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"Carpal Tunnel Syndrome Management: Merging Traditional Therapies with AI for Optimal Outcomes" Narrative Review.

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Abstract:

Background: Carpal Tunnel Syndrome (CTS) represents the most common form of peripheral nerve neuropathy of the upper limb. It results in pain, numbness, and limitation of function, especially affecting ADL activities. Conservative management includes physiotherapy, splinting, and activity modification, while corticosteroid injections and surgery are invasive or minimally invasive options. As artificial intelligence (AI) becomes increasingly common in healthcare, novel approaches to improve diagnosis, treatment precision, and rehabilitation effectiveness.

Methods: This narrative review examines how AI can improve patient outcomes simultaneously summarizing the most recently published studies on traditional treatments of CTS. We Searched through PubMed, Scopus, IEEE Xplore, and Cochrane Library (2020–2024) yielded 247 articles after applying inclusion/exclusion criteria (e.g., English language, human studies) 15 studies were selected by using keywords: “carpal tunnel syndrome,” “traditional therapies,” “AI,” “machine learning,” “rehabilitation,” “diagnosis.” through reviewing 15 studies from medical databases with focus on AI applications in monitoring of patients (e.g., wearable sensor technology), treatment planning (e.g., robotic-assisted therapy, AI-guided rehabilitation), and diagnosis (e.g., machine learning algorithms, electromyography-based models).

Results: A total of 15 studies were reviewed around 12 (80%) were randomized controlled trials (RCTs), and 3 (20%) were systematic reviews., published from 2020 to 2024. The majority of these studies were randomized controlled trials, followed by systematic reviews. The studies examined the effect of different modalities and techniques such as shock wave therapy, ultrasound, low-level laser therapy, manual therapy, exercises, and the role of AI in the diagnosis and management of CTS. The primary outcomes assessed in the studies were pain electrophysiological parameters, and functional improvement.

Conclusion: Merging AI with traditional CTS treatments has positive impact to revolutionize management of carpal tunnel syndrome. The combination of AI innovations with evidence-based conventional treatments will determine the future of CTS treatment. Healthcare professionals may provide more accurate, flexible, and patient-centered care by integrating AI into clinical practice, which will ultimately reduce the need for invasive techniques.

Keywords: Carpal tunnel syndrome, traditional therapies, Artificial intelligence (AI).

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Introduction:

The carpal tunnel is an osseofibrous tube in the anterior part of the wrist. Carpal tunnels: floor-carpal bones roof (the anterior view has stronger reliance on) CMC-joint The carpal tunnel has 9 tendons and a nerve: carpal tunnel: uppermost carpal bone(n)(distal tuberosity),The base of the pollicis longus and superficial-flexor muscles of the 4 digits (Superficialis, Superficialis) flexor digiti communis profundus as well as median. CTS: In the general population incidence ranges from 1% to 5%. CTS is a female predominance (F: M ratio of approximately 3:1). A 2-fold risk of CTS is due to obesity. CTS, is relatively rare in children and occurs mainly in adults aged 40–60. The early signs of CTS are tingling, numbness in the first three fingers and only radial aspect of a ring finger. Severe CTS can lead to muscle weakness and atrophy of the thenar muscles of the thenar in the grip, which can limit a person's day-to-day and job-related activities leading to decreased quality of life. Many CTS can be diagnosed by Physical examination of hands, arms, shoulders and neck as to determining related daily activities or another disorder. Chronic laboratory tests and x-rays to look for fractures, arthritis or nerve damaging disease may be required occasionally. Sometime will need far more nerve conduction study, EMG, and ultrasound. Management of CTS usually involves conservative treatment such as splinting. It has become one of the most

commonly prescribed often low-cost, non-surgical treatments for CTS. As activities associated with CTS are repetitive and forceful hand motions, besides the purpose of minimizing motion at rest, splint length is to reduce pain (or pressure) symptoms in fingers and adjacent areas by also limiting repetitive use of work and point. Splinting might also aid with the most common symptom nocturnal paresthesia by preventing hours of extended wrist flexion and extension while sleeping. Corticosteroid injections are a common treatment for CTS, and though considered safe for short-term use-effectiveness is also well-established. Chronic synovial inflammation has been demonstrated in pathology specimens obtained from carpal tunnel release patients, and corticosteroid injections are hypothesized to be effective because they decrease the flexion synovialis swelling. Hand therapy is another word for rehab that includes a variety of treatment modalities to restore the functional use of the upper extremities. Utilizing specific abilities to measure and score everybody, then interventions are selected according to symptom severity, patient need and goals, comorbidities and referral by doctor. In addition to clinic specifics such as iontophoresis, and ultrasound which are modalities used in hand therapy. These methods help treat hand and upper extremity problems such as CTS Symptoms of CTS (pain in the wrist, arm and under the elbow) are treated with repetitive exercises which are often the first-line therapy: mobilization e.g., tendon gliding and nerve gliding—aimed at improving axonal transport and nerve conductions Tendon and nerve gliding exercises may promote the relative excursion of the median nerve in the carpal tunnel and flexor tendons gliding against each other. Artificial Intelligence has a role in CTS definitely especially Virtual Reality, in the virtual reality model night symptoms significantly improved for CTS.[1-2]

Definition of Carpal Tunnel Syndrome:

Carpal tunnel syndrome (CTS) is a common condition related to nerve compression, occurring when the median nerve is compressed within the wrist's carpal tunnel.[1-2]

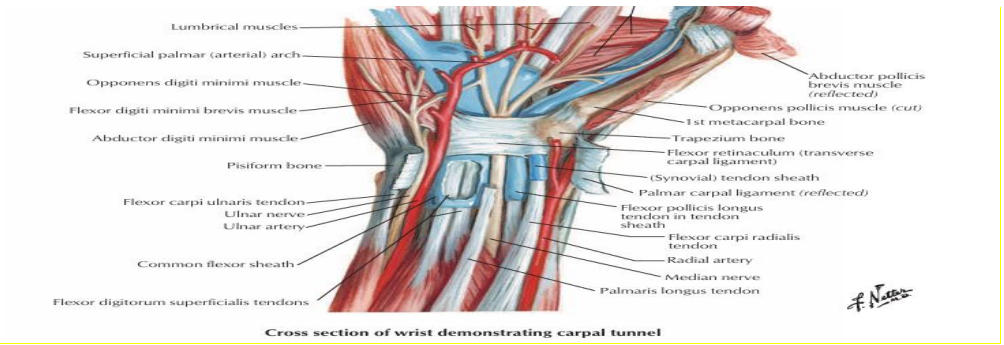

Figure (1). Anatomy of Carpal Tunnel [3]

Pathophysiology of Carpal Tunnel Syndrome:

The pathophysiology is defined by mechanical injury, elevated blood pressure, and ischemic nerve damage within the carpal tunnel.[4] Reports indicate that the typical pressure within the carpal tunnel ranges from 2 to 10 mm/Hg. Various pathological alterations that occur in the ligaments around the nerves, such as changes in the quantity and flexibility of connective tissue, are thought to lead to increased pressure, which is believed to cause ischemic compression of the median nerve.[5] Most cases of CTS do not have a clear explanation (idiopathic syndrome)[6]. Assessments of the patient's discomfort and symptom severity, functional status scales, and objective grip strength evaluations are just a few of the clinical and neurophysiological outcome measures utilized to assess therapy effectiveness. This evaluation can be conducted using dynamometers, sensory and motor nerve conduction studies, and ultrasonographical assessments.[7]

Diagnosis:

The diagnosis of CTS relies on clinical symptoms and is supported by various examinations and assessments: History of current illness in the history of current illness, symptoms such as pain, tingling, and numbness in the areas of median nerve projections can be noted, along with a burning sensation, reduced grip strength, and a sensation of swelling in the fingers. Nighttime pain and weakness in the affected thumb can also be recorded.[8]

Physical Diagnostic:

Provocation tests that can be utilized to identify CTS include Phalen's test, Tinel's test, Flick's sign, and thenar wasting. Phalen's test is performed by instructing the patient to achieve maximum hand flexion. This assessment is considered positive if symptoms such as carpal tunnel syndrome emerge within 60 seconds. Tinel's test is performed by percussion on the carpal tunnel while maintaining slight dorsiflexion positions. This assessment is deemed positive if radiating pain or paresthesia are noted. Flick's sign is

assessed by asking the patient to flick their hands or move their fingers. This examination is regarded as positive if the complaint decreases or disappears. Thenar wasting is evaluated by examining the patient's palms and performing palpation to detect the presence of atrophy in the thenar muscles.[9] Electrodiagnostic examination may be utilized to confirm the diagnosis of Carpal Tunnel Syndrome. Examinations that can be performed include EMG and radiology examination. In an EMG study, a decrease in nerve velocity can be observed when the distal latency is prolonged, indicating a disruption in nerve conduction within the wrist. A radiology study that can be conducted is a wrist X-ray to rule out the possibility of fractures, joint disorders, etc. Additionally, an ultrasound may also be performed to identify anatomical changes within the carpal tunnel. For cases necessitating surgical intervention, a CT scan and MRI can be done first.[8]

AI Role in Diagnosis:

ENMG is utilized not only to establish the treatment modality in CTS but also to assess the severity of median nerve entrapment. This allows for the application of ENMG in monitoring the progression of the disease and assisting in the identification of the treatment modality. Nevertheless, the consistency of the ENMG test can fluctuate greatly due to factors such as the expertise of the individual conducting the test, the technical specifications of the device employed, and the patient's adherence to the test. Furthermore, the significance of the test may change based on the test's objective; for instance, the sensitivity of the test must be optimized to avoid overlooking any instances of CTS screening intended for the industrial sector. The significant rise in publications regarding AI in recent years and the emphasis on artificial intelligence at professional and scientific conferences in recent years highlight the significance of this matter. Diagnosing and managing diseases is a challenging endeavor that cannot be solely derived from textbooks or classroom knowledge. It is incrementally gained through years of experience and observation.[10] CTS is a type of entrapment neuropathy that presents a diverse range of symptoms and signs. Proper grading of CTS is essential, as the selection of the appropriate treatment option may differ based on the CTS severity.[11,12] Implementing computer-assisted methods in medical practices can lower costs, save time, enhance human expertise, and decrease medical errors.[10] Kunhimangalam et al. indicated that by developing an expert system, they could assess CTS and its severity utilizing fuzzy logic, which assists the patient in pursuing suitable therapeutic actions prior to an escalation in CTS severity. They are convinced that the system they created can assist the GP or specialist in diagnosing and forecasting the patient's condition.[10] Park et al. employed a machine learning (ML)-based modeling technique to explore the viability of assessing the severity of carpal tunnel syndrome (CTS) using personal, clinical, and sonographic traits, similar to electrodiagnostic methods, and noted that the top ML models achieved an accuracy of over 70%. Although ML-based models excelled at distinguishing between mild and severe levels, their accuracy was relatively lower for moderate levels of classification. They mentioned that Extreme Gradient Boosting (XGB) exhibited the best performance among the assessed ML algorithms.[13]

Ergonomic Modification:

Systematic reviews of the management of CTS Previous systematic reviews conducted with observational studies and in-hospital, as well as out-of-hospital, evidence on performed interventions on ergonomic training variance as well as workplace redesign, physical therapy exercise (high-quality studies) with different degrees of quality and without consistency including the use of these interventions for management purposes workplace, disability management programs.[14]

Interventions for primary prevention of CTS reported their approach on engineering aspects use of alternatives keyboards, different mouse shaped plus support for wrist brace's support study equipment own individual said (engineering), kinder, ergonomics training regulators and especially fruit diets and cardio exercise.

Furthermore, interventions with Task Desing/workstation Modifications and trainings were taken as being eligible. However, no intervention was effective in primary prevention of CTS so rigorous studies and long-term follow-up is essential.[15] A systematic evaluation carried out by Verhagen et al. indicated that physical therapy, which encompasses hand therapy, massages, exercises, and cradles, among other treatments, along with ergonomic changes, has a crucial role in preventing these types of musculoskeletal disorders. Nonetheless, they note that there is scant evidence supporting the efficacy of these interventions in workplace settings, and they also characterize the quality of the studies they reviewed as inadequate.[16] Goodman et al. reported similar findings, although high levels of evidence were noted in developing interventional strategies such as education, ergonomic training, exercise, and rest periods to achieve recovery.[17]

The integration of treatment and educational programs or plans, created in collaboration with fields like physical therapy and occupational health, might be vital in promoting and preventing CTS. The current literature surrounding conservative intervention strategies used to prevent CTS in the workplace is diverse but limited regarding methodological design, evidence levels, specific groups, and populations, among other aspects.[18-22] Variations between prior reviews might stem from differing targeted populations, differences in the evidence quality of the incorporated studies, and the search time frame.[23] Goodman et al. focused solely on studies involving computer users[17], while Kennedy et al. included only studies of high and medium quality.[23]

Physical Therapy Factors Involved in The Treatment of CTS:

Orthosis for managing carpal tunnel syndrome: Maintaining the wrist in a neutral posture to reduce pressure on the carpal tunnel is the fundamental purpose of an orthosis for treating CTS[24] Maintaining a neutral wrist position is crucial because flexing or extending the wrist increases the pressure in the carpal tunnel[25]. On the other hand, this position may restrict wrist motion and result in discomfort when doing regular tasks.[24] The wrist is typically naturally flexed as you sleep, which puts more strain on the carpal tunnel.[26] Orthoses for individuals with CTS are therefore usually prescribed at night or while they are sleeping, although they can also be provided throughout the day or during the patient's active hours if asked or if symptoms intensify[24] Regarding the ideal duration of orthosis wear, there are no clear guidelines[27]. Recent studies, however, have revealed that the long-term benefits of orthoses may be underestimated. Gatheridge et al conducted a prospective cohort research in 2020[29] to assess the functional severity and symptoms of participants who utilized a wrist splint to keep their wrists in a neutral position for six and twelve weeks. While the intensity of the symptoms reduced during both periods, only the participants who wore the splint for six weeks saw a substantial improvement in functional severity. According to this study, wearing an orthosis for at least six weeks can lead to a noticeable improvement in clinical outcomes; however, continuing to wear it for an additional six weeks could not yield any further advantages.

Wearable technology: Various splints and hand braces were created following the research of Sir James Paget, aimed at minimizing hand movement to keep the wrist comfortable. Therefore, braces and splints[28] were additionally advised to be utilized[29] as beneficial treatment but were not pleasant to wear in specific weather conditions. Some commercially available splints and braces are quite effective in treating moderate and acute CTS. However, there
are particular concerns related to their usage such as insomnia due to wearing, swelling after their removal from high-pressure application during use, discomfort[31], pain, and irritation[30]. Besides these challenges, they are also prohibitively expensive to utilize[32]. In conjunction with splints and braces, various gloves with different features have been introduced, such as those with an embedded mouse for professional e-gamers and extended mouse users[33], and another designed to hold blistering objects[34] that included a heat-resistant wrist base to relieve the symptoms of CTS, burns, and repetitive stress injuries.[35] Various therapies have been created to soothe CTS patients, with surgery also being quite prevalent among them.

Kinesiotherapy: Kinesiotherapy, particularly mechanotherapy, aids in preserving the health of the paretic thenar muscles, enhancing nerve conduction and excitability, and restoring motor function. Muscle hypotrophy is affected by a gentle/careful massage that must be conducted daily.[36] Patients are instructed on how to engage in kinesiotherapy, including self-massage at home for brief periods, frequently and with low intensity. Patients need to be made aware that extended and vigorous kinesiotherapy and massage are strictly prohibited. Based on the level of functional impairment and hypotrophy, a personalized kinesiotherapeutic program is developed for the affected hand, varying according to the patient's condition. It is essential to provide instructions on the loading of the elbow and shoulder joint on the affected side as well as the opposite limb for preventive measures. In certain patients, despite a properly designed and performed rehabilitation program, the situation may not improve or could even worsen. This typically indicates a requirement for surgical intervention. During the postoperative phase, physiotherapy and rehabilitation again assume a crucial role. Several authors suggest immobilization for two weeks following surgery Splinting does not prohibit active movements in the other joints of the upper limb and the unaffected limb. After immobilization is complete, postoperative rehabilitation begins to influence postoperative edema and pain and to prevent the development of fibrosis. The previously mentioned physiotherapeutic modalities and methods of kinesiotherapy are applied, focusing on the active training of the muscles in the affected hand.[37,38]

Manual therapy for carpal tunnel syndrome: is defined as a series of quick hand movements used to reduce inflammation, soft tissue distension and pain, assemble or operate soft tissues and joints, improve tissue elasticity, expand joint range of motion, achieve relaxation, enhance muscle function, and restore normal movement. Massage is categorized into different types of touching, pressing, or continuous movements on the skin and underlying tissues that are used to relieve muscle tension and pain and to promote health. It involves systematic manipulations over the body's soft tissues, including muscles, connective tissues, tendons, ligaments, and joints, with the goal of promoting blood circulation, muscle relaxation, or creating physical stimulations. By stretching the adhesions and widening the space between the transverse carpal ligament and the median nerve, gliding exercises are known to facilitate venous return from the nerve bundle and lessen carpal tunnel discomfort.[39]

Strengthening exercises: strengthening exercises are essential for controlling carpal tunnel syndrome because they enhance hand function and lessen median nerve pressure. Squeezing a foam rubber ball develops handgrip strength, encouraging better control and endurance. The intrinsic hand muscles, which are crucial for fine motor abilities, are activated and finger abduction is targeted when the fingers are separated against a rubber band's resistance. The extensor carpi radialis (ECR) and other wrist extensors are also strengthened by wrist extension with a 1 kg weight, whereas the flexor carpi radialis (FCR) and other wrist flexors are strengthened by wrist flexion with the same weight. These workouts strengthen wrist function overall, improve stability, and assist regain muscle balance.[40]

Neuromobilization: wrist immobilization with a splint and various physical therapy techniques to lessen inflammation, pain, and oedema are two significant and often utilized non-invasive treatments for CTS. However, none of these treatments are able to restore normal hand functions.[41,42] Recently, a novel method called neuromobilization has gained popularity for treating entrapment neuropathies. In order to restore the nerve's normal physiological and mechanical processes during limb motions and frequently utilized postures, a combination of passive and voluntary movements is used.[41,42] Numerous researches have looked into noninvasive ways to treat CTS, some of which have employed the neuromobilization approach as a therapy intervention with varying degrees of success. According to a recent systematic study, nerve gliding, either by itself or in conjunction with other therapies, increased pain threshold, pain intensity, and hand function recovery in individuals with CTS more than other therapies.[50] The most important thing to remember when managing CTS is that the treatment plan should take into account all pertinent nerve-related structures.[41,43] Therefore, certain neuromobilization procedures, carpal tunnel widening, and flexor tendon gliding activities would be part of an effective neuromobilization approach for treating CTS.

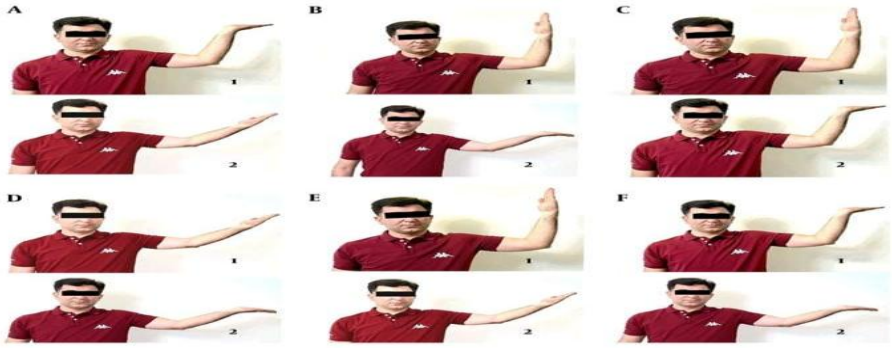

Figure (2). Illustration of the six different mobilization techniques: (A) sliding technique. (B) tensioning technique. (C) wrist motion with the elbow in flexion. (D) wrist motion with elbow in extension. (E) elbow motion with wrist in neutral. (F) elbow motion with the wrist in extension. The number 1 illustrates the starting position, and the number 2 illustrates the ending position. The techniques consisted of repeated movements between the starting and end position.[43]

Tele-rehabilitation: carpal tunnel syndrome affects hand grip strength and People with weak handgrip strength experience difficulty in performing everyday tasks, such as opening a door, holding a glass of water, and carrying a grocery bag. Studies show that physical exercise can strengthen weak muscles, thereby improving grip strength. When people perform handgrip exercises repeatedly, their grip strength can improve. While therapists often provide home exercise instructions in a paper format, people often fail to comply with exercise prescriptions because of boredom, repeated movements performed with no goals, and lack of supervision. Recent technological advances, or tele rehabilitation, provide an alternative way to deliver rehabilitation remotely. Exercises are delivered through a gamified environment, making the exercises enjoyable, goal-oriented, and supervised at a distance. If therapists want to monitor grip strengthening exercises via tele rehabilitation, an electronic device is required to measure grip strength remotely. To make tele rehabilitation effective, the person participating in the therapy should play games to improve grip strength using the same device and a therapist needs to be able to monitor a patient's progress remotely and adjust their goals.[44,45]

Acupuncture: Acupuncture may also be utilized to reduce the pain in CTS. When properly applied, its anesthetic effect is similar to that of topical corticosteroid treatment.[46]

Cupping Therapy: Pain has been lessened by the use of cupping therapy.[47] This is another recent development in the treatment of CTS. It is the oldest alternative medical technique for increasing blood flow and involves using quick, strong, and rhythmic force. It is one of the more affordable and conventional forms of treatment for a number of neuropathic conditions.[47,48] There are two types of cupping: wet cupping and dry cupping. Wet cupping uses scarification to draw blood into the cup, whereas dry cupping uses vacuum pressure to compress the skin into the cup.[48] As a routine physical therapy, cupping therapy can help with symptoms and enhance sensory conduction distal to the median nerve. As a supplemental treatment for CTS, cupping is advised as a practical and affordable option.[49]

Ultrasound therapy: therapeutic ultrasound (US) is a physical therapy modality producing both a thermal (deep heating) and non-thermal effect from the energy of sound which is produced by conversion from high-frequency electric current to high-frequency acoustic energy[50] This is commonly used to treat musculoskeletal pain and disability. The efficacy of US treatment for CTS has been focused on reducing inflammation and edema and nerve stimulation.[51] US is often neglected in the treatment of mild to moderate CTS cases, as the evidence on its

effectiveness is mixed across studies (due to heterogeneous treatment protocols e.g., intensity, frequency, continuity and duration) as well study methodologies.[53,54] Most commonly used as a coupling agent in therapeutic US applications, the gel and water show the highest transmission capacity. Exertion of therapeutic US underwater, a method particularly applicable and suitable for eg small irregular surfaces (hand/wrist) underwater.[55] In a transabdominal method (where ultrasound probe does not leave skin) there cannot be any microbial massage affecting in the treatment result as it classical US method due to non-dispensing skin contact. There has been a large amount of research validating the effectiveness of therapeutic US over more than 75 years in the treatment for musculoskeletal diseases.[56,57] This study is not rigorously powered in terms of type, intensity, what unit of treatment administered or how methodology constructs the effectiveness of US since more research is needed to establish the effectiveness of such treatment.[56-58] Ebenbichler et al.[59] conducted a study with 45 patients who presented mild-to-moderate unilateral CTS, and they were divided in two group. The first group was given pulsed US with 1:4 impulses at a mean intensity of 1.0W/cm2 on one side and the second group was subjected to place-bow US. A statistically significant beneficial effect on symptoms, grip and pinch strength were noticed in electrophysiological parameters like motor distal latency and sensory conduction velocity were observed in the group treated with active US. It remained up until 6 months ago this effect. As previously found by some of the studies stated, pulsed US is effective and comes with electrophysiological effect.

Laser therapy: Laser treatment is utilized for symptomatic relief: for pain and paresthesia. The application of laser therapy in managing CTS is among the first methods approved by the FDA. Using both low- and high-intensity laser beams based on the relevant dosage schedule is suitable (Figures 2-3).[60]

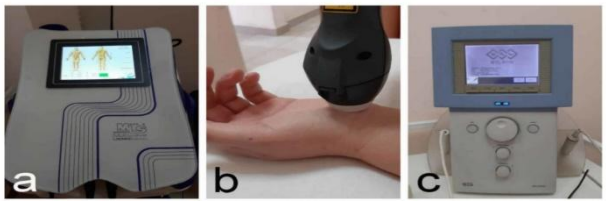

Figure (3).: Laser therapy a: device (MLS Laser); b: application technique; c: device for low-intensity laser therapy (61)

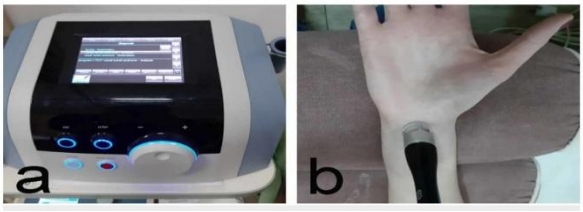

Figure (4): High-intensity laser therapy a: device for high-intensity laser therapy; b: application technique[61]

Shockwave therapy (SWT): Shockwave therapy is regarded as one of the non-invasive and evidence-based physical methods for treating CTS. It uses pneumatically generated shock waves at a low frequency (5-20 Hz) and a pressure of 1-5 bar applied locally to the affected region.[62] SWT is applied in the area of the transverse carpal ligament. The treatment regimen typically consists of 4-6 sessions, with 1-2 sessions per week (Figure 5). It is especially effective in the early stages of the disease and in young patients where the CTS is associated with occupational overload.

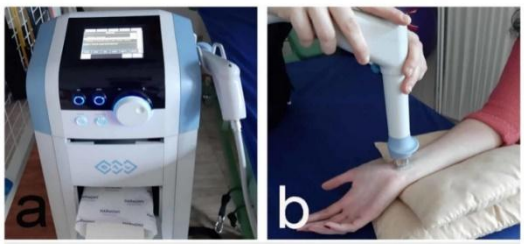

Figure (5).: Shockwave therapy a: device; b: application technique (61)

AI role in Treatment:

Recently, there has been a swift increase in evidence concerning the application of new technologies, such as virtual reality (VR) in rehabilitation medicine.[63,64] The implementation of VR in rehabilitation may provide several benefits, such as boosting patient motivation, improving therapeutic efficacy by ensuring the accurate execution of exercises, conserving time and expenses by decreasing the necessity for supervision, and reducing interactions between patients and health professionals during situations like the COVID-19 pandemic.[65] In rehabilitation

clinics, exercises that are difficult to execute and require time to master are usually overseen by a physical therapist. However, a VR-based exercise program can aid in learning exercises and guarantee their proper execution. Numerous studies endorse the application of VR technologies in neurorehabilitation[66], but there is insufficient evidence regarding its application in rehabilitating other upper extremity issues such as CTS. Given the significance of properly executing neurodynamic exercises, it can be presumed that tendon and nerve gliding exercises will yield better results in a virtual setting.

Discussion:

Artificial intelligence (AI) integrated with standard therapies of carpal tunnel syndrome represents a good strategy to improve patient outcomes [1]. The scope of this review showed that different conservative treatments especially manual therapy, stretching and strengthening exercises ultrasound, ergonomic adaptations, splinting are useful in the management of CTS symptoms (Kazantzidou et al., 2021; Huisstede et al., 2010). Nevertheless, while these are effective options they do not provide individualized treatment optimization which AI can deliver.
Traditional Treatment Effectiveness and Limitations
The literature currently supports the application of manual therapy and neuro-mobilization to improve symptoms in CTS patients with nerve gliding, as well joint mobilization McKeon & Yancosek 2008; Oskouei et al. But the methods themselves only offer symptomatic treatment variability in therapist skill and protocol implementation affect outcome. Likewise, ultrasound therapy and laser therapy have had varied success rates the level differences in treatment regimens (Baysal et al., 2006) All of which highlight the need for a more procedural and data-based approach, one that AI can help.
AI has significantly reshaped the industry of healthcare; from diagnostics and rehab (Tokgöz et al., 2022). Machine learning & AI based electromyography, has accurate in diagnosing CTS by looking at nerve conduction data [11] as well has been found through many studies using weakly AI algorithms driven with AI (Chen et al., 2022). Plus, AI with robotic-assisted therapy was also found to increase rehabilitation by guaranteeing exact manner of movements and therefore reducing therapist dependency (Errante et al., 2022).
AI allows clinicians to individualize rehabilitation programs, refine intervention algorithms and be able to assess patient progress remotely which ultimately increases adherence and enhances treatment effectiveness.
Wearable sensor technology, another advancement boosted by AI has begun to emerge in the context of CTS management. Such devices provide real-time data to continuously assess wrist biomechanics and modify activities (Russell 16 years ago). Furthermore, tele-rehabilitation platforms based on AIpowered virtual reality (VR) rehabilitation exercises have been reported to be effective in upper extremity rehabilitation that might contribute to augmented nerve and tendon gliding exercises for CTS patients too (Chen et al. 2022). The implementation of these technology can help in overcoming the barriers to in-person therapy, with the intention of achieving therapeutic exercise compliance.
AI alongside established CTS treatments presents a two for one package of improved diagnostic specificity and individualized post-thalamotomy treatment approach. The optimal approach should include future investigations of long-term efficacy for AI-driven rehabilitation programs in prospective studies. Well-designed clinical trials to support guidelines for care should also prospectively compare AI-assisted with best practice therapy. Patient data privacy and reliability of AI system are some of the ethical points need to be addressed in case of the large scale implementation.

Conclusion:

Combining AI with existing CTS management strategies can transform treatment modality through improved diagnostics, improved rehabilitation practices and enhance patient compliance. By the use of physiotherapy, as AI improves, it may allow for more targeted and dynamic care with less dependence on invasive procedures in the future.

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