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Commentary

Variations in cervical myotomes and dermatomes

K. Daniel Riew, MD*

Orthopaedic Surgery, Columbia University, 5141 Broadway, 3rd Floor, New York, NY 10034, USA

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"Half of what we are going to teach you is wrong, and half of it is right. Our problem is that we don't know which half is which."

- Charles Sidney Burwell, cardiologist, Dean, Harvard Medical School 1935-1949

When I think back
On all the crap I learned in med school
It's a wonder
I can think at all. . .
-With apologies to Paul Simon's "Kodachrome"

Rhee et al. found that only 54% of their subjects had "typical" patterns of radiculopathy. While this is something that is well known to experienced cervical spine surgeons and similar findings have been reported in the past, it is not adequately reported in the literature that most spine surgeons read [1–3]. Why is it that so few patients conform to the textbook descriptions of radiculopathy? There are several reasons. First, the seminal studies that informed the basis of these dermatomal maps are flawed. Second, the severity of the radiculopathy commonly results in variability of the symptoms so that even with one individual, repeated exams can yield different findings. Third, anatomic variations in nerve roots, the brachial plexus as well as peripheral nerves are common. It is no wonder, then, that the dermatomes and myotomes of a patient with a cervical radiculopathy often do not correlate with those described in textbooks.

If we closely examine the seminal studies that mapped cervical dermatomes and myotomes, we get a better understanding of why this information is so flawed. What we know about cervical dermatomes initially came from research by Ofrid Foerster, who in the 1930s published two works on the topic [4,5]. Foerster was a German neurologist and neurosurgeon who performed rhizotomies of the dorsal roots for intractable pain as well spasticity associated with cerebral palsy. The dermatomes that he delineated were the basis on which most dermatome diagrams, including Netter's, are based on. Unfortunately, Foerster's methodology has some serious flaws. First, the dermatomal mapping of each of the cervical roots was based on only two to five subjects. Given the variability in the dermatomes, two to five subjects are woefully inadequate to draw any meaningful conclusions. Second, he cut the nerves adjacent to the one being studied and mapped the dermatome as the area remaining. He noted that the sectioning of a single root usually led to no sensory deficits, making it difficult to isolate one associated dermatome.

It is now well recognized that there are many overlapping interconnections within the brachial plexus that confound exact localization and that a cut root can result in rerouting the function of that root to a different pathway within the plexus. This is in contrast to a herniated disc impinging on a root, which most commonly produces a sensory deficit. A third methodological problem is that he failed to identify the time course between the sectioning and the dermatome mapping. Since the dermatomes of uncut nerves can expand to fill in areas of deficit, the mapping should be done immediately following the sectioning [2]. The next seminal work on dermatome mapping was published by Keegan and Garrett in 1948, in their paper, "The segmental distribution of the cutaneous nerves in the limbs of man" [6]. They examined 1,300 patients with myelograms and mapped out the dermatomes in patients with a single level herniated disc. Although 1,300 patients seem like an exhaustive number of subjects from which to draw conclusions, closer inspection reveals the numerous methodological flaws of this study. First, it is now known that myelograms can miss a lot of pathology. For example, a foraminal disc or a small central herniation can be invisible on myelography. Second, only 165 herniations were

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* Corresponding author. Orthopaedic Surgery, Columbia University, 5141 Broadway, 3rd Floor, New York, NY 10034, USA. Tel.: (212) 932-4334; fax: (212) 932-5097.

E-mail address: kr2637@cumc.columbia.edu

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between C5 and T1, with only 47 of those verified as having a single-level compression at surgery [2]. Third, a large herniation can compress the cord, affecting multiple roots. Fourth, their surgical exploration was done posteriorly, via laminectomy in live subjects and it would have been unethical and practically impossible to do a comprehensive exploration of every root and every disc for every subject.

Another reason for Rhee et al.'s findings that radiculopathy may not conform to the textbook pattern may simply be due to its severity, which is difficult to control for. A mild radiculopathy may cause no numbness, or only numbness in part of the dermatome. This can be due to the variability in the compressive etiology and the degree to which it affects the sensory, motor or pain fibers. Even with any given patient, it is common to observe fluctuating patterns of numbness or weakness at different times, depending on factors such as neck position, activity, the degree of inflammation, response to treatment, etc. In such cases, the anatomy remains constant but the symptoms and physical exam will change.

The third reason that confounds our efforts to delineate cervical dermatomes and myotomes is that the human anatomy is highly variable. With such wide variation in human neuroanatomy, it is easy to understand the lack of agreement between textbooks and the findings by Rhee et al. Medical students and residents are tested on the brachial plexus anatomy as if there were only a single version. In fact, there are dozens of different variations to the brachial plexus that have been reported in man. Once the roots have emerged to form the brachial plexus, their variation in trunks, divisions, and cords are such that there are literally thousands of variations and permutations that have been identified [7–12]. In addition, as Rhee et al. point out, there are pre- and postfixed brachial plexi, where different cervical roots contribute to the brachial plexus [12–14]. Tubbs et al. examined 60 cadavers to determine the incidence of pre- and postfixed brachial plexus. They noted that 28% had a prefixed brachial plexus and 5% had a postfixed brachial plexus. A prefixed brachial plexus is one in which the C4 nerve root contributes to the brachial plexus, whereas the T1 nerve root either does not or has a minimal contribution. In a postfixed brachial plexus, the C5 nerve root has minimal contribution to the brachial plexus, whereas the T2 nerve root has a substantial contribution. While the exact percentages of those subjects with pre- vs. postfixed brachial plexuses varies from study to study, most agree that a prefixed brachial plexus is more common than a postfixed one. In addition, Tubbs et al. found numerous intradural interconnections. Because these interconnections commingled the roots of adjacent levels, they concluded that it could result in the misidentification of the pathologic level. Anatomic variations also occur in the peripheral nerves [15–17]. A Martin-Gruber anastomosis between the median and ulnar nerves occurs in up to 20%–54% of subjects such that median nerve innervated intrinsic hand muscles are unaffected by median nerve lesions. On the other hand, an ulnar nerve injury may cause total intrinsic paralysis. With a Marinacci ulnar to median nerve anastomosis, thenar muscles are unaffected by a median nerve lesion. With a Riches-Cannieu communication, there is an ulnar to median motor anastomosis and with a Berrettini Branch, there is a superficial ulnar to the median sensory nerve such that injury results in middle and ring finger sensory disturbance.

With such flaws in the original anatomic studies on which the textbooks are based on, the variability in the symptoms of even one individual at different times and the widespread variations in the anatomy of the roots, brachial plexus, as well as peripheral nerves, it is no wonder that Rhee et al. found a 54% discrepancy between the textbooks and their patients. Unfortunately, the vast majority of textbooks do not mention this variability, as most textbook authors have simply parroted previous textbooks, suggesting that radiculopathy symptoms and signs are uniform. Therefore, this is an important paper for those in training, as well as surgeons in the early years of their practice, when textbooks appear authoritative. For their sake, as well as our patients', all future textbook authors should point out the high variability in human dermatomes and myotomes.

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