. Blood is an expensive and finite resource and any saving of donor blood is a major advantage. The method described is safe, providing the anaesthetist is experienced and the blood pressure is accurately monitored. No long-term or short-term impairment of cerebral or spinal function has been observed.

REFERENCES