STUDIES ON THE SACRAL REFLEX ARC IN PARAPLEGIA

V. SURGICAL THERAPY OF AUTONOMIC HYPERREFLEXIA IN CERVICAL AND UPPER THORACIC MYELOPATHY*

C. D. SCHEIBERT, M.D.
Neurosurgical Section, Surgical Service, Veterans Administration Medical Teaching Group Hospital, Memphis, Tennessee

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RESTORATION of patients with spinal cord injury to a healthy active life is often deterred by pathologic reflex mechanisms peculiar to the isolated spinal cord. Not the least of these is autonomic hyperreflexia with its dangerous paroxysmal hypertension. It is the purpose of this paper to determine a rational approach to the too long neglected treatment of this phenomenon.

A clinically significant mass autonomic reflex may be seen in patients with myelopathy above the 6th thoracic neurotome. The symptoms in such cases are severe throbbing headache, sweating and cutis anserina, usually above the level of myelopathy, and occasional dyspnea, palpitation and nasal congestion. During the first World War, Head and Riddoch described excessive sweating in patients with spinal cord injuries. Autonomic reflexes in spinal man have been observed and described subsequently, but except for Bors and French who presented satisfactory experience in 7 cases of posterior rhizotomy of T9 through S5, no surgical attempt to relieve all manifestations of autonomic hyperreflexia and particularly the hypertension has been reported. List and Pimenta advocated sympathectomy or paravertebral alcohol injection for relief of reflex sweating while Thompson and Witham presented the use of tetraethyl ammonium chloride for paroxysmal hypertension.

In paraplegic patients with poorly functioning bladders, it was found that novocain injection of the sacral nerve usually relieved and spinal anesthesia always relieved the headache and hypertension that may be associated with a cystometrogram. Stimulation of areas supplied by the sacral nerves and particularly of the bladder is capable of causing a severe autonomic hyperreflexia although it may be elicited by any stimulus below the level of myelopathy. Therefore, filling of the bladder was selected as a stimulus for the pre- and postoperative studies. Only patients with extremely severe hypertension and persistent headache or sweating in response to bladder irrigation or catheterization, routine enemas and bathing of the perineum were considered for study and surgery.

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For preoperative study the patient was taken in his bed to a constant temperature room. After at least one-half hour of rest the following measurements were made: plethysmographic tracings from thumb, little finger and large toe, blood pressure, pulse, and skin resistance and temperature recordings from the forehead, ear, arm, thumb, little finger, chest, abdomen, thigh, foot and toe. A cystometrogram by way of urethral or suprapubic catheter was then begun by introducing 200 drops of normal saline into the bladder per minute. The flow was temporarily stopped at each 50 cc. to allow determination of resting bladder pressure and the above recordings. The onset of headache, cutis anserina, perspiration, pupillary changes and nasal congestion were noted. The procedure was terminated by bladder drainage when bladder pressure exceeded 40 cm. of water or discomfort became severe. In the first cases of this series sacral or saddle block followed by the same course of study was employed to predict the postoperative result, but this is no longer felt necessary. Identical postoperative observations were also recorded.

The 13 patients operated upon had in common a myelopathy at or above T4 which was physiologically complete in all except 3. Bladder distention resulted in marked elevation of blood pressure, bradycardia, headache, decrease in skin temperature as much as 8°F. in fingers and toes, marked constriction of blood vessels, dilatation of pupils, varied cardiac arrhythmias with rates as low as 36 and the following changes usually above the level of myelopathy: cutis anserina, blotchy redness of skin and marked decrease in skin resistance with profuse perspiration. Reversion to normal was usually rapid with bladder drainage. Stimulation of the legs by pin prick or rubbing usually resulted in mild subclinical changes. Postoperative bladder distention revealed absence of the above manifestations of autonomic hyperreflexia with the various surgical procedures.

Two of the 13 patients had a milder pressor reflex, but are included although they had division of sacral nerves primarily for elimination of recurrent pyelonephritis caused by ureteral reflux. Seven patients underwent 1st or 2nd through the 5th sacral rhizotomy or neurotomy performed through upper sacral laminectomy. This is a modification of the previously described technique for sacral neurotomy.11 Four patients had total lumbosacral rhizotomy with excision of the conus medullaris for concomitant relief of spasticity of the lower extremities. Posterior rhizotomy below T9, as described by Bors and French,2 was done in 1 case with thoracic chordectomy in the remaining patient.

Electrical stimulation of the exposed sacral roots revealed that stimulation of intact anterior and posterior sacral roots resulted in immediate hypertension, etc. Stimulation of the proximal divided anterior root was without effect, while of the distal anterior root resulted in elevation of the blood pressure which was eliminated on division of the posterior roots. Stimulation of the distal posterior root yielded no response, but there was consistent hypertension with stimulation of the proximal end of the divided posterior sacral root. Surgical manipulation usually resulted in severe enough eleva-
tion of blood pressure to cause increased bleeding, and this was found to be eliminated by local infiltration of novocain for exposure and the injection of 50 mg. of procaine into the exposed dural sac prior to nerve or root section.

The following 6 cases illustrate the various problems and surgical approaches.

**CASE REPORTS**

**Case 1.** K.B., a 22-year-old white male, had a 9-month-old 6th cervical, physiologically complete, traumatic myelopathy. He began to have evidence of autonomic hyperreflexia 4 months after injury. While receiving an enema on the ward the patient, after complaining of headache, lost consciousness with blood pressure of 240 systolic and 140 diastolic. Respirations ceased for 10 minutes requiring artificial aid. During the period of unconsciousness eight convulsions occurred.

An intradural sacral rhizotomy of S2 through S5 including anterior and posterior roots was performed bilaterally after control studies which showed the usual changes.

The patient is now, 1 year postoperative, relieved of the pressor reflex.

**Case 2.** R.M., a 23-year-old white male, had a 3-year-old 6th cervical, physiologically complete, traumatic myelopathy.

He underwent extradural division or neurotomy of the 2nd through the 5th sacral nerves bilaterally for the relief of severe autonomic hyperreflexia.

Postoperative studies and his 7-month postoperative course revealed freedom from the pressor reflex. The physiological alterations before and after surgery are illustrated by Figs. 1 and 2.

![Fig. 1. Case 2.](image-url)
Case 3. E.M., a 27-year-old white male, had a 2½-year-old incomplete, 7th cervical, traumatic myelopathy. Whenever the patient was exposed to cold air, generalized drenching sweats developed, although he was not bothered particularly with headaches. Preoperative studies revealed the presence of the usual findings of fairly severe autonomic hyperreflexia with profuse generalized perspiration. A preoperative low spinal anesthetic eliminated all symptoms and signs even with exposure on a cold December day.

Bilateral sacral rhizotomy of the anterior and posterior roots of S2 through S5 has resulted in 2 years of almost complete absence of abnormal sweating.

This is the only case in which relief of abnormal sweating was the primary reason for surgical intervention.

Case 4. J.H., a 26-year-old male, had a physiologically complete, 7th cervical, traumatic myelopathy of 3½ years' duration. The patient suffered almost continual headache precipitated by catheter change, irrigation, or enemas and this necessitated relief if he was to lead the life of a normal quadriplegic.

A bilateral anterior and posterior rhizotomy of S1 through S5 was performed with relief of the pressor reflex with good results.

Eight months later, relief of spasticity was necessary for the surgical closure of long-standing decubiti and at this time excision of the conus medullaris was carried out below T11 with continuing relief of the pressor reflex.

Case 5. T.A., a 28-year-old white male, had a physiologically complete, C6, traumatic myelopathy which necessitated relief of autonomic hyperreflexia 5 years after injury because of persistent headaches and hypertension.

This patient underwent bilateral posterior rhizotomy from T9 through S5 with relief of the pressor reflex for the 2½ years following surgery.

Case 6. V.R., a 28-year-old white male, had a 5th cervical, physiologically complete, myelopathy. Severe autonomic hyperreflexia developed 7 years after injury.
following a 2nd subarachnoid lumbar alcohol injection for spasticity. This was followed by a 3-week period of headaches and continued hypertension as high as 250 systolic and 160 diastolic. The sacral reflex arc had been destroyed by the alcohol injections. Ingestion of food or liquid seemed to aggravate the pressor reflex and it was felt that thoracic chordectomy would be necessary for relief.

This operation was carried out including the 4th through the 12th thoracic segments of the spinal cord with relief of autonomic hyperreflexia for the succeeding 3 years.

RESULTS

Postoperative study, consisting of cystometrogram with the above-noted observations together with the clinical course, revealed complete relief of the manifestations of autonomic hyperreflexia in 11 of the patients with postoperative observation up to 3 years. Table 1 presents a summary of the 13 cases with observations before and after surgery. Of the 2 patients not completely relieved, 1 (E.M., Case 3), who underwent sacral rhizotomy of

<table>
<thead>
<tr>
<th>NAME</th>
<th>LEVEL</th>
<th>OPERATION</th>
<th>BLADDER PRESSURE cm. H2O</th>
<th>BLOOD PRESSURE</th>
<th>PULSE</th>
<th>HEADACHE</th>
<th>PERSPIRATION</th>
<th>FOLLOW UP RESULT</th>
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<tbody>
<tr>
<td>R.R.</td>
<td>T9</td>
<td>S1 - S5 RHIZOTOMY</td>
<td>100 cm.</td>
<td>125 cc.</td>
<td>13 cm.</td>
<td>190</td>
<td>120</td>
<td>72</td>
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<tr>
<td>E.M.</td>
<td>C7</td>
<td>S2 - S6 RHIZOTOMY</td>
<td>45 cm.</td>
<td>270 cc.</td>
<td>15 cm.</td>
<td>210</td>
<td>95</td>
<td>60</td>
</tr>
<tr>
<td>E.L.</td>
<td>C6</td>
<td>S3 - S7 RHIZOTOMY</td>
<td>60 cm.</td>
<td>150 cc.</td>
<td>23 cm.</td>
<td>180</td>
<td>65</td>
<td>56</td>
</tr>
<tr>
<td>K.B.</td>
<td>C6</td>
<td>S3 - S7 RHIZOTOMY</td>
<td>12 cm.</td>
<td>360 cc.</td>
<td>12 cm.</td>
<td>170</td>
<td>100</td>
<td>56</td>
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<tr>
<td>R.H.</td>
<td>C7</td>
<td>S2 - S5 NEUROTOMY</td>
<td>15 cm.</td>
<td>400 cc.</td>
<td>133</td>
<td>80</td>
<td>72</td>
<td>48</td>
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<td>N.R.</td>
<td>C6</td>
<td>S2 - S5 NEUROTOMY</td>
<td>100 cm.</td>
<td>155 cc.</td>
<td>26 cm.</td>
<td>165</td>
<td>100</td>
<td>60</td>
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<tr>
<td>R.M.</td>
<td>C6</td>
<td>S2 - S5 NEUROTOMY</td>
<td>100 cm.</td>
<td>115 cc.</td>
<td>17 cm.</td>
<td>234</td>
<td>110</td>
<td>72</td>
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<tr>
<td>J.H.</td>
<td>C6</td>
<td>T9 - S5 CONUS EXCISION</td>
<td>62 cm.</td>
<td>250 cc.</td>
<td>12 cm.</td>
<td>200</td>
<td>100</td>
<td>76</td>
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<tr>
<td>E.J.W.</td>
<td>C6</td>
<td>T9 - S5 CONUS EXCISION</td>
<td>80 cm.</td>
<td>210 cc.</td>
<td>80 cm.</td>
<td>230</td>
<td>95</td>
<td>60</td>
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<td>C.G.</td>
<td>T9</td>
<td>T9 - S5 CONUS EXCISION</td>
<td>16 cm.</td>
<td>65 cc.</td>
<td>24 cm.</td>
<td>200</td>
<td>100</td>
<td>96</td>
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<td>J.N.</td>
<td>C6</td>
<td>T9 - S5 CONUS EXCISION</td>
<td>30 cm.</td>
<td>230 cc.</td>
<td>38 cm.</td>
<td>180</td>
<td>100</td>
<td>84</td>
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<tr>
<td>T.A</td>
<td>C6</td>
<td>T9 - S5 POST. RHIZOTOMY</td>
<td>25 cm.</td>
<td>200 cc.</td>
<td>12 cm.</td>
<td>210</td>
<td>105</td>
<td>68</td>
</tr>
<tr>
<td>V.R.</td>
<td>C5</td>
<td>T4 - T2 CHORDECTOMY</td>
<td>250 cm.</td>
<td>160 cc.</td>
<td>90</td>
<td>60</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

TABLE 1

Summary of 13 cases of autonomic hyperreflexia
S2 through S5 primarily for abnormal sweating on exposure to cold, has had only several episodes of profuse perspiration in 2 years, but these occurred only at the time the patient suffered a fracture of the lower extremity rather than with exposure to cold or other stimuli. The other (E.L.) had sacral rhizotomy of S1 through S5. This patient with a C6 myelopathy has had very infrequent headaches with slight elevation of blood pressure, but is able to withstand catheter changes and enemas without discomfort, whereas these two procedures previously resulted in hypertension and severe headache. Thus 11 patients enjoyed complete relief from autonomic hyperreflexia and 2 had almost complete relief.

These 13 patients had catheter drainage of the bladder with one through suprapubic cystostomy. Except for elimination of detrusor spasticity and increase in bladder capacity, bladder function remained unchanged. Reflex penile erections remained in 1 patient with an incomplete 7th cervical myelopathy after sacral neurotomy of S2 through S5, but division of sacral nerves usually results in loss of this function if present.

DISCUSSION

Previous authors have felt that complete interruption of the afferent nerve supply from the bladder which enters up to the 9th or 10th thoracic cord segments would be necessary if one were to eliminate this mass autonomic reflex on the afferent side. Bilateral thoracolumbar sympathetic blocks with cystometrogram have not eliminated the paroxysmal hypertension which is regularly checked by interruption of sacral nerve impulses. Thus the afferent portion of this vicious reflex arc seems to be primarily in the posterior sacral nerves from the pelvic viscera. Manning tried section of the lower thoracic cord in one case, but relief was incomplete. Once the impulse reaches the uninhibited spinal cord diffuse spread with efferent pathways through the sympathetic system occurs with the resulting symptoms. The headache is felt to be caused by the passive dilatation of intra-cranial vessels secondary to hypertension. Bradycardia overshadows tachycardia because of the intact aortic and carotid sinus mechanism. The danger of attacking the efferent mechanism by bilateral extensive sympathectomy is apparent in the patient with high spinal cord injury. Bors has reported the continual use for up to 6 months of hexamethonium with favorable results. This had shown promise in my experience with one such case. When surgical attack is necessary for the relief of severe autonomic hyperreflexia, the simplest approach that gives relief is the division of the sacral nerves or roots bilaterally through upper sacral laminectomy. Since neurotomy can be performed without opening the dura mater, it is felt that the procedure of choice is division of the sacral nerves after they leave the dural sac.

Again, it should be stressed that this operative approach should be used only when non-surgical management is of no help. Such medical measures include improvement in general nutrition and health, elimination of urinary catheter drainage if possible, correction of urinary tract infection and bladder calculi, the use of topical anesthetic agents before urethral, anal or bladder manipulation and the judicious use of hexamethonium.
In summary, autonomic hyperreflexia in patients with cervical and upper thoracic myelopathy is described. The results of several surgical approaches to its relief are presented in 13 cases. With failure of non-surgical management the surgical procedure of choice is bilateral sacral neurotomy of S2 through S5.

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