The Effect of Destruction of the Corticospinal Tract in the Human Cerebral Peduncle Upon Motor Function and Involuntary Movements

Report of 11 Cases

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Since Walker's first use of pedunculotomy for relief of involuntary movement, section of the middle third of the cerebral peduncle has been found to be effective for the relief of certain aspects of Parkinsonism, dystonia, cerebral palsy, and hemiballismus. We wish to report our experience with 14 pedunculotomies in 11 patients and include observations of its effect on Huntington's chorea.

One of the interesting theoretical aspects of pedunculotomy is the fact that the immediate postoperative paralysis is usually followed in time by a variable but often excellent recovery of voluntary motor function. This recovery is difficult to understand for, although ablation of the precentral gyrus in man interrupts a smaller percentage of pyramidal fibers than are severed by pedunculotomy, the procedure results in a more profound deficit. A discussion of some of the implications of the results of this procedure for the physiology of motor function will be presented.

Operative Procedure

The technique used is that of Dr. Paul C. Bucy who kindly demonstrated it to us. The patient is placed in a lateral position with the head laterally tilted to encourage dropping away of the temporal lobe from the floor of the middle fossa. Spinal drainage is begun as soon as the dura is exposed. A 7 to 9 cm incision is made from the zygoma curving slightly back to the mid portion of the temporalis, the temporalis fascia and muscle are split, and self-retaining retractors placed. The temporalis is stripped from the zygoma, thus affording additional exposure at the floor of the middle fossa. An approximately circular craniectomy about 4 cm in diameter is made, based on the floor of the middle fossa. The dura is opened close to the base and reflected medially. The temporal lobe is slowly retracted and the occasional bridging vein clipped and cut. The pia about the incisura is then opened. The peduncle is seen with its junction with the pons represented by a change in texture of the presenting nervous tissue. The posterior cerebral artery is also apparent coursing around the mesencephalon. An avascular area is selected and the pia opened with a Bard Parker #11 blade. The lesion is made with a Penfield dissector #1 which contains a disc 7 mm in diameter. The disc is placed through the opening in the pia and moved back and forth so that the resulting lesions have been no more than 7–8 mm deep but usually 8–10 mm wide.

Results

Fourteen pedunculotomies were performed on 11 patients with various movement disorders (Table 1). There was one death (7%) and one transient third nerve palsy. The results in the four cases of Huntington's chorea were poor; two patients had neither hemiplegia nor change in abnormal movements, one had moderate hemiplegia with little relief of symptoms, and one, a very poor operative risk, died. On the other hand, the four patients with choreothetosis, the two with hemiballismus, and the one with dystonia all fared better. Six patients
The effect of pedunculotomy upon motor function and involuntary movements

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Condition</th>
<th>Procedure</th>
<th>Weakness at last follow-up</th>
<th>Result</th>
<th>Follow-up (mos)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>dystonia musculorum deformans</td>
<td>bilateral pedunculotomy</td>
<td>minimal</td>
<td>good</td>
<td>26</td>
</tr>
<tr>
<td>2</td>
<td>kernicterus-choreoathetosis</td>
<td>unilateral pedunculotomy</td>
<td>minimal</td>
<td>good</td>
<td>18</td>
</tr>
<tr>
<td>3</td>
<td>bilateral choreoathetosis</td>
<td>unilateral pedunculotomy</td>
<td>minimal</td>
<td>no change</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
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<td>bilateral pedunculotomy</td>
<td>minimal</td>
<td>excellent</td>
<td>24</td>
</tr>
<tr>
<td>5</td>
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<td>unilateral pedunculotomy</td>
<td>minimal</td>
<td>fair</td>
<td>12</td>
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<tr>
<td>6</td>
<td>hemiballismus</td>
<td>unilateral pedunculotomy</td>
<td>minimal</td>
<td>excellent</td>
<td>16</td>
</tr>
<tr>
<td>7</td>
<td>hemiballismus</td>
<td>unilateral pedunculotomy</td>
<td>minimal</td>
<td>fair</td>
<td>18</td>
</tr>
<tr>
<td>8</td>
<td>Huntington’s chorea</td>
<td>unilateral pedunculotomy</td>
<td>moderate</td>
<td>poor</td>
<td>16</td>
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<tr>
<td>9</td>
<td>Huntington’s chorea</td>
<td>unilateral pedunculotomy</td>
<td>no deficit</td>
<td>no change</td>
<td>12</td>
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<tr>
<td>10</td>
<td>Huntington’s chorea</td>
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<td>no deficit</td>
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<tr>
<td>11</td>
<td>Huntington’s chorea</td>
<td>unilateral pedunculotomy</td>
<td>no deficit</td>
<td>no change</td>
<td>18</td>
</tr>
</tbody>
</table>

had definite improvement which has been sustained over a follow-up period of 12 to 26 months. One patient with bilateral choreoathetosis had no change; one with choreoathetosis and one with hemiballismus had fair results in that the amplitude of the movement was diminished. Two had good results (dystonia musculorum deformans and bilateral choreoathetosis) while excellent results occurred in one patient with choreoathetosis and one with hemiballismus.

There were only slight losses in motor function as measured by routine grip tests monitored on a dynamometer. The more violent movements were relieved, and even patients with bilateral pedunculotomy had excellent motor function, including use of individual fingers, alone or in combination. A fairly regular clinical course was observed in that immediately following the operation the paralysis was flaccid and usually but not always the deep tendon reflexes were slightly diminished. As voluntary function slowly returned, tone and reflexes increased.

We have assumed that the results are due to interruption of the corticospinal tract but in the absence of anatomical verification, damage to the underlying substantia nigra might conceivably be important.

**Discussion**

**Efficacy of Pedunculotomy.** The results of this procedure are much like other surgical and nonsurgical attempts at therapy in severe movement disorders. The frequent gratifying result encourages the surgeon to continue in spite of the occasional disappointment. The prediction of results is difficult although it can be said that the more violent the movement the more amenable it is to eradication by pedunculotomy. Thus in our series, as well as in those of Meyers,21,22 the children with choreoathetoid movements of such amplitude as to preclude self-care were often able to feed themselves or sit quietly following the procedure. This may not be dramatically convincing to the occasional observer, but the children and parents are often most grateful. Moreover, in this group of spastic athetotic children, lesions in the thalamus and basal ganglia have in our own limited experience been relatively ineffective. For instance, in Case 6 (Table 1) the thalamotomies were without effect but the patient benefited greatly from bilateral pedunculotomy.

In no instance has the permanent motor loss been marked as measured on routine grip tests monitored by the dynamometer. Nevertheless any amount of loss of function is probably too great for a patient with Parkinson’s disease who may benefit from thalamotomy.

**Physiological Correlation.** If we divide descending pathways in the spinal cord into those terminating upon the lateral aspect of the ventral horn innervating distal musculature and those terminating upon the medial horn innervating axial musculature, as suggested by Kuypers15-17 and further subdivide the lateral pathways into corticospinal and subcorticospinal, then a lesion in either the
corticospinal or subcortico spinal system alone apparently does not permanently impair motor ability even in man. Even larger lesions are compatible with good recovery in other primates.

In man, recovery of motor function including fine distal movement is compatible with complete section of the middle third of the peduncle and subsequent degeneration of the 83% of the pyramidal tract fibers. Moreover, more peripheral section of motor pathways in the spinal cord in lower animals is also followed by motor recovery. For instance in rhesus monkeys and cats complete hemisection of the spinal cord is followed by excellent functional recovery. In man although hemisection has profound permanent effects because it interrupts both cortico and subcortico spinal systems, lesions restricted to the lateral cortical spinal tracts are followed by recovery. In cats recovery of function occurs even with complete section of all long pathways provided that the ventral propriospinal tract remains intact. Thus although there is certainly a phylogenetic trend toward increasing importance of spinal pathways in motor function, a great variation is apparent even in man.

A more striking trend toward functional importance is apparent when we consider the evolution of the structure and function of the neocortical area giving rise to the pyramidal tract. In the tree shrew and hedgehog large neocortical lesions removing completely all areas giving rise to pyramidal fibers are almost without effect even within 1–2 hours of the surgical procedure. In the slow loris (Nycticebus Coucang), a prosimian primate, a large lesion does give a mild contralateral paresis which rapidly improves.

In adult rhesus monkeys a more profound deficit results from a cortical lesion. It is perhaps significant that the loris is the lowest primate in whom direct projections of the pyramidal tract on anterior horn cells has been demonstrated. Thus deficits from cortical lesions seem to correlate with projection of that area upon anterior horn cells. But it is not merely the interruption of these pyramidal pathways that accounts for the deficit since pedunculotomy and lateral cortical spinal tract section in man is not as incapacitating as a cortical lesion which destroys fewer fibers. This also applies to less advanced primates such as the rhesus monkey although with complete section of the peduncle much more profound weakness is seen.

It seems evident that something more is lost by a cortical lesion than from a peripheral lesion. Hughlings Jackson's conception of movements, not muscles, being represented in the cortex certainly finds support from our data. Thus although fewer fibers are interrupted by an area 4 lesion than by a pedunculotomy (60% as opposed to 83%) a greater deficit results. This added functional loss is undoubtedly related to other connections of area 4. Part of the pathway is probably outside of the middle third of the peduncle as indicated by the more profound deficits seen with complete lesions of the peduncle.

"Is There a Pyramidal Tract?" These and other conceptual difficulties in understanding the effects of pyramidal lesions have led to serious speculation as to the utility of continuing to think in terms of pyramidal vs extrapyramidal systems. As mentioned above, Kuyper's has suggested that the root of the problem is to be found in the tendency to look at the motor system in terms of the sites of origin of tracts rather than the sites of termination. Following this argument two divisions can be described, one terminating upon lateral aspects of the ventral grey of the spinal cord innervating distal musculature, and another terminating upon medial portions of the spinal grey innervating trunk musculature. A further subdivision of the lateral motor system to emphasize the unique anatomical features of the corticospinal system seems reasonable. We may then turn to the problem of recovery of function in these terms.

Perhaps the deficit following precentral ablation is greater than that seen after pedunculotomy because central control over other "lateral" motor system pathways is lost in former situations and not in the latter. It is interesting to compare this greater functional deficit from a cortical lesion as compared to a more peripheral motor lesion with the types of loss seen in lesions of sensory neocortex as compared with ascending brain stem lesions. For instance a lesion destroying the medial superior olive which abolishes the
ability to distinguish binaural clicks does not interfere with localization of sound in free space which can be accomplished with other albeit less efficient cues. On the other hand bilateral destruction of the auditory cortex does severely impair the ability in spite of intact peripheral mechanisms.\textsuperscript{15,19} Similarly a cortical lesion has a more profound effect on motor function than a spinal lesion where apparently recovery of function can occur if the cortex remains intact allowing utilization of alternative subcortico spinal motor pathways.

\textbf{Functional Significance of Ipsilateral Corticospinal Tract.} Meyers\textsuperscript{21,22} had noted some diminution of ipsilateral movements in his cases and in order to test whether or not this was due to the ipsilateral pyramidal tract, we carried out grip tests pre- and postoperatively on the patients with pedunculotomy as well as control patients who had undergone other intracranial procedures. Although functional ipsilateral innervation has been demonstrated,\textsuperscript{2,8} we found inconsistent ipsilateral losses and these losses were not greater than might be expected from our control data in which bilateral weakness often occurred. When bilateral improvement results from unilateral pedunculotomy, it may be that the ipsilateral tract is involved in the innervation of proximal musculature while our grip tests obviously tested only distal musculature.

\textbf{Summary}

Fourteen pedunculotomies were carried out for the relief of involuntary movements in 11 patients. The procedure ultimately resulted in only minimal weakness and was most effective in violent disorders. It was not effective in relief of Huntington's chorea.

Significant loss of strength in distal musculature could not be demonstrated on the side ipsilateral to the lesion. We have offered an interpretation of the difference in motor loss after pedunculotomy as compared with that following lesions in area 4 of the cortex.

\textbf{References}


