

WHITE PAPER

Automatic Nerve Tracing Ultrasound Technology in Pain Practice

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Introduction

According to the International Association of Pain, Pain is defined as “an unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage” [1]. Therefore, pain is thought as a unique and personalized symptom [1, 2]. Regarding pain evaluation, pain physicians frequently see patients who complain of severe low back pain without any significant lesion corresponding to their pain severity in MRI or other imaging workups. These cases might be so-called somatoform [2] or even malingering in the past; however, do pain physicians verify that it is not real pain? Further, even if pain physicians eliminated pain causes in the prognosis, the symptom could not be totally relieved (chronification), resulting in secondary catastrophic adverse events, such as depressive mood and insomnia [2, 3]. Due to these subjective and unique pain characteristics, it is always challenging to evaluate and manage pain. Therefore, it is a mission for pain physicians to begin pain management with acknowledgment and empathy to their patients.

Despite the pain subjectivity, modern technology has remarkably contributed to shaping objective ways to diagnose and manage various pain disorders. Best of all, Artificial Intelligence (AI) has been pivotal in it [4]. AI technology and machine learning have suggested algorithms to predict a pain phenotype class from a complex pattern of acquired parameters [4] and predictors of response to pregabalin for broad neuropathic pain [5]. Further, the effectiveness of AI in medical image interpretation is well-documented [6]. Pain physicians can benefit from AI technology during image-guided pain procedures. Ultrasonography (US) is one of the most efficient devices in adopting AI technology. In pain practice, US-guided joint injections, interfascial blocks, peripheral nerve blocks, and even neuraxial blocks have been popular since the early 2000s [7, 8]. Compared to fluoroscopy, US has several practical advantages, such as no radiation exposure, possible dynamic evaluation, and easy portability [8]. Therefore, it has been essential for pain fellows and trainees to study sonoanatomy to perform US-guided pain procedures. Peripheral nerve blocks under US guidance are commonly conducted for regional analgesia and pain management. For a successful procedure, start scanning the target nerve by tracing it with the probe, followed next by scanning the nerve pathway. This allows clinicians to examine the target nerve path accompanied by the adjacent muscles, ligaments, tendons, vessels, and bone. Without the pre-scanning step, clinicians may face ambiguous cases when distinguishing between nerves and tendons, as encountered with injection of the median nerve block in the carpal tunnel. Furthermore, the pre-scanning exam may be challenging for trainees and beginners to recognize the target nerve without an expert’s supervision.

What if the AI technology could assist us to trace those target nerves during the US scanning and even point to the target instantaneously when the probe is placed near the target structure? The NerveTrack™ developed by SAMSUNG MEDISON is a cutting-edge technology to assist clinicians during pain procedures and to intelligently find the target structure, especially nerves such as the median nerve, the ulnar nerve, etc. It is a built-in, commercially available software installed on Samsung's high-resolution US systems (SAMSUNG MEDISON, CO., LTD. Republic of Korea). It was created using AI deep learning technology to read hundreds of thousands of refined US images for each targeted nerve. By simply placing the US probe near the target area, NerveTrack™ can find the target nerve, automatically skipping the pre-scanning step. Further, it can point out the nerve instantaneously by tracing it. NerveTrack™ is expected to help clinicians and trainees perform effective and correct procedures under US guidance, reducing the procedure time and enhancing the patients' safety by avoiding injuries to the adjacent vessels and tendons. Additionally, this technology may contribute to education in pain medicine by assisting trainees, residents, and pain fellows to learn to recognize the target structure, reducing mistakes in practice as they are making medical decisions during procedures.

Here, we introduce a virtual case detecting the median nerve using the NerveTrack™ technology along with interim results of a survey regarding the technology answered by residents in the Department of Anesthesiology and Pain Medicine and 2nd and 3rd-year medical students at Seoul National University Hospital College of Medicine.

Case and Survey

The median nerve can be entrapped in several locations in the upper extremity. They include areas between the humeral and ulnar heads of the pronator teres muscle, under the fibrous arcade of the flexor digitorum superficialis, at the lacertus fibrosus of biceps aponeurosis or the Struthers' ligament, and most commonly under the transverse carpal ligament –also known as carpal tunnel syndrome (CTS) [9]. CTS is a prevalent entrapment disorder; the lifetime prevalence is 7.8%, higher for women (10.0%) than men (5.8%), depending on occupational risk [10]. Diagnosis of CTS is based on signs and symptoms found during a clinical exam with or without electrophysiologic studies [9-11]. Additionally, US has been frequently used to examine the morphology of the median nerve and guide the needle to the median nerve [10, 11]. During the US examination, enlargement of the median nerve seems to be the most sensitive and specific criterion, accompanied by a palmar bowing of the flexor retinaculum and distal flattening of the nerve [11].

The virtual patient was seated, with the forearm supinated and the wrist placed in slight dorsiflexion using a rolled towel. As the first step of the US examination, a transverse sonogram of the carpal tunnel was obtained by placing a high-frequency linear transducer on the proximal wrist crease at the entrance to the carpal tunnel. Within the carpal tunnel, we identified nine tendinous structures (four flexor digitorum superficialis, four flexor digitorum profundus, and flexor pollicis longus tendons), which had boundaries from the pisiform (medially) and scaphoid (laterally) [11]. They were covered by the transverse carpal ligament (Figure 1).

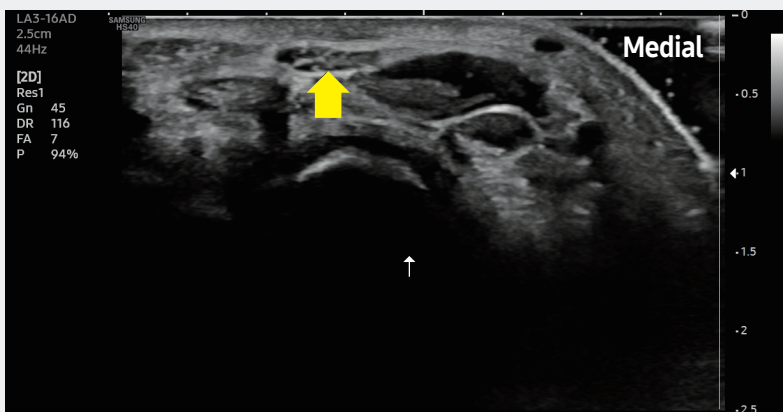


Figure 1. Transverse ultrasound image of the proximal carpal tunnel. The median nerve is shown at the middle top of the image with a yellow arrow.

Although identifying the median nerve under the proximal carpal tunnel is an easy technique for experts, it may confuse beginners. In 40 residents and medical students who were not familiar with the use of US in pain practice, we surveyed whether these beginners could point out the median nerve after an observational US tracing step without additional education. Only 6 participants pointed the nerve out correctly; however, they were still confused, did not display confidence and could not explain the other structures around the target. The remaining 34 trainees confused the median nerve with either the flexor pollicis longus tendon (N = 15), the flexor carpi radialis tendon (N = 13), one of the flexor digitorum profundus tendons (N = 4), one of the flexor digitorum superficialis tendons (N = 1), and the flexor carpi ulnaris tendon (N = 1). Next, we educated them, showing the median nerve traced at the forearm, and performed the same test. Nineteen participants correctly identified the nerve at the proximal carpal tunnel. Then, we educated them on activating the NerveTrack™ function (Figure 2A, 2B, 2C, and 2D).

At this point, 37 of the trainees pointed out the median nerve correctly at any location in the forearm without confusion or hesitancy. All participants indicated that the NerveTrack™ helped extremely (N = 29) or helped very much (N = 11) in their education. Before the education using the NerveTrack™, their certainty score for correctly identifying the median nerve, which was described from 1 (not confident at all) to 5 (completely confident), ranged from 1 to 2 (slightly confident). After the education using the NerveTrack™, their confidence to detect the median nerve even without activation of NerveTrack™ soared to 3 (N = 7) somewhat confident, 4 (N = 26) fairly confident, and 5 (N = 5) completely confident. Two participants responded that they were not confident using NerveTrack™.

Figure 2. Transverse ultrasound images tracing the median nerve using the NerveTrack™

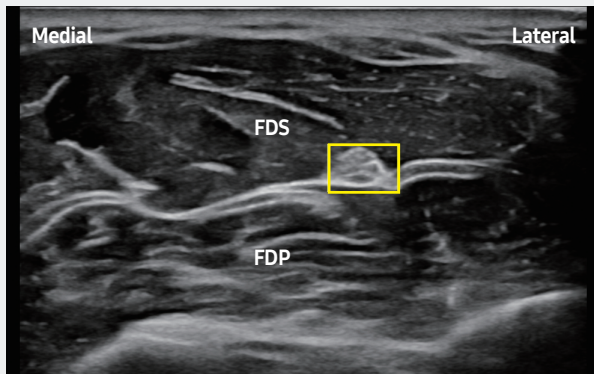


Figure 2A. Median nerve at the forearm. The nerve is identified between the flexor digitorum superficialis (FDS) and flexor digitorum profundus (FDP) muscles. The median nerve is identified within a yellow box.

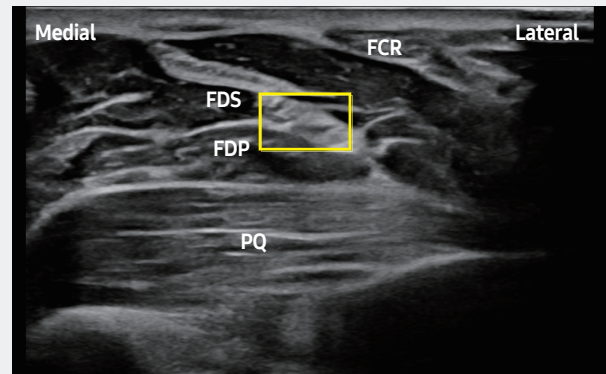


Figure 2B. The median nerve proximal at the forearm before it entered the proximal carpal tunnel. The nerve is identified between the flexor digitorum superficialis (FDS) and flexor digitorum profundus (FDP) muscles. Additionally, flexor carpi radialis (FCR) and pronator quadratus (PQ) are adjacently identified in the image. The median nerve is identified within a yellow box.

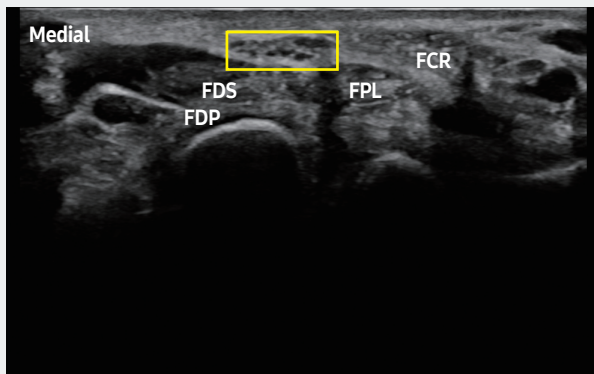


Figure 2C. The median nerve at the proximal carpal tunnel. The median nerve is identified within a yellow box beneath the transverse carpal ligament. There are flexor digitorum superficialis (FDS) tendons, flexor digitorum profundus (FDP) tendons, and flexor pollicis longus (FPL) tendon within the carpal tunnel. The flexor carpi radialis (FCR) tendon is shown outside of the tunnel. The median nerve is identified within a yellow box.

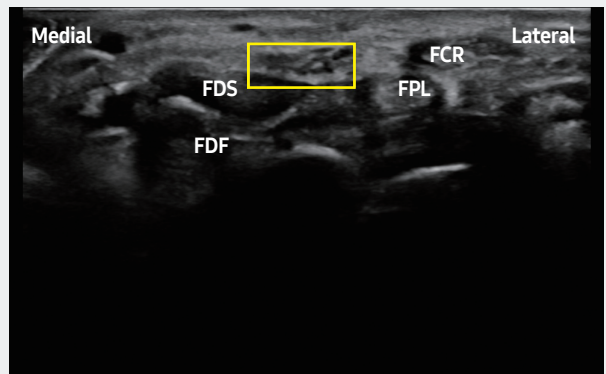


Figure 2D. The median nerve at the distal carpal tunnel. The median nerve in the yellow box runs deeply into the carpal tunnel.

Closing

Below are suggested impacts of AI on pain medicine. The AI and deep learning technology have assisted in:

1. Pain diagnosis and its evaluation, e.g., suggesting the ability to detect patterns of clinical characteristics in various phenotypes of chronic pain;
2. Pain management, e.g., when physicians perform ultrasound-guided procedures, AI technology assists pain physicians to recognize the target structures more efficiently to avoid damages to other critical structures, such as when using the NerveTrack™ technology; and
3. Education in pain medicine, e.g., helping trainees, residents, and pain fellows to learn the process of making diagnoses and finding the targeted structure during their procedures, as described in our survey results.

This AI technology will improve clinical performance and decrease mistakes in pain practice.

Some theorize that doctors will be replaced by machines using AI technology in the future. However, this appears to be an obfuscation so far and in fact, the opposite is occurring presently. The availability of big data has already driven the use of AI in healthcare to train predictive algorithms, which helps human doctors (instead of replacing them), encourages curiosity-based reasoning, empowers collaboration and eliminates unremarkable tasks. We know that medicine must be developed with technological advancement as well as humanism. Artificial Intelligence in healthcare will improve this technical advancement and humanism in clinical diagnosis and decision-making by automating patient assessments and eliminating assessor bias.

Supported system - HS40

NerveTrack™ is available in the following systems - V8, HS40

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