Regional Anesthesia

Functional Implications Beyond the Anesthetized Nerve

REGIONAL anesthesia is commonly used for a variety of surgical procedures; however, it is also used as a treatment for chronic pain. The effects of nerve blocks on chronic pain often far outlast the normal duration of a regional anesthetic block.[1] This suggests that the mechanisms by which peripheral nerve blocks improve chronic pain involve neural processes beyond those directly affected by the anesthesia. In a recent study, Silva *et al.*[2] explore the far-reaching effects of regional anesthesia in the preoperative setting to help explain the acute plasticity of the nervous system that occurs when afferent input is disrupted.

A growing amount of literature shows that immediate changes in central somatotopic representations occur after regional anesthesia.[3,4] These changes are similar to how receptive fields of neurons from neighboring regions encroach into deprived regions of somatosensory cortex after amputation or sensory deafferentation.[5–7] By using a motor imagery task, Silva *et al.*[2] identified psychologic/functional correlates associated with observed acute cortical plasticity after regional anesthesia. During a mental imagery hand rotation task, patients were presented pictures of hands in various positions and were asked to state whether the hand in the picture was a right or a left hand. This task requires the subject to rotate the pictured hand in his or her mind from its presented orientation and involves highly similar neurologic processes as those that occur when actually executing a movement.[8] After infraclavicular brachial plexus block of one arm, patients displayed impaired performance on the mental hand rotation task in conjunction with the experience of illusory sensory and proprioceptive sensations.

Previous studies[4,9] have focused on acute plastic changes within primary somatosensory and motor cortices after reversible deafferentation by anesthesia and ischemic nerve block; however, impairment of motor imagery task performance indicates that higher-order regions of cortex are also affected.[2] Although primarily somatosensory information was blocked, cortical regions involved in motor processing were affected by anesthetic deafferentation because regions involved in processing motor actions are known to subserve mental imagery of motor function.[8] Mental imagery of a motor task involves multiple regions of cortex, some of which overlap with motor execution, including premotor cortex, supplementary motor area, and cerebellum; others are suggested to involve multisensory integration, including superior and inferior lobules of the posterior parietal cortex.[10–13] Thus, although observations of plasticity in the somatosensory cortex are known to occur after deafferentation, it is apparent that regional anesthesia induces changes in additional regions implicated in motor imagery.

Additional evidence of the remote effects of regional anesthesia lies within the observation of the ability for visual input to modulate deficits in motor imagery. Patients were initially tested with their anesthetized arm hidden by a screen; however, in additional trials, when the anesthetized limb was in view, the deficits caused by anesthetic deafferentation were almost fully ameliorated (patients' reaction times and accuracy rates were practically unaltered from baseline). Therefore, although visual input is not required for the ability to perform the mental hand rotation task, it is able to compensate for sensory information lost during regional anesthesia. Sensory-visual phenomena often display the strength of vision in modulating perception of somatosensory input. Examples include mirror therapy for treatment of phantom limb pain, which involves visualization of a restored body image[14]; and the rubber-hand illusion, which involves perceptual displacement of touch from a subject's hidden hand to a visible dummy hand.[15] The convergence of multisensory afferent information with spatial memory may occur in regions such as the posterior parietal cortex, which is known to involve motor preparation and imagery, and spatial discriminatory aspects of pain processing.[10,12,16] The compensatory effects of visual input of a limb likely occur within these regions, where visual information counters the functional alterations produced by manipulated sensory input from the periphery.

In parallel with the effects of regional anesthesia in the study by Silva *et al.*,[2] alterations in motor imagery and central body representation occur in chronic pain states, including patients with complex regional pain syndrome and chronic low-back pain.[17,18] Patients with complex regional pain syndrome display delayed responses when performing a mental hand imagery task that does not require actual movements of the affected limb.[18] These patients also demonstrate altered visuospatial perception, with their visual subjective body-midline representation shifted toward their affected side, and they perceive their affected limb as larger than it actually is.[19,20] Further-

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more, patients with complex regional pain syndrome occasionally have pain that spreads from the initially affected region to the contralateral limb.[21] This occurs without any additional initiating neuropathic event and may be caused by bilateral spread of disinhibition within cortical representations of the body, similar to how a loss in inhibitory neurotransmitter function occurs in sensorimotor cortex after acute deafferentation.[22] Thus, altered processing in the central nervous system in chronic pain conditions appears to be closely related to and to affect mechanisms that subserve motor mental imagery and body representation.

In summary, there exists clear evidence that bilateral somatosensory and possibly some proprioceptive cues from the periphery contribute substantially to mental processes supporting motor imagery. Regional anesthesia alters both the perceptual and functional central representation of the body subsequent to its blockade of peripheral nerves. In the normal state, spatiotemporal maps in the cortex, which are highly dependent on incoming sensory input, are being actively referenced and compared with the current afferent sensory information to create the overall perception of a limb. During regional anesthesia and in disease states, such as chronic pain, the mismatch of what information the central nervous system expects to receive *versus* what it actually receives produces physiologic and functional alterations at multiple levels of the central nervous system. This mismatch may also produce sensory illusions. Vision functions as an alternative source of peripheral input that can partially rectify the mismatch between peripheral input and its central counterparts by acting on higher-order regions of cortex involved in the imagery component of the motor imagery task.

By involving patients scheduled for preoperative regional anesthesia, the study by Silva *et al.*[2] is an elegant example of the valuable opportunity for conducting basic science investigations in conjunction with clinical procedures. Future studies should take advantage of this approach to elucidate further the complex relationship between peripheral afferent information and central representation of the body and how it is disrupted in disease states. Furthermore, states of increased brain plasticity occur after regional anesthesia and may be useful for priming the central nervous system so that it responds more readily and quickly to therapies aimed at reforming neuronal connections.[23,24] Through continued investigation of its extensive effects within the nervous system, regional anesthesia may evolve to be much more than a routine, yet vital, clinical procedure.

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