A Literature Review Exploring Current Visualization Technology of the Proprioceptive Feedback System in Patients with Neuromusculoskeletal Injury

Dr. Barry Kenny, PGY-3 Michigan State University Osteopathic Neuromusculoskeletal Medicine Residency Program

Abstract

Neuromusculoskeletal (NMSK) injuries-including ligament tears, chronic pain syndromes, and neurological conditions like cerebral palsy-are known to disrupt proprioceptive processing. Traditionally, the technology clinical providers utilize to assess NMSK injury include Electromyography (EMG) and Magnetic Resonance Imaging (MRI). EMG's can be ambiguous and non-distinct; loss of sensory feedback is implied by change in muscle response and does not directly assess the proprioceptive feedback system. While MRI is invaluable for assessing gross musculoskeletal injuries such as ligament damage, joint effusion, or muscle tears, it does not currently allow for precise assessment of the microstructural and neurofunctional disruptions that affect proprioception. The purpose of this literature review is to explore the literature related to directly visualizing the proprioceptive system in order to better assist clinicians in diagnosing and subsequently treat patients with NMSK injury.

Research Aims

-Discover if proprioceptive fibers are detectable on MRI

-Explore the effects of neuromusculoskeletal injury on proprioception

-Explore limitations of MRI in assessing neuromusculoskeletal injury

Methodology

Goal: compile past research that is relevant to MRI, proprioception and neuromusculoskeletal injury. Searched keywords in PubMed, EBSCO host, Google Scholar, Jstor, Gale Academic OneFile,, Project Muse. Keywords used were: "proprioception" AND "neuromusculoskeletal injury" or "MRI" and "proprio" Ebrary

Literature Review Article Summaries

Authors	Year	Domains	Relevant Main Aims	Participants
Goble	2011	Ankle and Foot Proprioception	Understanding neural basis for proprioception and balance	20 young and 20 older healthy human adults
Papadelis	2014	fMRI, Cerebral Palsy and somatosensory remodeling	Investigate whether spastic CP is associated with abnormalities on fMRI	10 children-4 with diplegic CP, 3 with hemiplegic CP, 3 typically developing children
Hakoen	2022	Hand Proprioception, corticokinematic processing	Investigate whether cortical source location differs b/w proprioceptive stimulation of right hand digits	21 healthy adults
Turner	2016	Limitations of MRI, a literature review	Explore fundamental limitations of MRI	Systematic review
Ergen	2008	Proprioception and the Ankle	Review role of proprioception in preventing ankle injuries in soccer players	none
Moore	2015	Micron Scale MRI	Explore nuclear magnetic resonance (NMR) spectroscopy	None
Contreras	1954	Proprioception, chronic pain	Clinical study examining proprioception and pain	None
Lee	2022	Proprioceptors, chronic MSK pain	Review role of proprioception and pain fibers	Systematic Review
Partenen	2018	Pain and sensory systems	Somatosensory processing in pain	None
Hoon	2002	Cerebral Palsy and proprioception	Motor function and CP	28 children with CP

Results

The many and well-established physical therapy programs for proprioceptive rehabilitation clearly establishes the notion that afferent nerve damage is a common component in joint injury, but like EMG/NCV studies, it is an implied finding based more on dysfunction. Review of the literature revealed that MRI proprioception studies focused for the most part on the brain and less on the periphery because direct imaging of afferent nerves is not yet possible. Proprioceptive and other sensory nerves are of dimensions smaller than the resolution of the MRI, CT scan or any other imaging methods. MRI studies of the brain does provide visualization of changes in proprioceptive feedback centers in the brain but only grossly (Figure 1). Such changes in the brain cannot be assigned directly to joint specific injury sites.

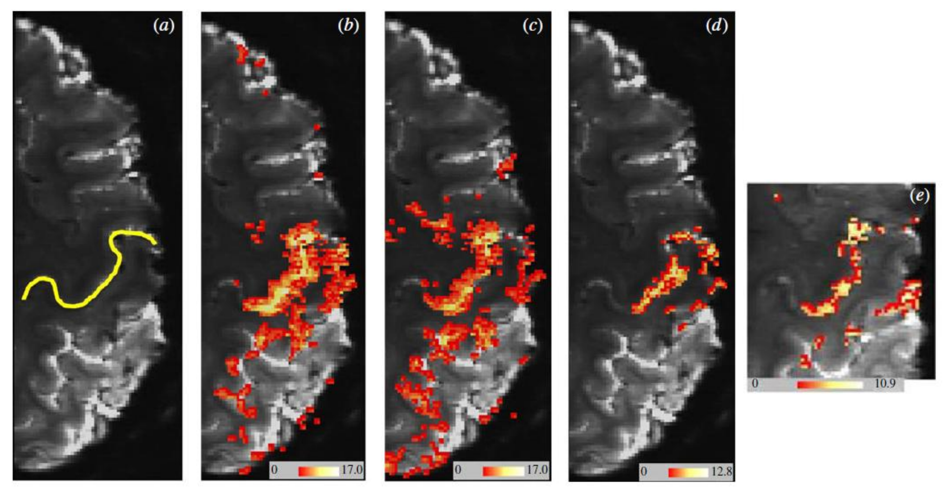

Figure 1. Single subject axial section images acquired with echo planar imaging slices, with colour-overlaid BOLD activation maps during finger movement and imagined finger movement (figure courtesy of Robert Trampel). Spatial resolution 0.75 mm isotropic. (*a*) Axial section acquired using zoomed EPI shows raw data quality. The yellow line indicates the central sulcus, with 'hand knob'. (*b*) Activation map during 'tapping' versus 'rest'. (*c*) 'Moving' versus 'rest'. (*d*) Contrast of 'tapping' versus 'moving'. (*e*) Activation map during imagined finger movement. Colour bars indicate *z*-scores. Functional maps thresholded at $p < 0.05$, using false discovery rate.

Recent studies have shown that proprioceptors are acid-sensitive and express a variety of proton-sensing ion channels and receptors (Lee and Chen, 2022). Accordingly, although proprioceptors are traditionally known as mechanosensing neurons that monitor muscle contraction status and body position, they may have a role in development of pain associated with tissue acidosis (Figure 2).

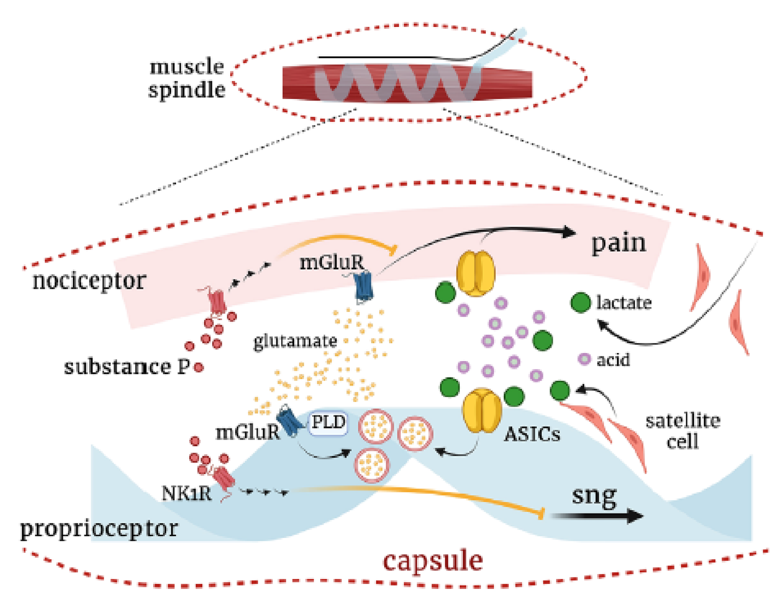

FIGURE 2 A schematic model of chronic nociception induced by hyperactive proprioceptors. With capsule leakage and altered satellite cell metabolic profile in microdamaged proprioceptors, lactate concentration is increased to create a local acidic environment. Proprioceptors become hyperactive via local acidosis by activating ASICs on proprioceptors, which leads to glutamate release. Nociceptors are activated by glutamate, and the glutamate release becomes a vicious cycle in the capsule. Hyperactive proprioceptors trigger an unpleasant feeling of sng. mGluR, metabotropic glutamate receptor; PLD, phospholipase D.

Discussion & Conclusion

At this point in technological development, direct assessment of injury to specific joint sensory feedback nerves cannot be made. This is a critical aspect of diagnosis and yet because of the inability to image these nerves, such injury is often left out of consideration as a diagnosis and treatment. This in turn commonly results in a failed or unnecessarily prolonged recovery for the patient. Recent advances in MRI technology, including ultra-high-field scanners (e.g., 9.4 Tesla) and Magnetic Resonance Microscopy (MRM), have pushed imaging resolution down to 5 microns per voxel. These developments suggest the potential for future direct visualization of proprioceptive structures. However, in current clinical practice, this level of detail remains largely inaccessible, limiting the utility of MRI for evaluating fine-scale proprioceptive integrity (Moore, et al 2015). This literature review study highlights the need to be aware of the inability to directly visualize afferent nerve injury and loss of sensory feedback is often overlooked as a cause of prolonged recovery using traditional protocols

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