RESIDUAL SYMPATHETIC PATHWAYS AFTER PARAVERTEBRAL SYMPATHECTOMY*

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(Received for publication August 14, 1947)

"Surgical denervation must be complete or it will be of little value." White and Smithwick italicize this statement to emphasize the ineffectiveness of incomplete sympathetic denervation. The history of the development of sympathectomy as a method of treatment of vascular and perivascular diseases is a chronicle of more accurate and more extensive interruption of sympathetic nerves. For the treatment of vascular diseases of the extremities periarterial sympathectomy, while occasionally beneficial, has proved far inferior to more complete paravertebral sympathectomy. Similarly, in the treatment of hypertension by sympathectomy, while the reports of different investigators are not strictly comparable, the results are more impressive as sympathetic denervation has been made wider and more nearly complete. In spite of progress in scope and in technique of the operations, failures still occur with disconcerting frequency. In an attempt to explain these failures attention has been largely focused on nerve regeneration and on the sensitization and the development of intrinsic tone of blood vessels. Of late, the maxim regarding the inadequacy of incomplete denervation has received relatively little attention primarily because we have assumed that our recent methods of denervation are complete. As a result, too much of the evidence that would attribute to regeneration the return of sympathetic activity following sympathectomy in man is inferential.

There have been sporadic reports suggesting that our present methods of denervation may not be complete. Regarding the upper extremity, there are differences of opinion as to what constitutes a complete denervation. The role of the first thoracic anterior root is unsettled and Geohegan and Aidar have demonstrated that a functional reorganization may take place, resulting in sympathetic activity through roots that previously showed no evidence of activity. Van Buskirk has described, in human embryos, sympathetic fibers which traverse as many as six segments via nerves in the vertebral canal, and Kuntz and Dillon who found evidence of sympathetic activity after sympathectomy, which included stellate ganglionectomy, attributed residual activity to these fibers. Derom and Grimson and Foerster have described unusual pathways to the upper extremity. These and other data indicate that the problem of complete denervation of the upper extremity is far from settled.

* Aided by a grant from the John and Mary Markle Foundation. Presented at the meeting of the Harvey Cushing Society, November 15, 1947, Hot Springs, Virginia.
Our concepts regarding complete denervation of the splanchnic bed are also based somewhat upon inference. Save for some excellent anatomic studies in man, most of our information is derived from experimental animals. Accurate physiological data regarding the vasomotor supply to the splanchnic bed in man are conspicuously lacking. Recently, Poppen and Lemmon have reported that they found evidence that the usual thoracolumbar sympathectomy does not completely denervate the splanchnic bed.

Sympathetic denervation of the lower extremity, on the other hand, is generally thought to offer no problems. Smithwick\textsuperscript{23} states, "... removal of the first, second and third lumbar ganglia results in complete denervation of the thigh and leg. Removal of the second and third ganglia results in a nearly complete denervation of the leg from the knee distally, but the effect on the thigh is not necessarily complete." Failure to denervate the lower extremity completely has usually been attributed to failure to remove the first lumbar ganglion even when the surgeon believed he had done so. Recently, Ulmer and Mayfield\textsuperscript{26} have suggested that the lower extremity may not be completely denervated unless Th.11 and Th.12 are also removed.

In a study of the results of 291 sympathectomies in 151 patients by the method of measuring skin resistance we have found that the lower extremity is not completely denervated even after total paravertebral sympathectomy, from the stellate ganglion to L5 inclusive. Residual sympathetic activity persists in the dermatomes from thoracic 12 to lumbar 3 (hereafter designated Th.12–L3), and this activity is abolished only after the appropriate anterior spinal roots are divided. There are indications that residual innervation following standard methods of paravertebral sympathectomy is not limited to the Th.12–L3 dermatomes and may occur in other parts of the body. Such residual innervation may require up to three months to become manifest and for this period of time may be overlooked in the belief that the denervation has been complete.

METHODS

The detection of sympathectomized regions by the method of measuring skin resistance has been described by Richter.\textsuperscript{17} While all the factors that determine the absolute electrical resistance of the skin are not understood, it is evident that, other things being equal, the resistance varies inversely with the sympathetic activity. It is possible by employing constant conditions of examination to obtain skin resistance patterns and resistance levels which are comparable from day to day in the same patient and from patient to patient. The change in skin resistance is logarithmic as one goes from completely denervated to normal skin, the levels being $1 \times 10^5$, $1 \times 10^6$ and $1.5 \times 10^7$ ohms for normally innervated, partially denervated and completely denervated skin respectively. The resistance of completely denervated skin frequently exceeds $1.5 \times 10^7$ ohms and may approach $6 - 8 \times 10^7$. The figure $1.5 \times 10^7$ is used only because it is the extreme range of the dermohmeter. The logarithmic change still holds and these differences far exceed the variations.